MSc Thesis in Interaction Design

Joining Bits and Pieces

- How to make Entirely New Board Games
using Embedded Computer Technology

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This thesis is dedicated to the worldwide members of the GulfGame-family.

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ABSTRACT

The aim of this thesis is to explore how to join the social activity and fun of a board game, with computers' possibility to add simultaneous and continuous action, and sensors' abilities to detect changes in their environment. Thus the aim is to enrich board games, using ubiquitous computing and interaction design as a way to achieve this. In practice this means identifying new features – so-called mechanics – that rely on embedded technology.

The thesis should appeal to game designers that want to explore a new design space, and to interaction designers that would like to know more about the design of board games and how board gaming could be related to the field of ubiquitous computing.

In addition to extensive background research on electrical components, game mechanics and game design, two board games using ubiquitous computing have been designed, though not fully realized, using methods and approaches such as participatory design, user studies, Wizard of Oz-prototyping and bodystorming. The aim was to explore the possibilities of ubiquitous computing combined with board games, and the outcome is a set of entirely new mechanics that can be used when designing such games.

Conclusions are that when designing board games, and mechanics for board games, one can benefit a lot from the use of sensors, microprocessors and other components normally used in ubiquitous computing, but that such games are more vulnerable and – at the time being – more expensive than ordinary board games. They also require thorough interaction design.
Some of the strengths when computer-augmenting a board game is that information can be made more visible, the components in the game may interact and react, thus being active, and that resources in the game can be linked and computed in multiple ways. Information may also be kept secret from all or some players. This all adds up to richer possibilities when designing a future board game.

Keywords: Board games, mechanics, ubiquitous computing, sensor technology, interaction design, embedded technology, embedded systems, games, The Hatchery, The MarbleGame.

ABSTRAKT

Syftet med detta examensarbete är att undersöka hur den sociala aktiviteten och nöjet med att spela brädspel kan kombineras med datorernas förmåga att tillhandahålla beräkningskraft, och kontinuerliga händelser, och med olika sensorers förmåga att upptäcka förändringar. Följaktligen är målet att berika brädspel med hjälp av mikroprocessorer, sensorer etc. (s.k. ubiquitous computing, "allestädes närvarande datorer/beräkningskraft") i kombination med interaktionsdesign. I praktiken innebär detta att uppfinna nya mekanismer som kan användas som byggstenar i ett brädspel, mekanismer som kräver inbäddad teknologi för att fungera.

Förutom bakgrundsforskning rörande diverse elektriska komponenter, spelmekanismer och speldesign, så har två spel som använder sig av ubiquitous computing designats, om än inte realiserats till fullo. I denna process har designmetoder som participativ design, användarstudier, Wizard of Oz-prototypning och bodystorming använts. Syftet var att utforska möjligheterna att använda ubiquitous computing i samband med brädspel, och resultatet blev ett antal helt nya mekanismer som kan används när man skapar sådana spel.

Slutsatsen är att man när man formger nya brädspel kan dra mycken nytta av användandet av sensorer, mikroprocessorer och andra komponenter som normalt används till ubiquitous computing, men att sådana spel är ömtåligare än vanliga brädspel och för tillfället kostar mer att tillverka. De kräver också en omsorgsfull interaktionsdesign.

Några av styrkorna med att datorförstärka brädspel är att information kan synliggöras, att komponenterna i spelet kan reagera och interagera med varandra, och att resurser i spelet kan länkas samman och beräknas på många olika sätt. Information kan också hållas dold för alla eller några spelare. Allt detta bidrar till att ge rikare mjöligheter vid design av framtida brädspel.

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CONTENTS

1 INTRODUCTION

Nowadays, computers can be built into almost everything. There are computers in your car, in your video, in many toys and even in your toaster! Of course this definition of "computer" is rather wide. Many of the computers that reside inside other products are small, so called microcontrollers that have limited computational powers and mainly respond to the output from different kinds of sensors, using it to compute the actions of other parts in the device. There are sensors to detect almost everything; light or its absence, temperature, movement, acceleration, proximity, height, pressure, moisture etc. Take for instance a large processing plant where thousands of sensors register the current state of numerous things; how full a certain tank is, if the temperature in a certain room is within given limits, if liquid flows through a certain pipe, and at which speed, that the working area is free from a certain gas etc. All this sensor data is processed by microcontrollers and/or computers that take action on the input. The tank is emptied, the temperature lowered, the pipe is closed, an alarm goes off, lamps start blinking in the control room and so forth. A simpler, more familiar example is an air conditioner that is equipped with a small thermometer, so that it can automatically go on if the temperature gets too high.

Such technology is also called embedded computing, or if the device is an everyday thing, **ubiquitous computing**, a term that will be used throughout this thesis. It was coined by Mark Weiser in 1988 (Weiser 1996, Abowd and Mynatt 2000). The concept of ubiquitous computing includes the notion that computational power should be within reach everywhere, but in a non-intrusive way; the user should hardly reflect on that he or she is using a computer, the interaction should be natural. It can be compared with the "writing technology" that was once hard to master and very unusual, but now is a natural part of everyday life. Today, text is everywhere, used for anything. When reading this, you don't pay any conscious attention to the act of reading (i.e. how your eyes should move across the page, how the letters look and what each word means), you instead focus on the important part: what you are reading. Ubiquitous computing strives to become just as common and as "invisible" as this.

As Weiser foresaw, ubiquitous computing is becoming a part of our world. The military uses it when building goggles that provide their user with information about the environment as projected text on the glass, and in a similar way, sophisticated glasses can help Alzheimer patients to recognize their family members. It can be used in offices to enhance whiteboards, so that everything that is written down or drawn also is recorded into a digital file for later access, long after the whiteboard has been cleaned, or to connect digital documents to physical items, thus making it possible to carry them around.

If computational power can be embedded into almost anything, why not use it in board games? Gaming has been important to man as long as history has been recorded. Playing games is a social activity, a way to loosen up, a way to meet friends under laid back circumstances, a way to compete in a friendly way, a way to stimulate the brain and learn new things – not necessarily all the answers to the *Trivial Pursuit*[1] questions, but tactics, strategy, math and probabilities, and anything that is part of a game's theme. And, last but not least, being a good loser – and a good winner!

This is not a new notion. Dutch historian Johan Huizinga presented it in his book "Homo Ludens" 1938. In it, he claimed that any aspect of society (art, law, language, war, piece, anything) can be explained in terms of play and playing. Also, the element of play is an essential characteristic of human society, perhaps the only one, according to Huizinga. It is a way of learning, relaxing, expressing emotions and explore new ideas.

People have played games since the dawn of time. Originally, these games were more or less abstract. The game pieces were more or less monochrome and the boards – or what was drawn on the ground – were made out of simple geometric shapes such as lines, dots, circles, squares and holes. As time went by, games became more colorful and elaborate. *Chess* conquered the world, its pieces reflecting the current times; for instance Napoleon being the white king (Parlett 1999).

During the 20th century, board games have become a stronger emphasis on their theme. Of course earlier games had themes also, *Chess* for instance is a war game, but the themes were not as elaborated as today. An ancient game might have a piece that was called a horse for instance, even if it didn't actually behave like a horse (e. g. a real horse never jumps two steps forward and one aside as a knight in *Chess*), or resembled a horse, and neither did the "board" resemble a running track; it was simply a combination of drawn lines and perhaps stones and or/holes.

At best, themes make a game easier to play, because it makes the rules make sense. At worst, the theme is simply added-on to a game idea – any game idea – using the theme mainly as an attraction for selling the game (Parlett 1999, ch. 19). Right now, it's popular to use a Tolkien or a Harry Potter theme, for instance, since these books – and the subsequent movies – are very popular at the time being. Such games could easily be published with any other theme; for instance there are numerous quiz and/or trivia games with different themes such as Star Wars, TV-series Friends, Superman etc.

[1] Trivial Pursuit by Chris Haney and Scott Abbott, Horn Abott 1981

Also, gaming has become more of a family activity, especially since many games released in the beginning of the century were educational games, *Monopoly*[2] for instance. Its initial name was *Landlord*[3] and it was a moral tale about how landlords who charged unfair rents ought to go to jail (Parlett 1999, ch. 19).

A true gaming revolution was that of the computer games, the first one being *Spacewar*, written by Steve Russel in 1962 (Herz 1997, ch. 1). The first ones, as simple as they were, added a new element to gaming, one that had only been experienced in real life games and sports before; simultaneous and continuous action. Even the simplest computer game could provide this; there was the constantly moving ball in *Pong*[4], the moving ghosts in the labyrinths of *Pac Man*[5], the crawling worm that was to be navigated on the screen, to find food without hitting itself, the falling pieces of *Tetris*[6]. Unlike board games, those computer games were normally not turn based; a lot of things could happen at the same time. Also, they had mechanisms of increasing the degree of difficulty; the ball moved faster, more and more ghosts showed up, the worm grew and so forth. Over the years, the graphics became better and the games themselves grew more complex. You could be a city major in *SimCity*[7], or a god, as in the game *Populus*[8], developing your own world. (Herz 1997).

At the same time, in the 1970ies, role-playing games entered the gaming scene. These had emerged from war games (Parlett 1999), and were initially defined with quite strict rules. *Dungeons and Dragons* for instance, had detailed tables and rules on things like how fast a horse could move, how much a mule could carry and how much damage a 2-handed claymore broadsword would make, depending on the user's skill. They are a kind of more or less open-ended storytelling games, with a game master who describes the current situation to the players, the players telling the game master how the character they impersonate will respond. In time, there were no limits but the fantasy of the players.

In the last decade, both computer games and role-playing games have expanded and evolved, whereas board gaming has not. Many role players have started to explore and enjoy Live Action Role-playing (LARP) which is more or less a live performance of whatever happens in the game, complete with authentic clothing, weapons and settings. It is

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[2] Monopoly, Parker Brothers 1935

[3] Landlord, by Lizzie J Magie, was patented in 1904. She renewed the patent in 1924.

[4] Pong, by Nolan Bushnell, Atari 1972.

[5] PacMan, by Midway 1980.

[6] Tetris by Akexi Pajitnov 1989 may very well be the world's most played computer game

[7] SimCity by Wil Wright, Maxis 1996

[8] Populus by Peter Molyneux, Bullfrog 1989

something quite like improvised theatre, but without any audience. The participants act out a loose story that has been given to them, trying to achieve their character's goals. Meanwhile, computer games have found their way to the Internet; many war- and "shoot 'em up"-games can now be played online, providing more fun and better opponents than in a single player version. Apparently, playing against other humans, instead of computer simulated resistance, adds a great deal to the game (Arnstad 1999), and in some game worlds some players form clans. This happens both in combat games as *Counter-Strike*[9], and fantasy games like *EverQuest*[10]. The latter is a so-called Massive Multiplyayer Online Role-playing Game, a MMORPG – an interesting mix of a computer game and a role-playing game; the online fantasy game, featuring thousands of players that roam a shared world.

As for board games, more are published per year than ever, mainly because the publishing process has become easier. Many board games are German, probably because there is a lot of family gaming going on in Germany, and the most prestigious game designer award in the world is considered to be the German prize "Spiel des Jahres", Game of the Year. But board games haven't changed that much over the last fifteen years though, as have computer games and role-playing games, other than that new features have swept in every once in a while. A typical example is modular boards[11] that were made popular through two popular games; *RoboRally*[12] and the smash hit *Settlers of Catan*[13] that has sold some 2 500 000 copies of the original game worldwide (sequels and expansions not included).

Board games have also become part of the web. However, most of these digital versions seem to be flat screen versions of the original board; they are played with original rules and the most common use of the advantages a computer can contribute with is to provide computerized opponents. There are numerous sites for playing traditional board games, for instance a Google search for the words "chess online" generates 404 000 hits! The German site Brettspielwelt[14] ("board game world") has Java implemented versions of 23 board games, that one can play against other people online. The site also has a number of cities where the registered users can "live"; the total number of citizens is some 13 500 people[15].

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[9] Counter-Strike is a modification to the game Half-Life. It has been created by a group called "The CS Team", led by Minh Le.

10 EverQuest by Sony Online Entertainment Inc 2001.

[11] A mechanic where the board of the game either changes during the game, or that it can be put together in different ways, meaning that some aspects of the game will change every time it is played.

[12] RoboRally by Richard Garfield, Wizards of the Coast 1994

[13] Die Siedler von Catan, aka The Settlers of Catan aka Les Colons de Katane, by Klaus Teuber, Mayfair Games 1995

[14] http://www.brettspielwelt.de

[15] http://www.brettspielwelt.de/gate/jsp/base/enter.jsp?nation=de&sel=1

There is a *Settlers* site called Java Settlers of Catan[16], that typically gets a 1400 users per day (Thomas and Hammond, 2002). These are just a few examples, but it is safe to assume that a lot of board games are being played online.

But there are few board games that are enhanced with computer technology such as ubiquitous computing. Perhaps people who work with game design are not into ubiquitous computing or vice versa? Still, using ubiquitous computing could add a great deal to board games since it opens up for entirely new kinds of rules and interactions. What if one could spy on other player's resources during a game, but not be quite sure if the information was correct? What if the board changed during a game, depending on certain events, not all necessarily known to all players? What if bidding was kept secret so that only the winning bid and player was announced, the other player's bids kept secret? These functions could only be provided by having either a neutral human player, or some kind of ubiquitous computing technology. To explore how this – and more – can be done is the overall goal of this thesis.

However, when designing any game, and especially when adding hidden technology into it – technology that should be non-intrusive, easy to use and almost invisible – there is great need for a fairly new discipline called **interaction design**, that is used when designing "…interaction with (and habitat within) computer-based systems." (Winograd 1997). It draws from many other disciplines, especially Human Computer Interaction design (HCI), but has it's own distinct set of methods and approaches, all directed towards making the new technology feel natural and hardly noticeable.

In the case of applying ubiquitous computing to board games, this means that the role of the interaction designer is to support the visions of the game designer, perhaps suggest improvements, apply the ideas to a suitable embedded technology, make it look good and, last but not least, make this technology so easy to use that the players don't have to reflect on using it, supporting play in a discreet, non-intrusive way. This is not an easy task, but it is made easier by the fact that games are in themselves very formal systems; actions are gone through in predictable sequences, and there is a limited set of allowed actions and outcomes. Thus, the interaction design can be "hidden" in the rules of the game.

To sum up, the main question throughout this thesis is how to join the social activity and fun of a board game, with the computers' possibility to add simultaneous and continuous action, and the sensors' abilities to detect changes. Thus the aim is to enrich board games,

[16] http://settlers.cs.northwestern.edu

using ubiquitous computing and interaction design as a way to achieve this. In practice this means coming up with new board game mechanics that rely on embedded technology.

Thus, the thesis should be of interest for both game designers that want to explore new design spaces and technologies, and to interaction designers and others that would like to know more about board game design. The outcome is an examination of existing technologies and the other part is two examples of how this technology can be applied on board games, resulting in a set of game mechanics that have been improved, extended or renewed with ubiquitous computing.

2 BACKGROUND

In the following section, many of the references are to Boardgamegeek[17], which is a large user-driven website that covers information, rules, pictures, reviews, session reports, comments and articles for more than 3800 games. The site receives 500 000 hits every month, thus probably being one of the most valuable online resources for gamers worldwide.

2.1 What is a board game?

Typical examples of board games that everyone has heard of and most people have played are *Chess*, *Monopoly*[18] and *Ludo*[19]. But was is a board game, really? Now, since this thesis deals with how board games can be enhanced by ubiquitous computing, a definition of such games is needed.

An old definition, mentioned by David Parlett (1999) is the division made in "Casells Book of Sports and Pastimes" (1893), where is it stated that sports are "manly games", implying that board games are those games that are only played by wimps! Since then, board games have been referred to as being "indoor games" and "mental games". In Homo Ludens, Huizinga simply states "Every game has its rules". David Parlett (1999, ch. 1) claims that every game is its rules, and defines a board game as a game that consists of an agreed set of (physical) components – such as game pieces, markers, money and the like – and an agreed set of rules. The game is a contest to achieve an objective ("winning"), set by the rules.

The successful[20] board game designer Wolfgang Kramer (2001a), labels board games as "games with rules" and defines them as games that have components, rules, a goal, and (in addition to Parlett's criteria) an element of competition as well as the demand that a game must be non-static; every time a game is played, the course will always be different and unpredictable; when starting out, no one knows who will win, and why, or how. But, according to Kramer, the board game must also fulfill a certain set of criteria that apply to all kinds of games; they should be an experience shared by the players, all players should

[17] http://www. boardgamegeek.com

[18] A classic, first published by Parker 1935.

[19] The ancient game "Pachisi" has many derivatives in western society, for instance "Ludo" which is known under the name of "Mensch ärgere dich nicht" in German and "Fia med knuff" in Swedish.

[20] Kramer has won the prestigious game designer award "Spiel des Jahres" five times out of twenty-four, and has had more then ten other games among its nominees.

have an equal chance to win, players play because they want to, playing means being active and whoever plays leaves behind reality and dives into the world of the game.

On principle, I agree with Kramer's definition of games and "games with rules", but some of the latter criteria are highly subjective and hard to measure, and thus they have been ignored. Instead Parlett's criteria have been used as a starting point, but to limit the research a few limitations have been added. Their main purpose is to define the range of board games that will be examined when looking for mechanics and types of games suitable for enhancement:

- A board game is normally played on a board, or with components laid out on a table.
- It might just as well be a card game, as long as the deck of cards is not the same as the classic deck with clubs, diamonds, hearts and spades. This idea is based on the fact that if you ask a **gamer**[21] (e.g. a person who often plays and owns a lot of board games) which game she or he plays or owns, the answer will include various types of board games, card games and dexterity games, but hardly ever "a deck of cards" or "Bridge" or "Poker" etc.
- It is played by a group of people that are at the same place at the same time. Also, the game is played more or less as a social activity (which agrees with Kramer's criteria of a shared experience).
- Playing a board game is more about decision-making, tactics and analysis, rather than about trivia knowledge, dexterity and/or creativity (in its common sense).

These limitations have been chosen to rule out online-versions of board games as well as sports (which very well fit the wider definition, but still aren't considered as being board games by most researchers, including Parlett). The last notion has been added to exclude trivia games such as *Trivial Pursuit*[22], word- and creativity games as *Scrabble*[23] as well as dexterity games. The latter types are normally regarded as being board games, even if hardcore gamers tend to see them as quite light-weight and uninteresting.

[21] Gamer site Boardgamegeek defines a gamer as "A person that likes to spend a most of his free time playing games."

[22] Trivial Pursuit by Chris Haney and Scott Abbott, Horn Abott 1981

[23] Scrabble, aka Alfapet by Alfred Mosher Butts, 1948

2.1.1 Games in terms of concepts: elements, game systems, themes and categories

All board games consist of two things: **elements** (i.e. the physical components such as dice, board, cards and the like) and rules (Parlett 1991 ch. 1). If a set of elements can be used for several games (i.e. with different sets of rules), this is called a **game system** (Hale-Evans 2001). The most well-known game system of them all is probably a standard deck of cards. Thousands of games can be played with some or all cards in the deck, or with more than one deck. The opposite is any board game that only has one set of rules (including variants).

The term **theme**, on the other hand, merely describes what kind of real-life activity the game tries to represent. Parlett (1999, ch 19) distinguishes between ten different groups of themes for board games, namely Business & trading, Detection & deduction, Crime, War, Fantasy, Alternative histories, Politics, Sports, word games, and finally games of social interaction and/or trivia.

To add to the confusion Boardgamegeek also lists 58 **categories** where some are strictly related to the theme – such as Science fiction, Arabian and Nautical – whereas others refer to mechanics (see below), such as Bluffing, Negotiation and Dexterity.

2.1.2 Games in terms of interaction and rules: Mechanics, mechanisms and game patterns

To describe and design games, one can use the concept of mechanics. A **mechanic** is a part of a game's rule system that covers one general or specific aspect of the game. It is a short description of something that is done during the game, and sometimes it implies what elements and rules are needed to do this. A game normally consists of more than one mechanic, and a mechanic can occur in many different games.

For instance, the mechanic "roll and move" is very common. It simply states that something – almost always one or more dice – are rolled and that something else is moved in a way that is related to the outcome of the die roll. The mechanic does not state how something should be moved or why; this is determined in the rules for the particular game.

When giving a quick introduction to a game, gamers tend to refer to the game's mechanics, rather than to the rules in detail or the components, simply because this is a quick way to tell what kind of game it is. If a game is being described as " a bidding game", one can immediately conclude that the game is a lot about deciding if one wants something, calculate the right price for it and then cunningly outbid the other players. And one would know, that if one doesn't like other bidding games, one will most likely not enjoy this game either. Again, the mechanic "bidding" itself doesn't state how the bidding is carried through;

bidding may be open or closed, be free or go around the table once, it may be allowed to pass and then jump in again, or not. What is allowed and what isn't is stated in the rules for the game.

Mechanics are also sometimes called mechanisms (this expression seems to be widely used by computer game designers), and a game can consist of one or more of them. Another, similar, term is **game pattern** (Kreimeier 2002). A game pattern is used as a way to express existing design knowledge, being a formal description of a general problem that occurs in more than one game, and the solution of it. The essential core of a game pattern thus consists of a name, a description of the problem it solves, a solution and its consequences (i.e. costs and benefits of the solution). Game patterns denominate problems, whereas mechanics denominate solutions or interaction methods.

However, the term mechanic seems to be the most common one amongst board gamers; they also use it widely across the web for instance at Boardgamegeek. Parlett (1999) also mentions the term mechanic, using it as a synonym to ludeme, being games' equivalent to genes.

In September 2002 Boardgamegeek's list of mechanics consisted of 40 distinct mechanics that combined with others or alone describe thousands and thousands of games. Most of them[24] are listed below, and a full explanation can be found in Appendix 1. It should be mentioned that the number of mechanics increases; in January 2002 there were 28 listed ones. This is probably not because they are invented at this speed, they are just being listed at this pace.

- Action Point Allowance System
- Area Enclosure
- Area-Impulse
- Area Movement
- Auction/Bidding
- Betting/Wagering
- Campaign/Battle Card Driven
- Clue-giving
- Co-operative Play
- Commodity Speculation
- Open Card Selection
- Partnerships
- Pattern Building
- Pick-up and Deliver
- Rock-Paper-Scissors Role-playing
- Roll and Move
- Secret Unit Deployment
- Set Collection
- Simultaneous Action Selection
- Singing

[24] The mechanic called Paper-and-pencil has been left out; it isn't really a mechanic, it just states that paper and a pencil are needed in the game. The mechanic Chit-pulling has also been left out since it's similar to Campaign/Battle Card Driven.

- Crayon Rail System
- Drawing
- Event Card Interaction
- Hand/Resource Management
- Hex-and-counter
- Matching
- Memory
- Modular Board
- Negotiation
- Stock Holding
- Storytelling
- Tile Placement
- Trading
- Trick-taking
- Unit Deployment
- Variable Player Powers
- Voting

When studying games and gaming from the perspective of ubiquitous computing and interaction design, the interesting thing about mechanics is, again, that they specify how one interacts with the game, and sometimes with what kind of pieces. For instance, in a bidding game, we can conclude that we need two kinds of things; something to lay bids on, and something to bid/pay with. This might be non-physical things such as promises and turn order, but more commonly they are items in the game such as money and resources.

2.2 What is ubiquitous computing?

The concept of **ubiquitous computing**, also known as pervasive computing, was founded by computing pioneer Mark Weiser in 1988. He was a key person in the early days of it, working at Xerox PARC where most of the first products using ubiquitous computing were created (Weiser 1993, Abowd and Mynatt 2000). He foresaw upcoming changes in the relations between people and computers. He divided computing into different eras, the first being the mainframe era, when each computer was shared by lots of people. The present era is the personal computing era, when a typical computer is owned and used by one person. The upcoming era is that of ubiquitous computers, where each person owns, uses and accesses many computers in his or her daily life, mostly without thinking about it (Weiser and Brown 1996). In Weiser's vision computers would disappear, becoming an extension of the human mind. Computational power should be everywhere; quiet, calm, disappearing, automatically within reach when needed:

> "We will dwell with these computers, whose presence we will ignore most of the time, and they will provide us with constant clues about our environment, our loved ones, our own past, the objects around us and the world beyond our home. Computers will act like books, windows, walks around the block, phone calls to relatives. They won't replace these, but augment them, make them easier, more fun. […] Ubiquitous computing just

> might help to free our minds from unnecessary work, and connect us to the fundamental challenge that humans have always had: to understand the patterns in the universe and ourselves within them." (Weiser 1996)

Remember the furby? This little toy has an IR-sensor between the eyes to distinguish between light and darkness, pressure sensors on its back and front etc. Among many other features, it reacts when being stroked, it can play hide and seek and a few other games, and its language improves the more you play with it. All this is regulated by a small built-in computer connected to the sensors and output channels. In this sense, it is a good example of ubiquitous computing. Some of the interaction also comes naturally; it looks like a pet and it feels natural to stroke it, but where is the logic in that if you want to ply hide-and-seek you have to clap your hands hard three times in a row?

Abowd and Mynatt (2000), commenting on the need for natural interaction, list the following three themes of ubiquitous computing research of today as being the most important ones:

- To create **natural interfaces** between humans and computers, interfaces that support common forms of human expression, such as talking, drawing and writing.
- To create **context-aware** applications that can adapt their behavior to the information it collects from its physical and computational environment.
- To create applications that automate the **capture of life** and provide easy access to those experiences.

When applied to board gaming, the two first themes are the most interesting ones. The pieces of computerized board games, and/or the boards themselves must have some kind of context-awareness, so that they might "know" what they are, which other pieces they are connected to and/or which other pieces they are close to; otherwise computerization of the game would be useless, because then the users would have to enter this data themselves, into some sort of computer-like device, in which case one might just as well make a computer variant of the game. Moreover, it is appropriate that the logic is built into the physical items of the game since the game itself is a "natural interface" for a player, who wants to enter data to the computer that is built into the game. One might say that this embedded computer is "invisible" (Norman 1998) since the players are not conscious of that it is there, and still naturally interact with it.

2.2.1 Tangible bits

Building logic into game pieces is close to the concept of what is called "tangible bits" (Ishii and Ullmer 1997), a part of the ubiquitous computing research field, dealing with alternative ways to interact with computers and data. In the early days of computing, the only way to communicate with the computers was through punch cards. Later came text interfaces, and, beginning with the Xerox Star 1981, the graphic user interface (GUI)[25]. The concept of tangible bits is that the bits (the smallest piece of data, being a 1 or a 0) should be "carried" by atoms (Ishii and Ullmer 1997). In a more elaborate way, this means that one should be able to manipulate data (bits) in the computer by manipulating physical objects (atoms).

One example of this is the I-LAND project (Streitz et al 1999), where a sub application called Passage provides the possibility to carry data in physical objects. Data can be linked to any unique physical object – a bunch of keys for instance – by putting the object on a certain device called a bridge, and indicating which document it should carry. A small program notifies the network about the connection between the document and the object. The keys can then be picked up and carried to any other bridge that exists within the network. Whenever the keys are put down on such a bridge, the document can easily be retrieved to that bridge's screen/visual interface.

This could be used when constructing board games. Wouldn't it be nice if the game pieces and cards by themselves could carry some data about how they affect each other, the board or something else?

2.3 What is interaction design?

Interaction design is a fairly new discipline. Terry Winograd (1997) defines it as an entirely new design area, that, even if it draws from many other disciplines, has it's own distinct set of methods and approaches, that are used when designing "…interaction with (and habitat within) computer-based systems." He states that the need for interaction design has emerged as the computers, and the use of computers has evolved; from computations to communication, from machinery to habitat, from aliens to agents; the latter referring to the idea that computers may develop an artificial intelligence, turning into independent alien beings, versus the semi-intelligent agents used today to filter email, choose music etc; a focus shift from intelligence to knowledge. In his article "From Computing Machinery to Interaction Design" Terry Winograd (1997) concludes:

[25] E.g. most computer programs that run under Windows or Macintosh use GUIs; data is shown visually on the screen and is manipulated by, for instance a mouse, rather than with textual commands with plain text as feedback.

> "Interaction design in the coming fifty years will have an ideal to follow that combines the concerns and benefits of its many intellectual predecessors. Like the engineering disciplines, it needs to be practical and rigorous. Like the design disciplines, it needs to place human concerns and needs at the center of guiding design; and like the social disciplines, it needs to take a broad view of social possibilities and responsibilities. The challenge is large, as are the benefits. Given the record of how much computing has achieved in the last fifty years, we have every reason to expect this much of the future."

This means that the interaction designer has to consider both technology and human concerns. Gillian Crampton Smith and Philip Tabor (1996) see it as a discipline whose main activities that should be directed towards the users, the task and the situation are understanding-abstracting-structuring-representing-detailing. This implies a design process that emphasizes on analysis followed by creativity. They acknowledge the need for scientific method and engineering knowledge amongst interaction designers, but choose to see interaction design as "more art than science", claiming that since interaction design is focused on human users, and human likes and dislikes, there cannot be any perfect methods and predictable outcomes; the informed instinct and a set of reliable methods to choose from will have to do. Others, like Mitchell Kapor (1996) state that interaction designers do need a firm grounding in technology since the focus of interaction design is to take technology and adapt it to the users.

This means that a skilled interaction designer has to have knowledge in a number of areas (Winograd 1997): psychology, cognition science, design, technology, material science and ergonomics being some of the more prominent.

A more HCI-like definition is the one of Preece et al (2002); "designing interactive products to support people in their everyday and working lives". Like HCI, interaction design deals with the interaction between humans and any computational power or computerized system. It explores ways to take non-physical, highly abstract computations and transfer them to something – physical or non-physical, that humans can detect, interpret and use. Unlike HCI, that "something" doesn't have to be a traditional computer with all its belongings such as screen, keyboard, mouse, loudspeakers etc; it can be a mobile phone, a coffee machine or a bike that emits various horse gait sounds depending on the speed (Landin et al 2002). And unlike HCI it is not solely concerned with usability, but also with the whole experience of using an item; it should not only be easy to use, but also delight and be enjoyable to use, as Gillian Crampton-Smith puts it (Preece et al 2002).

Interaction design can also be concerned with the design of an environment where a task occurs, creating designs where presence, appearance and environment can be expressed (Hallnäs and Redström 2001). This means that the focus should be on the task, the act, the action rather than on the tool, the item.

2.4 Previous work

Some recent work within the field of ubiquitous computing have concentrated on entertainment and even games relying on various broadcasting end sensing techniques. Likewise, computerized and/or electronic toys[26] have become increasingly popular during the late 1990ies, and new kinds of toys in this segment are constantly being introduced. (Barnes 2000). But board games enhanced with ubiquitous computing have not yet hit the market on a large scale; few efforts have been made to see how computers and sensor technology can enhance board games and board gaming.

2.4.1 Projects of interest for game design

Björk et al (2001) have created Pirates!, a mobile multiplayer game. The game is implemented handheld computers (typically PDAs), connected by a wireless local area network (WLAN). Players roam the physical world to explore the virtual game world; an archipelago of islands, where the players are captains on ships. The object of the game is to succeed in a number of quests; visiting islands to try and find various treasures, supplies, etc without being killed by monsters, pirates and other inhabitants on the islands – or by other players for that matter.

Gorbet et al (1998) created the Triangles interface. It consists of a set of identical plastic triangles. Each of them has a microprocessor inside and magnetic edge connectors. The connectors make it possible to physically connect the triangles, and through them digital information can be carried. Information about which pieces are connected to which is sent to a computer that keeps track of the configuration.

The main purpose with the Triangles-project was to create a tangible interface that could be used to create input to any digital system, having the advantages of being easily handled, being able to be combined into three-dimensional systems, giving tactile feedback and having a familiar and general shape.

Among other things, this interface was used as a storytelling device for children. By combining triangles depicting characters and places from the Cinderella story, children could

[26] E. g. Barney the talking Dinosaur, the Furby, Lego Mindstorm System, Sony's robotic dog Aibo (and cheaper copies in form of various robotic pets).

hear different aspects of the story. For instance, combining the Cinderella-triangle with the stepsisters-triangle resulted in sound of the sisters teasing Cinderella. There was also an event triangle that triggered an event and changed context of the story, such as the invitation to the ball, and an information triangle which made characters reveal information about themselves. Earlier experiments with Triangles had shown that sound was a better feedback than visual changes on a screen, since especially children got somewhat disturbed and confused by constantly changing visual and intellectual focus from the assemblance of the triangles and the output on the screen.

Rauterberg et al (1996) conducted an interesting experiment that is relevant since it explored various interaction techniques. At a large computer fair in Switzerland they encouraged visitors to play a quite simple (in terms of rules) computer game against a computer, using any one of the following four interfaces; a keyboard and a command language, a mouse, a touch screen or what they call a "Digital Desk"; a physical chip that is to be moved upon a virtual (projected) board. Results were collected via a questionnaire and a field test. In the questionnaire, the touch screen was rated as the easiest interface to use, followed by the mouse and the Digital Desk. According to the researchers, a significant result was the strong correlation between age (the median was ca 30) and how the Digital Desk was perceived; older people preferred it. In addition, children also seemed to be able to interact without any serious problems. Another observation was that people that played on the Digital Desk used both hands, enabling more parallel inputs than traditional techniques. Also, the Digital Desk seemed to favor social activities, i.e. playing in groups, discussion solutions and make suggestions.

2.4.2 Board games using ubiquitous computing, or ubiquitous computerized versions of board games

Mandryk et al (2002) have created a hybrid Board/Video game called False Prophets. It is a six-player game where the main objective is to find out which other players are on one's team. The board is projected onto the table and consists of a hexagonal grid where the hexagons symbolize different kinds of terrain. Initially, the board is not projected except where the players are; the map is dynamically updated as the players move around the board. Clues are hidden in the terrain, and players also make observations by physically passing near other players on the board. Movement is energy-based, not turn-based.

The player characters communicate with the board via infrared pulses sent to the board. The pulses can be varied by pressing buttons on the characters, symbolizing actions in the game. Each player has a handheld computer that receives and displays private information. These are also used as input devices.

Jay Schneider and Gerd Kortuem (2001) have created a pervasive mystery game, called Pervasive Clue in the form of a Live Action Role-playing (LARP) game. They define a pervasive game as a LARP augmented with computing and communication technology in a way that joins the digital and physical space. The technology is supposed to support the game, not be the focus of it; it should naturally blend into the gaming environment.
Their game, Pervasive Clue, is based on the board game *Clue*[27], and it's played in a building with several rooms, in analogy with the rooms that are on the Clue board. Just as in Clue the object of the game is to find out who killed the host, in which room and with what weapon, and just as in Clue this is found out by eliminating possibilities. The players' main tool is a Personal Digital Assistant (PDA) that can also pick up radio signals. The PDAs are also equipped with a magnifying glass attached to the top, to illustrate the function of the device and how it should be used. In each room there are up to three clues, "hidden" in physical devices such as books, candlesticks or whatever. These objects contain a short range RF beacon with a range of one foot (ca 30 cm) that broadcasts the clue. If a PDA is placed within it's range the clue will be picked up by the PDA and the player can see it. The PDA will keep track of all the clues a player has found, eliminating possible murderers, weapons and rooms.

Somewhat like in the original game, players can exchange clues, but this is done by trading. Also (unlike the original game) players may lie when they exchange clues. Therefore, this exchange is done without involving the PDAs, even if a player may choose to enter the given information into the PDA if he or she trusts the information

Pervasive Clue is an example of how a traditional board game could be fortified with computer characteristics, but the designers have left the board game itself behind and turned it into a LARP. A similar example is another version of *Clue.*, called Sleuth (Drewes et al, 2000), but Sleuth is a plain computer game using sounds as the only clues; one moves one's avatar around in the mansion, eavesdropping, recognizing each room by the ambient soundsin it – a dripping leaky pipe in the kitchen etc.

Svanaes and Verplank (2000) mention a possible way of making a tangible *Reversi*[28] game. Reversi is a game for two players. They place pieces of their own color on an 8 x 8 square board and the aim is to trap the opponent's pieces between one's own. Trapped pieces change color. A piece will typically change color some twenty times throughout the game; normally they are made out of discs with one color on each side, so they are simply flipped.

[27] Clue, aka Cluedo by Anthony E. Pratt, Parker Brothers/Hasbro 1946

[28] Reversi, aka Othello, aka Annex, aka Annexation. First published under the latter name by James Mollett 1870.

Svanaes and Verplank suggest that this can be computer enhanced by letting the tiles themselves be able to toggle between black and white, by simply tapping them.

There was a faint attempt to reach the masses with computerized board games in the 1980-ies. Thus, there are a few commercial games using electronics sensors and perhaps some computational power, one example being the numerous clones of chess computers. Another electronic game is *Stop Thief*[29], a game played on a city map. A thief has to be found and originally, this thief is played by a handheld "crime scanner" resembling a calculator. The crime scanner emits clues in form of sounds; the thief walking, breaking windows, running down a street, riding the subway and so forth. Using these clues, the players try to deduce where the thief is. A successor was *Dark Tower*[30] a sort of fantasy quest game where players should find the three keys to the Dark Tower and then defeat the monsters in it. The whole game is directed by the tower itself which is electronic and keeps track of troops and supplies, and conducts combat with random monsters.

The British company Maldoo Ltd. have quite recently created an electronic board called Maldoo[31] that can be used for playing 13 games (making it a game system), among others Reversi and a variant of Go. The board consists of some command buttons for choosing game etc., an alphanumeric display to show points etc., and the board itself, being made out of 9x9 touch-sensitive areas/buttons, that can light up in red, green (player colors) or yellow (neutral). Players make moves simply by touching the area they want to move to or activate. However this does not seem to have become a hit; it does not seem to be for sale. Apart from this, the few attempts to somehow computerize board games have stayed within the scientific community.

[29] Stop Thief, Parker Brothers 1979

[30] Dark Tower, Milton Bradley 1981

[31] http://www.maldoo.com

3 METHOD

Since this thesis covers notions from both interaction design and board game design it was natural to use design methods and notions from both of these fields, as well as from traditional (industrial) design methods. The methods mentioned in this section are either extremely common, or are ones that have been taught at the IT-University in Gothenburg.

3.1 Methods and approaches for HCI and interaction design

3.1.1 Participatory design

Participatory design (Löwgren and Stolterman 1998), sometimes called participative design (Preece et al 1994), is more of an approach to design, than a method in itself. It has become a fairly common approach within HCI, and it acknowledges mutual understanding and learning; not only should the users be involved in a design process, but the designers should also take part in the daily tasks of the users. The users can for instance participate by analyzing organizational requirements and planning appropriate social and technical structures, since their knowledge of the problem domain is better than the designers'. They can also be subjects of studies and interviews.

This is an appropriate approach when designing a product or system that has to be tailor-made for a certain company or branch, or if the group of future users is very homogenous. Good examples are for instance hip clothing – the users being urban youth – or a process control system for a company that obtains certain chemicals, the users being process engineers, chemical engineers, plant workers and other employees from that very company.

3.1.2 User studies

One of the corner stones in HCI and later in interaction design is to study how users interact with a product or a system (Löwgren and Stolterman 1998). User studies can be done at any stage in the design process; in beforehand to gather requirements and information, during development to evaluate designs and solutions and to assess requirements, and afterwards to evaluate the work and to see if set goals have been achieved (Preece et al 1994). There is a vast variety of such methods; some of the more prominent include:

- **User observation** (Preece et al 1994) – studying users that interact with a system, product or prototype. This can be done either in a special lab for user testing, or on site. Observations can be collected by an human observer or by video recording, eye tracking, by asking the user to "think aloud", by continuously interviewing the user ("why did you do that?" "How do you accomplish a certain task?") etc, in almost any combination. This is merely done to draw conclusions on how well the existing system works and how it can be improved. A problem is of course that the user may be disturbed by being observed.

- **Questionnaires/surveys** (Preece et al 1994) – asking users about themselves, their needs, wishes and their opinions regarding a certain system, product or phenomenon. This is particularly useful when developing an entirely new product or when the potential user group is large and non-homogenous. It is a fairly fast and cheap way to get information from many users, but the quality and nature of the data depends highly on how the questions and alternative answers are phrased.
- **Interviews** (Preece et al 1994, Beyer and Holzblatt 1998) – asking a selected group of users their needs, wishes and their opinions regarding a certain system, product or phenomenon. This will result in rich data from a small group of people. Also, the interviewer may react on, and explore certain statements, which may lead to new problems or possibilities not known or anticipated by the designers. The method is particularly useful if designing for a homogenous user group, but it can be expensive and the data may be biased. Also, interviewees may tend to give answers that are biased towards what is "politically correct", since they are not being anonymous.
- **Using an expert group** (Preece et al 1994) – having the design team working together with a group of experts that have extensive knowledge of the context where the design is to be used. Expert groups are necessary when designing for situations and environments that are unusual or unknown to the design team, but can be useful in any design process. The method may be expensive, and there is a risk that "ordinary" users may be left out.
- **Contextual inquiry** (Beyer and Holzblatt 1998, Preece et al 1994) – having the design team visit the site where the product or system is to be used. The designers study the work and try to find tasks, they work and talk with the users to find hidden knowledge and alternative ways to complete tasks, helping the users to articulate needs, tasks and problems. The designers then try to interpret and analyze data as well as categorize tasks, seeking feedback from the users. Finally the design team establishes a focus for the design process; which requirements are important and why.

3.1.3 Prototyping

User-centered interaction and HCI design relies heavily on prototyping. Prototypes can be used to visualize a design, to test it and to discover its implications. A design team may use prototypes to test and compare different designs, and to clarify design decisions and highlight design issues (Beyer and Holzblatt 1998, Preece et al 1994). Prototypes can be made in a number of ways; which one is chosen depends on what is being tested. Prototypes can for instance be (Preece et al 1994):

- **Full prototypes** – containing complete functionality but with low performance.
- **Horizontal prototypes** – showing the user interface but without functionality.
- **Vertical prototypes** – showing only one part of the system/functionality, containing complete functionality but with low performance.

These different kinds of prototypes can come in different varieties (Preece et al 1994):

- **High fidelity prototypes** – using a medium that is fairly close to the final product, e.g. having an HTML-dummy showing the possible functionalities of a website.
- **Low fidelity prototyping** – using cheap materials to make a prototype quickly, e.g. having sketches or cardboard models of the product.
- **Chauffeured prototyping** – involving a user that watches while a designer "drives" through" the system at its present state, explaining how it will work.
- **Wizard of oz-prototyping** – having a person acting out the behavior of the computer (see below)

In addition, the designers may have different approaches to the prototyping procedure (Preece et al 1994):

- **Requirements animation** – demonstrating possible requirements in a prototype, letting them be assessed by users.
- **Rapid prototyping** – making a number of quick prototypes to test possible designs and collect information on requirements, partly to see if they are accurate. It is important to evaluate the prototype and its impact on the conclusions before discarding it.
- **Evolutionary prototyping** – having one prototype that constantly evolves until it has turned into the final system.
- **Incremental prototyping** – building a system one section at a time, basing it on one overall design.

3.1.4 The Wizard of Oz-method

The Wizard of Oz-method (Salber and Coutaz 1993, Preece et al 1994) can be used whenever a computerized product or system is being built, thus being fairly common within HCI. It has gotten its name from the book "The Wizard of Oz" where everyone believed that the Wizard was a large impressive being, whereas this was actually controlled by a small man behind a curtain.

It is used for evaluating the ongoing design of a not yet completed computer system. A remote human being ("the wizard") acts out the systems tasks, so that the system appears to be fully functional even if it's not. Typically, the test persons are not aware of the human wizard until after the test.

3.1.5 Relabelling design

Relabelling design (Djajadingrat et al 2000) is a method that helps designers to explore the richness in actions, being a design method for interaction design. Participants are asked to consider an existing product and its functions, and then transfer these to another, entirely different, product. The method works best with groups, rather than individuals, due to the competitive and inspirational forces that will occur in a group. It seems to work best when relabelling onto an more or less everyday thing with lots of mechanical parts (e.g. a Swiss Army knife), perhaps because much of the ideas seem to come up when interaction with an object, plus that such an object can have many different states.

For instance, one could relabel a paintball gun to a cellular phone. Calling someone could then be transferred into shooting at them, and the nature of the message could be shown by the color of the bullet. Perhaps the shot would miss the person, but that person could then pick the bullet up from the ground and smash it (to see the color) at a later occasion. Or, one could go to their home, and if they weren't in one could fire a shot onto their door. To listen to an incoming call one would point the gun to one's ear, or shoot at a wall to see the color, and to record a message on the gun's answering machine, one would point it into one's mouth, or just load it with a bullet of the appropriate color. To "call" a lot of people and give them the same message, one would simply fire a shot in the air. The metaphors needn't be consistent or "logical"; the main point with this exercise is to look upon an object's functions in a different way, and to explore alternative ways to interact with such functions.

The method is quite quick and it is fairly easy to spot usable ideas. It might come off as a bit silly, but it is a surprisingly good tool when a group is stuck within a set of ideas and notions. It can also be used as a way to generate ideas for a new product.

3.1.6 Scenario writing

Scenario writing (Beyer and Holzblatt 1998, Grudin and Pruitt 2002) is a quite common HCI design tool. It is a way to embody the users and the design situation, the design team and/or some users write short stories about fictional users and how they carry out a task. The story should include other events than carrying out a task. e.g. the phone ringing, drinking some coffee, gossiping or arguing with colleagues etc.

Scenarios can be very helpful and inspiring for any designer, and they are quick and cheap to create. However, one must beware of that that the choice of characters of highly bias the outcome, as does the designers emotional response to the story. Also, it can be hard to stop, and it can be hard to let go of the characters; they may be influencing the design long after the exercise, having more impact than they should. One must never forget that the scenario is made up.

3.1.7 Personas

Grudin and Pruitt (2002) argue that instead of using Scenario writing, a similar but better effect can be achieved by creating detailed personas, claiming that some detailed personas will be more engaging than a number of scenarios. It can be easier for the designer to reflect on how the different personas would react to certain issues and solutions, than to relate to a number of scenarios describing various tasks and users. Also, the personas can be used for creating scenarios, and in these scenarios, making them more memorable.

Of course, the creation of the personas is critical; any choices made in this process will have consequences whenever the personas influence the design process. Creating the right set of personas is a challenge.

3.1.8 Design for extreme characters

Many products are targeted towards a certain group of users. When using the method of designing for extreme characters (Djajadingrat et al 2000), one does this in absurdum. The purpose is to explore character traits that may be common, but not prominent; they may be inferior to other traits, or perhaps they are considered to be "forbidden", anti-social or of low status. This is a fairly new method, used within interaction design.

Initially, one comes up with a couple of extreme personalities. It could be anything; a teacher that cannot read, an extremely social old man that imposes himself onto his friends rather than being alone, a compulsive liar etc. The characters are explored by writing down short descriptions of them and perhaps act out their behavior in a role-playing exercise. Thereafter, one tries to target one's product/design towards each of the characters separately.

This method is very helpful when it comes to finding new or alternative functions for an item. Again, it helps breaking boundaries of design. However, one must be aware that one tends to stereotype the extreme characters. The method also has the same weaknesses as Personas and Scenario Writing.

3.2 Common board game design methods

Since board game design isn't a very academic discipline, most of the methods below have been gathered on the Internet, or have been described to me and others by the Swedish board game designer Dan Glimne during a very interesting seminar[32].

3.2.1 Designing by mechanics

This approach is sometimes called the German approach, probably because one of it's advocates is one of the most well-known game designers in the world, namely the German Reiner Knizia. In this approach, the game designer first comes up with the main mechanics for the game, and which other mechanics that are needed to support it. Often, but not necessarily, this method involves a careful mathematic analysis of resources, values and flows in the game. A theme may be added later in the process, but it's significant for this type of game that the theme can always be taken out of the game, or changed without this affecting the game very much. A striking example is The 1997 game *Showmanager*[33] and the 2001 game *Atlantic Star*[34]; the rules are identical, but in Showmanager one tries to find actors to four different shows, whereas in Atlantic Star the theme has been changed to cruising.

Of course, the game might not get a theme at all; even if most if the games published nowadays have more or less significant themes, some don't, e.g. Kris Burm's series of abstract strategy games: *Tamsk*[35], *Gipf*[36], *Zertz*[37], and *Dvonn*[38].

[32] GothCon, Göteborg 29th of March 2002

[33] Showmanager aka Premiere (in an earlier version published by dbSpiele) by Dirk Henn, Queen Games 1997

[34] Atlantic Star, aka Showmanager aka Premiere (in an earlier version published by dbSpiele) by Dirk Henn, Queen Games 2001

[35] Tamsk, by Kris Burm, Schmidt Spiele 1998.

[36] Gipf, by Kris Burm, Don & Co/Schmidt Spiele 1998.

[37] Zertz, by Kris Burm, Schmidt Spiele 2000.

[38] Dvonn, by Kris Burm, Don & Co 2001.

3.2.2 Designing by theme

This is sometimes called the American approach, and when using it one analyzes a certain theme and tries to come up with suitable components and mechanics that fit it. The benefit of using this method is that the theme will support the rules; they will be easier to understand and remember since they seem logic to the players. E.g. it will be easy to remember and understand that a boat marker cannot be moved across a land tile, or that the value of a building will increase if it is built close to a park and a shopping center and far away from a factory. Of course this means that the rules must follow the implications of the theme; a last-minute tweak of the rules to make the game more balanced cannot easily be thrown in; it has to fit not only the requirements but also the theme. One cannot throw in a rule about a space ship or teleportation in a game about dinosaurs.

3.2.3 Evolutionary game design

Just like anything else that is designed, games and game rules are not flawless in their first incarnation. Thus, they need a design process. The most common design process for many games is an iterative one, quite similar to the iterative design processes that are common amongst interaction designers and HCI professionals. Daniel Cook (2002) calls it Evolutionary Game Design. One simply starts out with a basic set of rules, and a prototype. These are tested, modified and tested again and again; hardly surprising this process is called **play testing**, and the people who take part are called **play testers**. The designer can either take part, or observe the game being played. In both cases valuable insights will be collected. The play testers are encouraged to come with suggestions of new or changed rules, and the designer should also ask questions such as "Why don't you like this?", "Why is this frustrating", "Could you give me an example", "Why did you perform that action?", "Which problems did occur, and when, and why?" and the like.

The designer should keep an eye on such things as the flow of resources throughout the game, what rewards are given and when (like, finally capturing the queen in a game of chess, or being able to purchase/reach/find something that is scarce or valuable in the game) and whether there are long relatively "boring" periods in the game.

Also, the designer must be willing to remove or change existing rules. In most cases, it is better to tweak existing rules than to introduce an entirely new complex of rules to fix the problem. The latter may cause unnecessary complexity.

Normally, the evolutionary process goes through three stages. Initially, there are few rules, and each change has great effect. This stage is driven by careful analysis rather than on user comments and suggestions. The second stage is more about balancing rules, and here, play testers can contribute a great deal. In short, the concept is set, but the game is still dull and has a number of frustrating flaws. Finally, the game reaches equilibrium. The rules are stable, supporting each other. Small changes in the rules or in the prototype, such as introducing a new action card or commodity, do not affect the game play significantly. Play testers don't have that many comments, and the rule suggestions are more like "advanced rules", rather than "throw this out and try this instead". The game is "done".

3.2.4 Using a checklist: What makes a game "good"?

There is no guarantee that a game – any game – will be considered to be "good" or "funny" by its players. However, there are some rules of thumb that can be followed. Probably each game designer has his or her own individual checklist (being conscious of it or not). The one presented below has been put together by the board game designer Wolfgang Kramer (2001b), probably somewhat reflecting the thoughts behind the Design by mechanics-method:

- **Originality** – the game has to use a combination of elements and/or mechanics that have not been used together before.
- **Replayability** – it should be fun to play the game over and over again. The course the game takes should be as different as possible each time it is played.
- **Surprise** – repetition in sequence, progress, and events should be strictly avoided.
- **Equal opportunites & winning chances** – at the start of the game, every player should have an equal chance of winning, and every player must have at least a theoretical possibility of winning until the very end.
- **No "kingmaker effect"** – a player should win a game due to his own efforts, not because some other player has to make a choice that determines a winner.
- **No early elimination** - all players should be involved in the game until it's almost over.
- **Reasonable waiting times** – there should not be any long periods of inactivity while players wait for their turn or are unable to affect the game, or plan ahead.
- **Creative control** – players must have the opportunity to affect the progress and direction of the game.
- **Uniformity** - the title, theme, format, and graphics of a game must give a unified impression.
- **Quality of components** - durability, functionality, and the visual appeal of the materials contribute greatly to the perceived value of a game.
- **The type of game should fit the target group** – a strategic game for hard core gamers for instance, should have no elements of luck. It should offer abundant alternatives each move. A game for children may very well include luck, and should feature fast turns with few choices.

- **Tension** – long periods of relatively low tension should be avoided. Just as in film making, it is preferable to have several peaks of tension during the game.
- **Learning and mastering a game** – it is an advantage if a game is quick to learn but takes a long time to master.
- **Complexity and influence** - if a game has complex rules, they should provide numerous possibilities to affect the game.

3.3 Other methods

3.3.1 Literature studies and information search

John Chris Jones (1992, ch. 3.2) describes this as a six-step method where the most significant parts are to identify the kind of publication that may have relevant information, and to select a suitable standard method to begin the search. Standard methods mentioned by Jones are:

- Using encyclopedias
- Using library indexes and catalogues
- Consulting industrial librarians or some kind of information staff
- Consulting experts
- Consulting journals
- Using keyword indexes
- Consulting someone who is likely to have searched for, and found, similar information
- Consulting periodicals

A recent addition in this area is of course searching the Web, especially using search engines and databases of various kinds of publications.

It can be very frustrating to keep on searching without finding any relevant data. Therefore, one must continuously evaluate the various sources and the applicability of the found data, to keep the search effective. If this isn't done, the search can be lengthy and costly. Thus, one should not underestimate the value of asking peers and/or colleagues who are likely to have had retrieved similar information.

3.3.2 Stating objectives

Before starting the design process, it can be useful to state the objectives of the design or product. (Jones 1992, ch. 3.1). These objectives are then used when designing the actual product or system and its components. Thus, the aim with this method is to identify external conditions with which the design shall be compatible. Initially, one identifies the situation in which the design shall operate. Further, one shall identify features that must be fulfilled to reach a satisfying result, looking at the sponsor's expectations, the available resources and the essential objectives (the hidden agenda for the project; demands that, even if not stated, would cause a failure if not fulfilled). Finally, one makes sure that the different objectives do not contradict each other or are incompatible with given information. For instance, if one of the objectives is to send an unprotected man into space, and get him back alive the project will fail, since we have information stating otherwise.

It is well worth spending some time and money on carefully stating the objectives for an upcoming project, using methods of information search in addition to meetings and letters. This is particularly important if the project is extensive; since the penalties for misstating or misunderstanding the objectives may be critical.

3.3.3 Brainstorming

This method is used to come up with a lot of ideas in a short time, hopefully some innovative ones. When using the brainstorming method as John Chris Jones (1992) describes it, the participants are not allowed to criticize each others' ideas, to come up with as many ideas as possible and to try to combine or improve each others ideas. The ideas are evaluated and analyzed afterwards.

This is a very valuable method for almost any design situation. It can be used for coming up with totally new products or systems in the beginning of a project, but it may just as well be used at a later stage; this time to solve unforeseen problems in a creative way. Also, it is quick and will generate many ideas. The difficulties with the method lie in the subsequent analysis.

3.3.3.1 Method 635

This is a more structured variant of brainstorming, proposed by Pahl and Bietz in 1988 (Löwgren and Stolterman 1998). One starts out with a group of six participants that spend some time on studying a problem, after which each member writes down three possible solutions. Each solution is passed on to someone else that expands or revises the idea, and this proceeds until all participants have worked on all solutions. This means that the group will end up with 18 ideas that all have been revised, analyzed and extended by five persons plus the person that first came up with it.

The advantages with this kind of brainstorming is that the ideas are developed in a more systematic way, at the expense that the dynamic group process is lost.

3.3.4 Experience Prototyping and Bodystorming

Experience Prototyping (Buchenau and Fulton Sari 2000) is an approach that focuses on how a certain task or situation is being experienced. the experience of a certain task. It's main objectives is to understand existing user experience and context, to explore and evaluate design ideas and to communicate ideas to an audience.

A subset of it is bodystorming, which is a kind of role-playing exercise. A task or action is acted out by using suitable items. It is useful since it is easier to spot requirements that otherwise wouldn't be noticed when going through the task intellectually. Bodystorming may for instance reveal that a certain, carefully thought-out sequence of actions just won't work; maybe the steps should be carried out in a different order, or maybe one or more steps are missing. Bodystorming is fast, cheap, and can be done without careful prototyping; one simply uses what comes to hand. It can also be used to explore the interaction possibilities of a certain item, or set of items or functions.

However one must be aware of the influence the choices of items may have. If trying to come up with a new card game by bodystorming with an ordinary deck of cards, one may actually design for that deck, forgetting the possibilities to use only a subset of the cards or a different kind of deck.

3.3.5 System transformation

System Transformation (Jones 1992, ch. 5.4) is a way to remove inherent faults of a system, but of course new faults may occur trough this process. In short, one identifies the flaws of the system, identify the reasons for them[39]; tries to come up with new solutions, improvements or components that remove the faults, and finally find a sequence of changes that will allow the new solutions to evolve into the system.

It is best suited for changing large already existing systems where the transformation is slow and costly and will span over years, e.g. traffic systems, since such systems are hard to redesign with traditional methods. It will always be more popular to strengthen and rebuild an existing bridge, than to tear it down and build a new one at the same spot.

The method has some flaws, one being that even if it is easy to identify the flaws and even come up with possible solutions, it may be hard to come up with a suitable transformation process. Second, one can never be quite sure that the proposed solution actually works. Third, during the transformation sequence the changing system may have more flaws that both the predeceasing and succeeding systems.

[39] Jones calls this step the "Why? Why? Why?" method; one persistently keeps asking until one has found the true problem. Why don't you use your new saucepan? Because the handles get hot. Why do they get hot? Because the sauce pan is made out of one solid piece of metal, meaning that heat is conducted from the hotplate to the handles.

3.4 Choosing an approach

Again, this thesis is about how to join the social activity and fun of a board game, with the computers' possibility to add simultaneous and continuous action, and the sensors' abilities to detect changes. Thus the aim is to enrich board games, using ubiquitous computing and interaction design as a way to achieve this. In practice this means coming up with new board game mechanics that rely on embedded technology.

It should be mentioned that one of my main reasons for choosing this subject for the thesis is me being a gamer myself. Thus, I have a lot of experience of, and knowledge in board games and role-playing games, gamers and gaming, gathered by playing games, discussing games with other gamers – live and on the Internet, owning some 300 games, going to gaming conventions in both Sweden and the USA, organizing activities on gaming conventions on more than ten occasions etc. This has been my largest basis of knowledge throughout this work.

When it comes to structuring the work, practical research will be combined with theoretical findings, and therefore the work will be divided in three parts; studying mechanics and games, trying to come up with new solutions using gathered knowledge on sensors and microcontrollers, and then explore these findings in a more practical way, creating prototypes and presenting them and various ideas to fellow gamers and "users". The latter feels essential, since it will be hard to discuss and conclude theoretical findings without having tried them out at least a little bit to get an initial feeling of how the new technologies would work out. In addition, some game design techniques can be explored during this practical part of the work, to see how they would work together with the process of technical development. Finally, the work will have to take a more thoughtful, theoretical direction, consisting mainly of analysis of findings and experiences, attempts to apply this to mechanics and board game design.

The initial intention was somewhat optimistic; to create a great game using ubiquitous computing, but the goal that has been set is more realistic; instead the ways to create such a game will be explored, trying most steps but not necessarily carrying them out to perfection. In practice, this means that the work process will split itself up into two parallel paths, one theoretical and one practical, joining again when it is time to discuss the results and draw some conclusions based upon them. Thus, the work has been divided into the following set of sub tasks:

Theoretical path

- Information search on previous work and background information

- Information search on game mechanics, sensors and ubiquitous computing.
- Gathering knowledge on how to design games for ubiquitous computing

Practical path

- Establish goals for a prototype/game system and build it.
- Testing gamers' reactions to the idea of computer augmented board games
- Create rules for a game using the prototype/game system, test and tweak the rules.
- Come up with suitable interaction design applied to the game

Concluding work

- Analyze results,
- Propose computer-augmented mechanics
- Discuss & conclude work

3.4.1 Theoretical Path

This part mainly consisted of gathering necessary knowledge. To accomplish this, the method Information Search and Literature Studies was used throughout the thesis work. Although there are no significantly different alternatives to the method in itself, the outcome depends highly on which parts of it that are used. Most information was found by either searching for it on the Internet or by "consulting someone who is likely to have searched for, and found, similar information", namely my supervisor, colleagues, fellow gamers and class mates.

When it comes to Internet searches, Citeseer[40] and the HCI Bibliography[41] were the prime sources to find scientific publications. Unfortunately I do not have access to the ACM Library; which is probably better than Citeseer when it comes to both search engine and amount of material.

As for experts, a colleague may very well be considered an expert when it comes to ubiquitous computing. Information from gamers and game designers was also fairly easy to achieve, due to my relationships in the gaming community.

Encyclopedias, on the other hand, could hardly be used since the information sought after is to specialized, and since many relevant books are within reach at work, libraries and librarians were not needed.

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[40] A search engine for academic papers: http://citeseer.nj.nec.com/cs

[41] A search engine for scientific reports on human-computer interaction: http://www.hcibib.org/

3.4.2 Practical Path

To clarify the goals and aims of the game that was to be created, the method of stating objectives was used. It was appropriate, since it was more important to satisfy the objectives directed by this research process, than to create a great game for a certain group of users. This meant that it wasn't suitable – as it mostly is – to gather requirements and opinions on a computer and sensor enhanced board game by making interviews, questionnaires, surveys etc. Also, it is hard to get opinions on a non-existing, never-seen product from ordinary users in this way; it takes a considerable amount of engagement, fantasy and intuition, especially if the means of communication is a survey. In addition, it would have taken a considerable amount of time to gather and structure these amounts of data.

To come up with more concrete ideas concerning the game, brainstorming was used, as well as discussions with my supervisor and some fellow gamers. In a way, the latter is somewhat related to asking an expert group, or at least consulting experts for information. Here, the method of using Extreme Characters could have been applied also, but gamers can already be considered to be pretty extreme when it comes to gaming and games, meaning that it was hard to come up with an extreme gamer character. And to create an extreme non-gamer would probably not have been beneficial. Either way there was a risk that I, myself being a gamer, would have biased the outcome in a non-producible way.

A prototype was built, and some components were chosen to go with it. This game system was tested by using bodystorming. Initial tests were made by myself and someone else, just to eliminate the worst flaws before presenting it to the public and more elaborate user testing.

Again, there were two reasons for actually creating a prototype, one being my need to actually experiment with practical design, one being the need to present something physical to be able to encourage and explore user's hands-on interaction with it; which would have been harder with a less elaborate prototype.

.As mentioned, two of the sub goals were to create rules for a game using the prototype/game system and observe gamers' reactions to the idea of computer augmented board games. The fulfilment of these goals was combined by testing the prototype at the gaming convention GothCon. The purpose of this test was only to see which kind of behavior and rules the game system encouraged. It was performed as a kind of rule writing contest, and the participants (being competing teams) can be regarded as more or less experienced gamers. Thus this test was somewhere in between participatory design and asking an expert group.

Of course the rules could have been created by a group of expert users, using brainstorming sessions followed by testing the best ideas. But such a group can easily get caught within the boundaries set by the first ideas regarding theme and/or mechanics, plus that the outcome of the experiment would most likely be only one set of rules. Thus it seemed more beneficial to have five-six groups working with the same initial postulation regarding game materials and goals. First of all, more games/rules came out of it and second, the total amount of ideas (used or unused) was hopefully larger.

Since this prototype was non-computerized, but still should have the characteristic of a computer-augmented game, a variant of the Wizard of Oz method was used. However, the condition that the test persons shouldn't be aware of the wizard until after the test couldn't be fulfilled since the prototype had to be manipulated in sight of the test persons, being a physical prototype and not a more or less working mock-up of a computer system, which is what this method is normally used together with. This may have been somewhat mitigated by the fact that most gamers are used to having a game master when playing role-playing games.

The reason for using the method was to enforce the concept of a computer performing certain actions, partly to keep this notion alive during the design process so that the groups were encouraged to incorporate actions performed by a computer within the rules. Also, their reactions to having a computer embedded in the board game, came across clearer. Another reason was to avoid the application of human characteristics onto these actions, i.e. imperfect or slow calculation, deliberately moving something too slow, too fast, too far or too short.

As expected, one team came up with a set of rules that was chosen to be explored further. These rules were tested and tweaked using evolutionary game design, since this is a de facto standard when designing board games. Also it naturally involves quick feedback from other people. In addition – since being specialized for game design – it helps keeping the focus on things such as rewards and resource flows; if using a more generic design method these aspects could easily be forgotten. Another reason for choosing it (and for doing this step altogether) was to show interaction designers the flow of this process. It also has very much in common with Evolutionary prototyping.

An alternative method for tweaking the rules would have been to use System Transformation. One might say that this method is a more formal, less specialized variant of evolutionary game design. It wasn't used, since it is normally used for larger systems though, and the last step, to find a sequence of changes to reach the new solution(s) is obsolete in game design; necessary changes are simply done and tried out.

Brainstorming was used to come up with a suitable (but yet theoretical) design for an imagined computerized variant of the game, focusing on conceptually developing the ways in which one should interact with this future game, i.e. choosing input and output devices; in this case various buttons, LEDs etc. Some thought were also given to the placement and coloring of the devices. Had this been a "real" full scale project, these designs of course have to be user tested before implementation.

3.4.3 Concluding work

Finally, all the knowledge gathered during the previous work was analyzed in order to draw conclusions on computer augmented board games. Existing mechanics were examined and new mechanics made possible by ubiquitous computing, were identified. The latter is probably be the most significant result of the work.

4 SUITABLE TECHNOLOGIES

To gather this information, the "Literature studies and information search"-method was used for searching for information, as described above. You will notice that there is no price indication for most of these components. This is due to the fact that process vary very much depending on supplier, and the amount that is bought, and that prices keep dropping.

4.1 Input devices

Input devices are any kind of controls that humans will use to deliberately communicate with a computer. It can be buttons, knobs, switches, handles etc. It can also be sensors, that triggered by some kind of "data", not necessarily bits, but changes in light, sound etc. Almost all input devices will use electricity to communicate with the computer; when they are interacted with, a circuit will either be shut or opened, or the resistance in the device will somehow change, increasing or decreasing the current that flows through it. Such changes are easy to detect.

4.1.1 Sensors

Sensors are a kind of input device that typically pick up environmental data, most of them turning it into changes in voltage, resistance or capacity (Person 1998). Unlike the input devices mentioned above, they do not need a human to interaction to register and/or send data. There are sensors to measure presence of, or changes in almost everything. Common ones are:

- **Light sensors** come in a variety if types with different resolutions and kinds of output, e. g. photodiodes, LDR resistors and optic switches.
- **Ultra sound sensors**, that are used to measure distances; an ultra sonic pulse is sent out by the sensor, which measures the time it takes for the pulse to bounce off an item and return to the sensor, thus measuring the distance.
- **Temperature sensors**; these normally need physical contact with the item whose temperature is to be measured, and the measuring takes some time, perhaps a minute. They use the fact that some materials conduct current better at higher temperature, or that the density of some materials depend on the temperature.
- **Bend sensors** that are built into flexible objects and can measure how much they are bent. Their resistance increases with bending.
- **Accelerometers** measure acceleration in one, two or three dimensions. They measure changes in gravity and can measure tilts as small as 1 degree.

- **Capacitive proximity sensors** measure proximity of almost any non-metallic material, and are quite easy to calibrate. They can also be built into almost anything. In practice, they are one half of a capacitor, the object to be detected working as the other half.
- **Pressure sensors** that can measure for instance air pressure. Since air pressure decreases with height, they can be used to measure changes in height, but not as small changes as one would probably have in a board game.
- **Flow meters** that measure the speed with which a fluid flows, for instance through a pipe.
- **Compression sensors** measure physical pressure; their resistance will increase with increasing pressure. They can be used to measure weight, or to detect if something has been lifted (if the sensor is put underneath the item).
- **Doppler radar** can sense moving objects, even through walls. They send a radar pulse from two different spots, and then measures the time it takes for the pulse to bounce off an item and return to the sensor, thus measuring the distance. Since there are two sensors, the results can be compared to calculate the direction of the moving object.
- **Magnetic sensors** come in a variety of types, for instance Hall sensors, that are commonly used for bicycle computers. A small magnet is placed on the bike's spokes and the Hall sensor is put on the front fork. It notices the variations in the magnetic field each time the magnet passes by it, and thus the speed of the wheel can be measured.

Unlike the other sensors mentioned above, that only react to and refer some kind of physical stimuli, there is at least one kind of sensor that can actually be used for reading data:

- **RFID-tags and readers** is a technique used for keeping track of items. The abbreviation stands for Radio Frequency ID, and as implied, they use very weak radio signals to communicate. The RFID-technology consists of two components. First, there is one or several **RFID-tags** hidden in the relevant components of the game (such as money markers, certain cards or whatever one wants to keep track of). A tag only holds one piece of information; its value or identity, and it does not require any electricity to work. It is small, cheap and very useful. Second, there is a **RFID tag reader**. It is flat and could thus serve as a shortcut to the rules[42] at the same time. This one has to get power from some source, but it needs quite little, so

[42] This is sometimes called a cheat-sheet, and it's a quite common accessory to many games; its simply a pieces of cardboard that summarizes the order of play and the possible actions during a turn. It may also conation any other information that the players need to have handy, e.g. building costs.

a battery of the flat kind that is used in watches might work just fine. The tag reader activates the tags, reads their value and then treats this data in some predefined way. It might also have a small display built into it, or have some other way to show certain data. Unfortunately, and unlike most sensors, the tag readers cost fairly much.

Sensors can be used to enhance board games by collecting information in many ways. A few examples are listed below, but actually it's only the game designers creativity that sets the limit.

- **Keeping track of the deployment on the board:** This means that if the board is divided in areas, that each has a sensor connected to it, it will "know" which areas are occupied, and with some logic built into the microcontroller it could also calculate how many connected areas there are and how large they are. This can be done with several kinds of sensors, a few being
  - **Light sensors**, that can detect if something is put onto them, blocking out the light. If the pieces also are diverse when it comes to opacity, extra sensitive sensors could be used to determine which kind of piece it is, depending on the amount of light it lets through.
  - **Compression sensors** that react on weight. If different pieces have different weight, the microcontroller will also know which pieces are where.
  - **Capacitive proximity sensors** can also detect a piece, and if the pieces are made of different material, which piece.

- **Measuring proximity with magnetic sensors**: If some pieces in a game contain small magnets, the sensor can detect if one or more of them is close to it.
- **Measuring movement with accelerometers:** These can be used to measure if the object they are attached to is moving, or if the velocity or direction changes. This could be useful in dexterity games.

4.2 Output devices

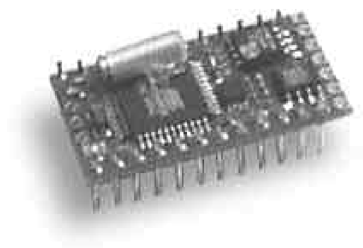
Output devices are used to show data, or the state of an item. Typical output devices are for instance light emitting diodes (LEDs), small lamps, typically used to indicate if the TV, computer, or some other electrical equipment is on. Others are loudspeakers and/or liquid crystal displays (LCDs), the kind that are common in digital watches and pocket calculators.

Another kind of an output device is a motor, that instead of displaying information, moves something. There are many different types; they may be small or big, strong or weak, run on direct current or alternating current. Some are step motors, which means that the turning of their driving shaft can be controlled down to less than a degree, resulting in a very exact motion. The rotating movement of the driving shaft can be converted to linear movement by using cogs an cog racks.

4.3 Microcontrollers

A microcontroller is a kind of one-chip computer (Person 1998). When applying ubiquitous computing a microcontroller must be used if one wishes to embed computational abilities within small objects. It will serve as a hub, receiving input from various sensors, input devices etc., processing it, and finally using the outcome to affect output devices, motors etc.

Microcontrollers are common in most everyday appliances and are also often used for data logging (e.g. of environmental parameters). The microcontroller is a highly integrated chip which includes all or most of the parts needed for a controller. It typically consists of a central processing unit, some memory, timers, an interrupt controller and easy and direct access to input/output. It is of course programmable, even if it cannot support as much and complex code as a normal computer[43]. Since it is a one-chip solution it drastically reduce parts count and design cost.



A microcontroller, namely a BX-24 chip, natural size.

[43] A BX-24 chip for instance, can hold about 8000 lines of Basic code.

5 RESULT: GAME DESIGN EXPERIMENTS

This section covers the practical part of the work; experiments on how ubiquitous computing can be used when designing board games.

5.1 The Hatchery

To get inspiration from peers as well as to explore the possibilities of the ubiquitous computing field, I attended a one-week atelier for exploring fun and entertainment with ubiquitous computers (Björk et al 2002). The atelier took place in February 2002, at the IT-University in Gothenburg and was organized by Staffan Björk and Peter Ljungstrand (PLAY Research Studio/Interactive Institute, Sweden), Karl Petter Åkesson (Swedish Institute for Computer Science) and Jussi Holopainen (Nokia Research Center, Finland). Apart from the organizers, eleven people took part.

The first two days were spent using various techniques to try to foresee the future in 2010, as well as introductions of the participants and available tools and technical solutions. Thereafter entertainment concepts using ubiquitous computing were developed, one by each group. The group I joined[44] started out by stating some objectives (e.g. that reasons for playing should be earning money, having fun, express creativity, and to collect cards, in that order) and then created a game system called Multi Monster Madness, mainly using various non-formal variants of non-formal brainstorming (i.e. coming up with and analyzing/criticizing ideas continuously) and body storming.

Also, myself and organizer Jussi Holopainen came up with a game for Multi Monster Madness, called *The Hatchery*. This was done using a combination of the methods Stating objectives (i.e. only stating features we wanted to use, such as avoiding turn-taking), non formal brainstorming, a lot of bodystorming and designing by mechanics. There was neither time nor players nor some suitable prototype items to conduct any evolutionary game design.

The reason for using the methods in a quite non-formal way when working in group was due to sheer time pressure; we only had two days to come up with both the game system and the game, starting more or less from scratch. Since the atelier was one week, none of the game environment or the game itself has been implemented in any form. However it would

[44] Mads Haahr (University of Dublin, Ireland), Niels Reijers (Delft University of Technology, Netherlands) and myself.

be possible to build a fully-functional version of this game system and the game given enough time and resources. Another group that took part in the Atelier actually built and tested a prototype of their game idea.

Creating *the Hatchery* was for me an exercise in finding game mechanisms that would be non-existent without ubiquitous computing. It is described below, simply to show the possibilities of ubiquitous computing and tangible bits. A more elaborate description of its game system plus the entire rules for *The Hatchery*, and can be found in Appendix 2.

5.1.1 The game system

The Hatchery is played with a game system of monster cards, called Multi Monster Madness. The cards depict monsters and are small touch screens that carry all data about that certain monster's possibilities. Each monster is unique – it has it's own genetic properties determining its looks (e.g. how many legs, arms and eyes it has) and abilities.

5.1.2 The game itself: The Hatchery

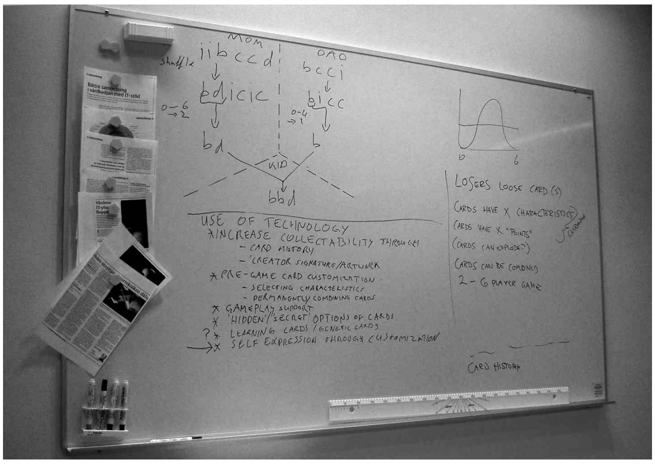
The game that was invented to go with the monster cards was called *The Hatchery*. This game is played with teams of monsters. Each team has four eggs in their chamber in an egg-hatching factory. Also, each team has the same setup of eggs; one purple, one pale green, one pink and one turquoise. How fast eggs grow or shrink depends on the environment in the entire factory. This environment is visualized with a color – the closer this is to an egg's own color, the better it grows. Each player gets points for hatching his or her eggs, the sooner the better. Points can also be earned by cooperating with other players.

The color in the factory can be changed by feeding pellets into its heating system, and therefore the game is about the following things;

- Getting pellets and feeding them into the factory.
- Cooperating to get more pellets and points.
- Saving shrinking eggs by temporarily taking them out of the hatching chamber.

The game ends when all eggs have been hatched, and whoever has the most points at this point wins.

Niels Reijers and Mads Haahr trying out an early game idea



A whiteboard full of ideas

Jussi Holopainen working on the final game idea

5.1.2.1 Special features made possible with ubiquitous computing

There are several things in *The Hatchery* that can readily be accomplished with ubiquitous computing; courses of events that continue throughout the game and would need complex rules if they were to be simulated in a non-computerized game.
Some of the mechanics use the computer's and the screens possibilities to proved changeability, by providing an ever-changing appearance, or letting an object's properties change over time.

- **Factory colors:** Most obvious are the color changes in the factory. It is calculated using information about how many pellets have been fed, which colors they had and from that creating a color tone… constantly and smoothly. Also, there is a time aspect involved in this; pellets only contribute to the color of the factory for a certain amount of time; after that they have been used. If the suggested special rules are used, and the color is supposed to be unevenly distributed, this course of events is a bit more complex to calculate and almost impossible to simulate.
- **Grow rate of eggs:** The eggs' color values are compared with the momentary color value of the factory environment, and their growth (or non-growth or shrinkage) is calculated based upon the difference. This is a continuous process.
- **Grow rate of pellets:** The pellets grow in pellet fields, where monsters can go to gather hem. But, just like real crop, pellets grow quite slow, and one field cannot produce and endless amount of pellets on its area. The growth rate is of course calculated by the pellet field card itself.

This changeability could also be combined with the activities carried out with and by the cards/monsters: When a monster is moved physically it also moves virtually. There are a couple of locations (e.g. pellet fields and the factory) in the game, and monsters move between them. Thus, proximity sensing is used to find out if a monster is either a) next to a location or b) not next to a location (which is treated as being next to a certain non-location: the void). Monsters move with a different speed depending on how many legs and wings they've got. Now, in the game, movement is measured in time – it takes a certain monster a certain time to get to a certain location. From a computers point of view the locations reside in a virtual space where every location is exactly the same distance away from any other location (the cards making up the factory counting as one location), including the void area.

To practically move a monster, its card is moved from one location to another. The time it takes for it to actually get there is computed by the card and a little status bar is counting down on the card. While the status bar is counting down, the monster is busy and cannot do anything else. The practical implications of this is that the physical layout of the location cards do not matter; a board is not necessary. Also, it means that the game is not turn based; all players may move any one of their non-busy monsters at any time, or interact with them in other ways. The computer is also used for handling information and keeping them hidden from the players; a suggestion was to keep the points secret from everyone (including one's own points) until the end of the game.

5.2 The MarbleGame

The aim with this experiment was to develop a game system that could easily be enhanced with ubiquitous computing. To outline what was wanted, the method of stating objectives was used, which led to the following:

- The game system should be suitable for four or more players, and have at least one set of playable rules, to show that the idea was feasible. If possible, it should be a "good" game, but this was not the main objective, since this can be very hard to accomplish and measure.
- The sponsors'[45] expectations, also being the essential objectives were that
    - The game should need ubiquitous computing to work properly; otherwise it would be useless as an example.
    - Still, the game should be possible to create a non-computerized prototype for the first tests. The reason for this was that the rules were to be created using this prototype; without any rules it would be hard to foresee which behavior the final prototype would have to support. This seems to contradict the previous statement, but the plan was to use the non-computerized prototype together with the Wizard of Oz-method to create rules and to see how people reacted to the idea.
    - The game should include some complex behavior that is hard to cover with rules or algorithms carried out by humans,
    - It should be hard, or impossible, to recreate as a plain board game or a computer game.

[45] The sponsor in this case, was above all myself, but also my supervisor Staffan Björk, examiner Lars Hallnäs an the IT-University.

- Available resources were play testers, players, game designers, tools and materials to build the various prototypes. The only identified scarce resource was the help to build the real prototype.

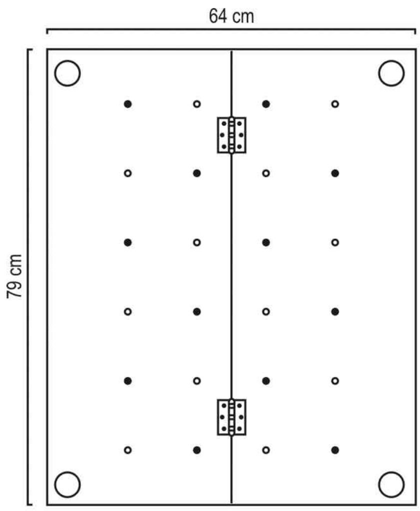
Given these objectives, in combination with some brainstorming, the decision was to have a variable board having sticks moving up and down under a cloth, thus creating an ever-changing landscape of hills and valleys. This fulfills both the objective that the game needs ubiquitous computing to work properly, and the object that it should be possible to build a non-computerized prototype. To fulfill the last objective marbles were introduced as game pieces, since it is rather hard to predict or calculate exactly how a marble will roll across a non-even surface.

The physical parts were constructed partly for being used in the "Build your own board game" contest (see below) and therefore the parts were chosen to encourage lots of different uses.

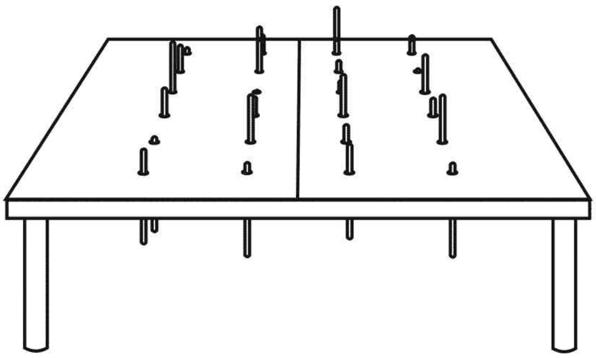
5.2.1 The first prototype

The aim with the first prototype was simply to be able to try out ideas regarding how to play, which tokens to use, and to see if additional changes and add-ons were needed. Also, it was used to check which measurements and proportions could be suitable, and to test materials – especially for the surface. Since these things could be tried without any built-in electrical components none were used. Another reason for building a non-computerized prototype was that the creation of the rules and/or changes in components may very well affect the assembly, layout and logic of the motors, sensors, buttons and microchip; changes that would be very time consuming and perhaps expensive. Instead the computer's actions were to be simulated with dice or with a person acting as an engine (i.e. moving a stick up and down at a certain speed throughout the game).

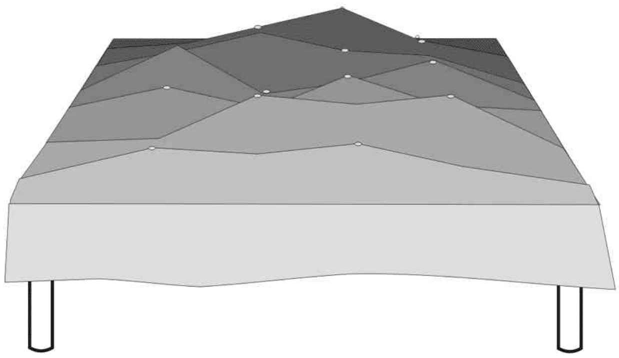
The prototype was assembled during a weekend and consisted of two shelves joint by two hinges. The entire board had the proportions 64 * 79 * 2 cm. The shelves had 12 holes each, making a total of 24 holes, placed in a 4 x 6 grid with 12 cm between the holes. The reason for having a 4 x 6 grid instead of, for instance 5 x 5 was to give the board a distinct orientation. The holes were clad with Wettex dishcloth on the inside, to provide some friction. 24 sticks, 10 cm long, were mitre-cut, as well as four legs of round staff, 20 cm each. The sticks were also sandpapered to get smoother edges, so that the edges wouldn't tear apart or stick to the cloth. Also, nine lines were drawn on each stick, 1 cm apart, thus dividing the stick into ten segments. The idea was that this could be used when determining how much a stick should be moved upwards/downwards.



The board seen from underneath. The four larger holes in the corner are for the legs. The 24 holes in the middle area are the holes for the sticks. Holes marked with a black filled dot symbolize that the stick in that hole will be attached to the cloth with a drawing pin.

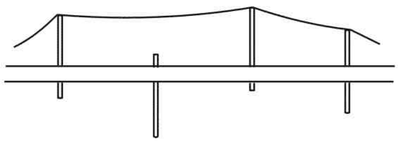


The board from the side. Note that the sticks are held in place by friction. This means that they can be moved up or down to change the pattern.

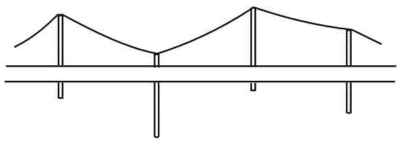


The board with the cloth on top. The white spots are the drawing pins.

Finally a piece of black elastic cloth was put over the board and every second stick was pinned to the cloth with a drawing pin. The reason for doing this was to provide a more variable landscape; pinned sticks can provide a valley in-between two heights.



Board seen from the side. The cloth stretches from the first stick to the third without touching the second, lower stick.



Board seen from side. Here, the cloth is attached to the second stick, thereby being pulled down by it, creating the valley.

Initially, the idea was to use some kind of rubber for the surface, but since rubber tends to get old, and is easily torn apart if holes are made in it – it was abandoned in favor of elastic cloth. Also, one attempt was made to protect the holes in the cloth with eyelets, but ironically enough the eyelets themselves tore the cloth, since they were of the smallest kind, and thus had no rings on the backside; they were simply deformed by a tool to fit.

5.2.1.1 A quick test

To test the behavior and feeling of the board, Staffan Björk and myself sat down to test it. With the help of a couple of marbles and later a couple of quickly drawn cards (made out of Post-Its) we created rough rules for some five two-player games within an hour. In most of them the goal was to get one's own marbles, or a significant "football marble" across the board.

One of the better ideas included cards numbered 1–6 and A–D. The aim was to get one's three marbles across the board without being hit by a non-player pestilence marble that immediately killed every other marble it touched. The lead player played a number card and the second player played a letter card. This determined the coordinate of a stick that was to be pushed upwards or pulled downwards according to a die roll.

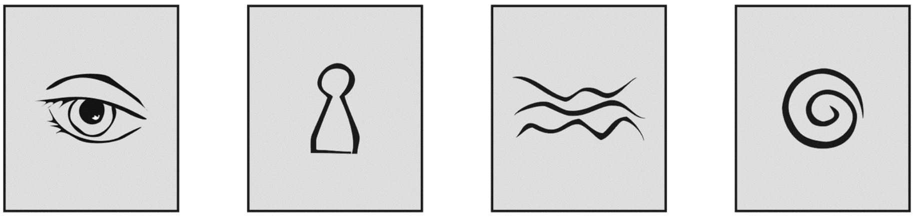
The marbles rolled off the board very often. This was both a feature and a bug at the same time. A possible improvement would be to put some kind of rim along the edges, maybe with a few gaps.

How the marbles rolled depended a lot on how the sticks were raised or lowered, respectively. If a stick was moved upwards in a powerful manner, marbles rolled all over. If it was raised or lowered slowly the player doing this could pay careful attention to the marbles, trying to stop at the exact right moment. This by itself is a behavior that could be built into the game.

5.2.1.2 Improvements: cards

Since the game idea with the cards worked out quite well, a couple of cards were designed. They were 5 x 6 cm, made out of colored cardboard, and laminated. Thus, a card has the same color on both sides.

- One series of cards was white and numbered from 1 to 6. There were eight cards of each number, meaning that in a four-player game each player could get two cards of each value, in case they were to be used to get coordinates.
- The second series of cards was gray, and were lettered from A to D. There were four cards of each letter.
- The third series was dark gray and contained some kind of fortuitous cards that could be used for practically anything by the game designers. There was three of each kind.



Fortuitous cards

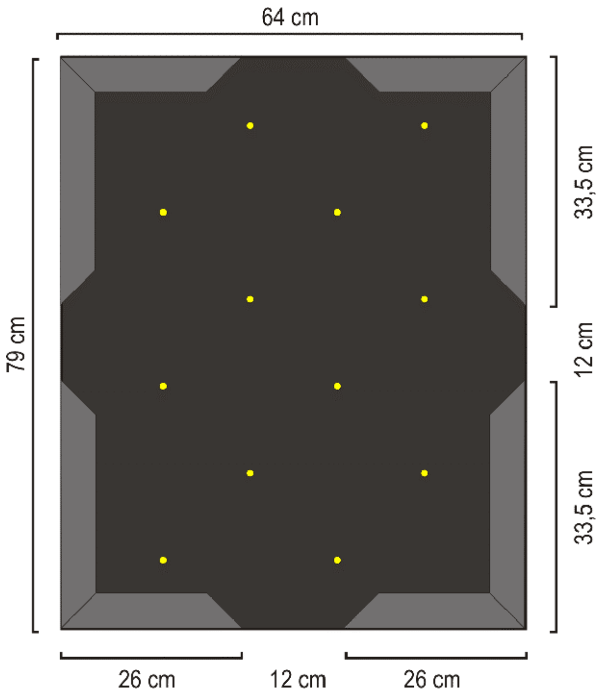
There were some design decisions behind this. The reason for giving the cards different colors was to explicitly give players a chance to see what kind of cards and how many of each kind, the other players had. Now, if the game inventors did not wish this, they had the option of using the extra white cards as a substitution for the gray ones.

The eye symbol on the leftmost fortuitous card was plain arbitrary, while the other ones vaguely depict things in the game, from second left to right; the game piece, the board, a marble. They might as well be interpreted as something else though (and later findings showed that they were). Game designer could also use the more neutral A, B, C and D-cards for symbolizing certain events.

The cards were made in different grayish colors so that they can be distinguished from what will probably become the player colors namely red, yellow, blue and green.

5.2.1.3 Improvements: a rim

As mentioned before, the marbles easily rolled of the board. This was prevented by creating a kind of rim, made out of loose pictures for a picture frame, the kind you can buy in stores for artists. Since many of the previously invented games had been about getting marbles off the board, the rim was not made in one piece; it consists of four corners that, if aligned to the corners of the board, leave a 12 cm long "goals" on each edge. Since the rim should be optional, it was kept in place with clips. The rim could be put on top of, or beneath the cloth, which gave different effects; if put on top it would only prevent the marbles from rolling off the board, but not cause them to roll back towards the center as in the other case.



Board with rim, seen from above

5.2.2 The final game system

After the improvements, the final game system consisted of the following components:

- 1 board, including four cornered rims and clips to keep them in place
- 30 marbles; 6 red, 6 yellow, 6 green, 6 blue, 2 black, 2 white, 2 black-and-white
- 2 larger marbles
- 12 wooden pellets; 3 red, 3 yellow, 3 green, 3 blue
- 4 wooden eggs, 1 red, 1 yellow, 1 green, 1 blue
- 4 game pieces; 1 red, 1 yellow, 1 green, 1 blue
- 48 white cards, numbered from 1 to 6, eight of each number
- 16 gray cards; four marked with "A", four with "B", four with "C", four with "D"
- 12 dark gray cards with four different symbols; three of each

The components were deliberately designed or chosen to be as non-specialized and neutral as possible; it should be able to combine some or all of them in many different ways, being able to generate many different sets of rules for the game system.

In a way, this can be regarded as Designing by mechanics, since the components partly were chosen to impose certain interactions, in turn imposing certain mechanics; e.g. the fortuitous card were included to perhaps trigger the Event Card Interaction-mechanic. Also, the asymmetric board could trigger Partnership or Co-operative Play.

5.2.3 The "Build your own board game" - experiment

To get several user groups that could come up with one or several sets of rules for *The MarbleGame* game system I arranged a rule writing/game design contest called "Build you own board game" as an event at the gaming convention GothCon XXVI. Each team had five hours to come up with a game, using some or all of the predefined component in the game system.

5.2.3.1 Purpose

The purpose of the "Build your own board game" - experiment served three purposes, the first one being to observe how people interacted with it and the idea of building computer technology into a game, the second being to see if the contestants could come up with a good set of rules for the game, and hopefully to get more than one set. These rules could later be used and perhaps be redefined while building the computerized prototype. The third purpose was to see which of all the components that were actually used.

5.2.3.2 Setup

GothCon is Sweden's largest and the world's oldest gaming convention[46]. It takes place in Gothenburg (hence the name), Sweden, each Easter, and has some 800-1200 visitors each time. According to GothCon's own statistics 86% of the visitors in 2001 were men. The average age of the visitors in this year was 22 – this increases slightly from year to year. GothCon's focus used to be on role-playing, but the last decade other activities such as board games, miniature games, war games and card games have become more and more important. In 2001 38% of the visitors came to GothCon to engage in these activities, and another 38% came to play role-playing games. The rest came mostly to meet other people and to socialize.

[46] The first GothCon was arranged under the name "Konvent 77" in 1977.

5.2.3.3 Rules for the competition

The rules in total can be found in Appendix 3. In short, each team had five hours to come up with, write down, and hand in rules for a game. To do this, they were given the *The MarbleGame* game system. They had to use the board, at least one marble or pellet and some – but not all – cards.

They were encouraged to apply computer finctionalities to the game. To promote this, the game designers were **not** allowed to move sticks up or down during game testing; this was made by myself, acting as the computer. Another reason for this was that if a player gets to move the stick herself, she can move it at a chosen speed and stop when she is satisfied with the outcome. This kind of fuzzy quality could not be computerized, and therefore it could not become a distinct part of the game.

Before each session, every team got the background of the research explained to them, including my purpose with the contest, as well as the game materials, and the possibilities of the board. This was not a part of the five hours they had to complete the game.

A jury then chose the winning game. I was not a part of the jury myself, but took part in its work by acting out the computer.

5.2.3.4 Participants

Six teams took part in the competition. Overall, there were 24 participants, five of them women (20,8 %). Their gaming experience was measured by giving them a list (see Appendix 4) and asking them which ones they had played. The statistical outcome was as follows:

	Age	Games played (max 35)
Span	17 – 32	8 – 32
Average	21.6	18.2
Median	19.5	18

The jury was significantly older and more experienced in gaming. They were three men and one woman, aged 22, 28, 33 and 43 respectively, having played 20, 20, 26 and 30 games each.

5.2.3.5 Observations

The computer's actions were performed by myself, using the Wizard of Oz method. Typical tasks were to move the sticks, generate random numbers and keep score. Three of the five teams specified such computer qualities in their final rules. Unfortunately humans have some limitations when it comes to acting out computer behavior. For instance, only one or two sticks could be raised or lowered at a time. Also, it was very hard to do this with the same speed every time, and sometimes the sticks got stuck. Also, when moving a stick downwards, it was sometimes hard to know when to stop. One participant remarked that he would have liked to try out a game where the board changed constantly, with the cloth moving in a wavelike manner caused by the sticks moving continuously.

All teams expressed some enthusiasm towards the idea of computerizing board games, and a few persons were highly interested. In general though, the teams were more focused towards the upcoming task of creating the rules, and did not reflect further on this concept.

Devoted gamers (four of the participants and one jury member) were more skeptical than the others to the idea of the sticks moving, mainly because this gives a game a touch of luck and randomness as compared to the pure logic oriented games favored by such players. They explicitly disliked the difficulties in foreseeing the outcome of a stick move. It should be mentioned though, that randomness not necessarily makes a board game bad. Many good games contain certain elements of luck, be it dice, randomly mixed and dealt cards, luck of the draw etc. It's just that many hardcore gamers dislike such elements. It's worth mentioning that the difficulty to make good predictions were partly due to myself being an insufficient computer.

None of the user groups used a formal method to come up with ideas, perhaps since the design situation was a contest under time pressure, but they all used variants of brainstorming and bodystorming. The user groups did not do this in a very formal way; their design processes involved a frantic cycle of suggestion-evaluation-criticism-trying out ideas. Some of them did start out with discussing whether they should determine theme or mechanics first.

Glass marbles were used on all sets of rules. In four, they were pieces belonging to different players, but in one game[47] the marbles were used as part enemy (knocking game pieces down) and part goal. None of the teams used the eggs. They were too large, they needed a lot of slope to start rolling, and it was to hard to predict how they would roll.

All teams but one[48] used the fifteen "invisible" squares drawn out between the sticks. All teams also used the rims. They had many creative ideas on how to use them, like putting them under the cloth, having them make out a track, or dividing the board into different sections with them, but finally they used them as intended.

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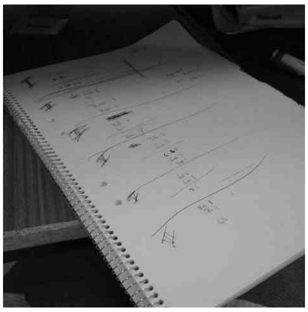
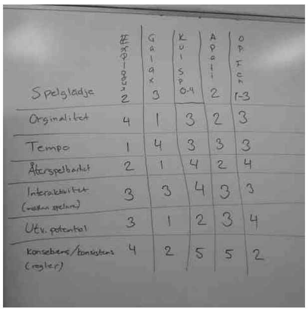
[47] Explodus

[48] Explodus






Galax
Spelglädje 2 3 0-4 2 1-3
Orginalitet 4 1 3 2 3
Tempo 1 4 3 3 3
Återspelbarhet 2 1 4 2 4
Interaktivitet 3 3 4 3 3
Utv. potential 3 1 2 3 4
Konsekvens/konsistens 4 2 5 5 2
(regler)






Other creative ideas (not used in any rules) included

- Simultaneously moving up to four sticks (one per player).
- Having an extra board on the side for resolving fights.
- Making pure dexterity games throwing marbles or eggs that would bounce on the stretched cloth.
- Having to play pieces in a defined order (marble-pellet-egg).
- Making a singing game
- If one or more sticks were moved x steps in one direction, this had to be compensated by moving one or more sticks x steps in the other direction, making it a zero-sum-game.
- Having one marble that should be moved by the computer.
- Having a tilted board, using it as some kind of pinball game
- Having one or more sticks that moved continuously.

For some reason it was hard for the participants to come up with the idea that the sticks could move upwards or downwards and then immediately return to their start position. It took at least one hour for any team to come up with this, and some never did.

5.2.3.6 Result

Out of the six teams, five handed in rules. Interestingly enough, the oldest team with the most gaming experience was the one who bailed out. They claimed to like the idea with the sticks moving, but were unable to use it. Below is a short summary of the five competing games/sets of rules.

A fun game (Ett kul spel) [49]: A Ludo-like game using the fifteen "squares" on the board. The object is to move one's marbles from one's own corner of the board to the opposite corner. Marbles can be moved by physically lifting them and putting them down in an adjacent square, or by moving sticks so that marbles roll. Sticks then return to their initial position. Special cards can lock sticks in a high or low position, extra marble moves, moving two sticks simultaneously, and changing places of two opponent's marbles.

[49] Rules were written by Alexander Dahl, Olof Dahl, Teresia Dahl and Rickard Elfgren. The title contains an untranslatable pun; the Swedish word "kul" means "fun", but can also mean "marble" when used in compounds with other words.

Explodus[50]: The object of this game is to collect three fortuitous cards and then move one's game piece to the Mount Sinai (symbolized by one of the larger marbles; both of them are in play). Fortuitous cards are collected by moving one's game piece to a stick for which one has the coordinates (indicated by letter and number cards). Only sticks with drawing pins can deliver cards, while other sticks can be made to explode (rise quickly and then return back down again), hopefully throwing other player's game pieces over. Cards have special functions such as looking at other player's cards, protect one's game piece against explosions, explode any stick, explode the stick closest to Mount Sinai.

Apathy [51]: This is an advanced rock-paper-scissors-game. Players bid points (20 each round) to control marbles and/or exits from the field. Some bids are open, some secret. Gaining the control of a marble means that the player gets one victory point and will move the marble to any adjacent square, including diagonal moves. Gaining the control of an exit means that that player gets ten victory points per marble that passes through that exit that round. The game ends when two or less (out of six) marbles are left on the board. The sticks are not used at all.

Pushing Galaxies [52]: A quick game where the object is to have one's marbles left on the board. Marbles are moved by playing number cards (numbered 1 – 3) and moving one marble that exact number of squares. If landing on another square where there's one marble belonging to another player, that marble is taken out of play. Fortuitous cards are used for locking and unlocking marbles, looking at opponent's cards and reverting another player's move. The sticks are used only to indicate the squares of the board.

Operation Phoenix [53]: The object of this game is to get rid of one's marbles by somehow moving them to the square of a black (neutral) marble, or moving the black marble to their square. Marbles can be moved by physically lifting them and putting them down in an adjacent square, or by moving sticks so that marbles roll. Sticks remain in that position. Fortuitous cards can be earned by having many marbles on the board, and these can be used for steeling one card from any opponent, moving one's game piece twice as far, moving the sticks in someone else's turn, switching places between one of one's own marbles and the

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[50] Rules by Henrik Pedersen, Karl Schmidt, Pontus Fernström, John Johansson, Sofia Larsson, Elmir Sayudin and Johanna Lundmark. Subtitled "Exodus with explosions".

[51] Rules by Lars Johansson and Ludvig Fungmark

[52] Rules by Robin Mellberg, Sofia Neergaard-Möller, Johan Thorstensson, Zaid Hermansson and Erik Andersson. The Swedish name, "Galax med knuff" is a pun on the Swedish name for Ludo, "Fia med knuff".

[53] Rules by David Hagman and Jenny Nordgren

black marble. The rim is used as a kind of track; a player gets a fortuitous card when completing a lap.

5.2.3.7 Winning game

The jury chose "Operation Phoenix", since they thought that this game used the different possibilities of the game material best. "A fun game" came second.

Operation Phoenix was also chosen as the embryo for *The MarbleGame*, since this was a game that had a potential to become a good game after changing some elements of the board and tweaking the rules. This decision was taken independent from the one of the jury. The function of the jury was simply to chose the winner of the competition, so that prizes could be given out etc, which had nothing to do with the further work in this thesis project, or the choices made in it.

5.2.3.8 Conclusions

As mentioned initially, the purposes of the contest was to see if people liked the idea with a variable board, and computerizing one, and to see if some usable rules would emerge. The idea with the variable board was appreciated; people in general seemed to be in favor of it. An exception was hard core gamers, who disliked the randomness in the game, partly depending of me acting as an inaccurate computer.

I consider it impressive that all teams but one managed to come up with playable rules in such a short time as five hours, especially since all teams but one first spent at least 2 – 2,5 hours with a brainstorming and trying out ideas. It is probably significant that the winning team found their concept almost immediately and thus had more time than the other teams to develop it.

5.2.4 A second prototype

After an expert evaluation of the first prototype, a second prototype was built. It had a slightly different design than the first. First of all, the board was made out of one piece of thin fiber wood; to provide a flat surface. Second, this prototype was smaller and square, not rectangular. Also, the sticks were somewhat closer to each other, the distance was 10 cm instead of 12, and they were placed in a 6x6 grid, meaning that the board now had 36 sticks, making out 5x5 squares, since the expert group had concluded that there were to few "squares" on the original board and that they were too large.

The rim was placed very close to the outer sticks, which practically meant that some squares had the rim as an edge. This prevented marbles from landing in a kind of no man's land; outside a square but inside the rim.

5.2.5 Testing and tweaking rules using Evolutionary game design

To improve the rules for *The MarbleGame*, evolutionary game design was used, as described in the "Methods" section. The method felt appropriate even if it – like any other method for game design – cannot guarantee a "fun" game, but this is a lack all methods have, more or less. Neither does it guarantees that the game is "good", meaning interesting to play, as stated by Wolfgang Kramer in the "Methods" section.

Evolutionary design is an iterative design process. The same steps are gone through over and over, testing and refining the game in each cycle. I chose to end each iteration with a new set of rules. Typically an iteration then would consist of the following steps:

- Play testing
- Discussing suggested changes with players
- Identifying which changes that worked.
- Evaluation of these suggestions and their consequences
- Choosng which suggestions to carry through
- Carrying trough the suggestions regarding changes and components

Three iterations were done, the second prototype being built after the first iteration. Most of the play testers were experienced gamers, and the group of players changed for every iteration. I observed them playing during the first iteration, and then took part as a player in the following two. These three iterations improved the game a whole lot. The iterations are described in detail in Appendix 6. The final rules can be found in Appendix 7.

5.2.6 Other interaction matters: How to make a computer enhanced prototype

The initial intention was to build a fully functional prototype of *The MarbleGame*, both to see how it worked out and to let players test it and compare it with the non-computerized prototype. Unfortunately my skills in electronics were lacking, and there was little help to get. Also, the time was running out. Therefore, this last step of the design experiment is purely theoretical.

To come up with ideas of how a computerized version of *The MarbleGame* would work, and look like I went through an informal brainstorming session/discussion with Peter Ljungstrand, a researcher within the field of ubiquitous computing.

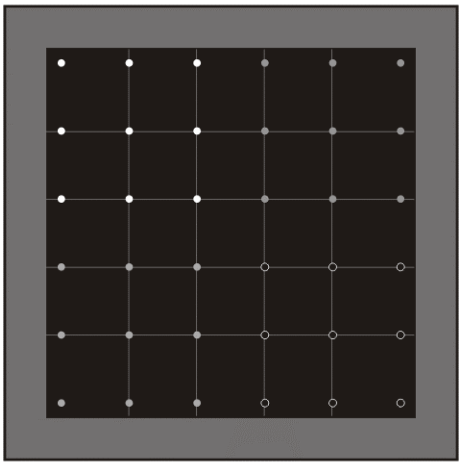
Since our main concern was the interaction with the board, we started out by trying to define the various interactions users would like to carry out with the game, thereafter translating these needs to technology. They were:

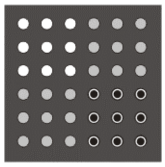
- Moving one or more sticks in one's turn. This includes the sub actions
  - Selecting one or more sticks that shall be moved
  - Selecting how many steps each stick shall move
  - Selecting in which direction each stick shall move
  - Stating that all these selections have been made and that the sticks shall actually move
- Playing any fortuitous card that affects the appearance of the board.

But, how do the players input which sticks they want to move? Denominating sticks using numbers would be very unnatural, and it would hard to make a good design of the board that envisioned these numbers in a good way. One could of course use a chess-like grid writing letters and numbers on the rim, and use them in combination to denominate row and column (using for instance a keyboard), but having 6 x 6 sticks, it would be easy to make a mistake and enter, a value like A4 instead of A3. Also, a stick's position might not be prominent, e.g. if it is the only lowered one in a group of raised sticks, it my be easy to overlook.

A better solution could be to have a 6 x 6 grid of buttons, each one naturally mapped to the corresponding stick. This, on the other hand, prompts two problems; a) to map one of 36 identical buttons to one of 36 sticks that are not on the same place (meaning that one has to shift focus) isn't entirely easy and b) the orientation of the buttons have to be aligned to the sticks on the board. This can easily be solved by fixing the buttons onto the board, as a kind of control panel, but it would also mean that players had to move over to the control panel to enter their input.

Luckily, there is one possible solution that eliminates both problems. By grouping the buttons and sticks into four 3x3 group and giving each group a distinct look (e.g a distinct color, both on the buttons and on the cloth) it will be possible to align a loose control panel to the board, and also, it would be a lot easier to recognize and remember a button in a group of nine, as compared to a group of 36.





The board to the left and the layout of the buttons above. When choosing colors, one must take colorblind people into account; thus different grayscales combined with outlines may be preferable, and in addition there will be no mix up with player colors.
Seeing this layout, a user might think something like “I want to press the white button that is in the center, and then the lower right black button.”

As for selecting number of steps and direction, one could imagine several different interaction styles;

- Having a switch to indicate upward or downward movement, and combine this with pressing the corresponding stick button a number of times to indicate that same number of steps. Feedback could be given by lighting up LEDs, one for each step, red LEDs indicating a downward movement, green LEDs indicating upward movement. A problem would in this case be that one wouldn’t want to have two sets of LEDs for each button/stick; this would clutter the design and increase the complexity of the construction. One would have to do with two sets for all buttons. This has an advantage though; it is easy to see how many step the player has “spent” so far in the turn.
- Using RFID-tags carrying numbers and a tag reader to collect them, or perhaps two tag readers labeled “+” and “-“ respectively, used for ascending vs. descending movement. Again, feedback could be given with LEDs in the same manner, and with the same drawbacks and advantages as mentioned in relation to pressing buttons above.
- Using a keyboard to enter both number and direction, e.g. “-3”, combined with a display to show the input.. If no button has been pressed to indicate a stick, the display would not show any input, thus indicating that the input isn’t valid. It could instead show an instruction, e.g. “Please press a button to show which stick you’d like to move”.

Finally, these settings have to be confirmed by pressing some kind of OK-button. They could of course also be cancelled by some other button. Since player might want to move more than one stick, and the game rules state that the sticks should be moved simultaneously, the OK-button would trigger movement of all sticks.

It might occur that a player, after having entered several commands, would want to cancel only one of them. It would be fairly simple to cancel stick movement by assigning the same number of steps to it again, but this time in the different direction. The computer must then be programmed to handle this. Still, this might be more tedious than simply resetting and starting over. The problem could of course be solved in other ways as well but this implies a more complex interaction and feedback system, that would be harder to understand and master, and therefore it will probably be better to try to carefully eliminate the risk of mistakes when creating a simpler design.

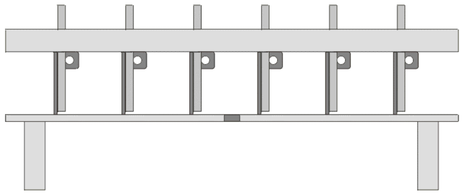
At present there is only one fortuitous card in *The MarbleGame* that influences the layout of the board, namely the Flatlands-card that simply resets the board, descending all sticks to their lowest position, but one could very well imagine other cards that for instance move all sticks in a wave-like manner, or move all sticks randomly. Of course, playing such a card should not mean that the player should have to input all these actions; they should be carried out automatically. The most elegant way to solve this is to embed RFID-tags into the cards, and then simply placing them on an RFID tag reader when playing them.

A critical issue is how to signal that a stick cannot be moved the required amount of steps. (Since the sticks aren't of infinite length, they can not be raised more than eight steps above the board in total, or be lowered more than to the level of the board). Probably this would be indicated with a warning sound in combination with either a message on the display (if using a keyboard for input) or by refusing to light any LEDs.

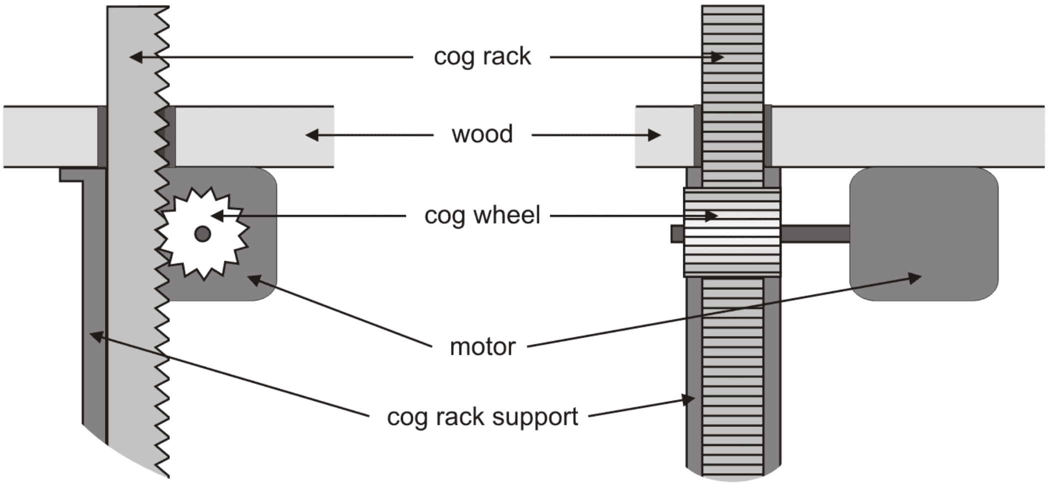
Experience shows that this is almost impossible to guess or predict which ones out of a number of interaction variants will turn out to be the best; and sometimes different groups of users prefer different interaction styles. Thus, all the interaction proposals made above should be tested and evaluated – until this is done we cannot know which ones work best.

5.2.6.1 Technical comment

To move the sticks, one can use step motors. Instead of sticks one can use cog racks; through each hole goes a cog rack, that is supported so that it will keep in place. Each cog rack is attached to a corresponding cog wheel, that is moved by a step motor. Thus, the circular movement of the motor is transferred into a vertical movement.



Intersection of the board.
Instead of sticks there are cog racks that are moved by cog wheels and a motor. (See close-up below.) Below this layer is a second 60x60 cm piece of wood for support.



Close-up of the cog rack – cog wheel – motor construction, from the front vs. from the side.

Since the BX-24 chip only has 21 pins suitable for standard input/output, and since each of the 36 step motors is controlled via four input lines, in addition to all the output lines needed for various input and output devices, two intermediary layers of multiplexers have to be used to transfer and divide all the signals. A mutiplexer is the digital equivalent to a rotary switch, having only a few input lines and numerous output lines. It gets input in form of what kind of data that should be passed on to which one of it's outlets, and then transfers this signal to the correct outlet. It is sometimes called a MUX.

6 RESULT: MECHANICS

This section summarizes mechanics enhanced by, or made possible by ubiquitous computing. Existing mechanics have been analyzed in addition to an analysis of the results when creating *The Hatchery* and *The MarbleGame*. The numerous examples are taken from my own collection of games.

Again, the great advantage of enhancing board games with ubiquitous computing is that the computer qualities of calculation, randomization, track keeping and score keeping come with it, allowing the players to concentrate solely on the game, instead of dedicating mental effort to such things. Why, are board gamers stupid people? Of course not. But with this technology, one could add complexity to a game if it needs it without making it harder to play, since some of this complexity will be "taken care of" the game itself.

But, before diving into this, just a short caveat: Just because a mechanic can be enhanced, this does not mean that it should be. Of course, the roll of a die can be substituted with a random number generator, but why? One mustn't forget that there is a significant difference between rolling a die and pressing a button to get a random number. It feels different, the items involved act different etc. Here, we find a strong aspect of interaction design.

Also, strictly speaking, some of the mechanics mentioned below do not actually need ubiquitous computing. They can depend on the players to keep track of things and states, to calculate it, and to use dice or similar devices to generate a random outcome. But such tasks are tedious, and if accomplished erroneous they can affect the game negatively.

6.1 Turning traditional mechanics into computer enhanced ones – which and why?

When analyzing traditional mechanics (see Appendix 1 for a summary) I felt the need to divide them into sub groups, when trying to grasp what functions they have within a game. This also helped the identification of new mechanics, as did the design experiments with *The Hatchery* and *The MarbleGame*. It is of course impossible to direct whether a certain mechanic always is or isn't suitable for enhancement with ubiquitous computing; this is depends on the current context. But – it is more or less probable that a certain mechanic can be enhanced.

I have found that most of the traditional mechanics can be divided into four groups (three of them having sub groups), depending on if they deal with relations (between players), gameplay, conditions in the game, or resources.

6.1.1 Human-human interaction mechanics

These of course deal with what goes on between players in a game, being more or less regulated in the rules. It would be hard to enhance any of these mechanics since the richness in human behavior is not easily quantified or measured.

Examples: Co-operative Play, Negotiation, Partnerships, Rock-Paper-Scissors, Roleplaying, Storytelling and Trading.

Sub group: Talent mechanics: Memory, Singing.[54]

6.1.2 Influential mechanics

These influence the board, the gameplay or other players. Some of these mechanics involve items that are easily kept track of, or information that is easy to gather (e.g. where pieces are, how the board should look like, which tile lies where etc.) and these could be subject for enhancement. Others, that deal more with movement or choices aren't as suitable though, even if one of course could add functionality to warn for illegal moves.

Examples: Campaign/Battle Card Driven, Clue-giving, Crayon Rail System, Event Card Interaction, Modular Board, Open Card Selection, Secret Unit Deployment, Tile Placement, Unit Deployment and Voting.

Sub group: Movement mechanics that regulate how players move their pieces or other items in the game, e.g. Area-Impulse, Area Movement, Hex-and-counter, Roll and Move

6.1.3 Condition mechanics

These regulate conditions in a game or regulate goals or sub goals. Usually the ones concerning conditions would be hard to enhance since they direct the way a game is being played, in a way setting a structural framework. The mechanics concerning goals, on the other hand, can all be enhanced, since they are strongly connected to items or placement on the board.

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[54] Actually it is sort of unfair to label only these talents as mechanics; intelligence, analysis, negotiation skills or being verbal and similar talents might as well be mechanics in that case, being more or less prominent in many games.

Examples: Action Point Allowance, Drawing, Hand/Resource Management, Simultaneous Action Section, Variable Player Powers. In the case that a partnership is regulated by the rules (i.e. players must form teams that are consistent throughout the game), Partnership is a Condition mechanic too.
Sub group: Goal mechanics: Area Enclosure, Matching, Set Collection, Pattern Building and Pick-up and Deliver

6.1.4 Gathering mechanics

These are used to gather money, points or other kinds of resources. Some are fit for enhancement and some are not, highly depending on how the mechanic is actually used, and the components involved.
Examples: Auction/Bidding, Betting/Wagering, Commodity Speculation, Stock Holding and Trick Taking. The Trading mechanism can fit here also, if the trading process is very simplified.

6.1.5 Conclusion: Qualities of mechanics suitable for enhancement

It turned out that most of the new mechanisms that will be presented below are somehow information-related. This is rather unsurprising, since the strength of ubiquitous computing lies in keeping and manipulating information. The new mechanics can all be classified as handling the following:

- Where items are on the board and if they are allowed to be there
- Which resources or combination of resources a player has
- Hidden information submitted by players or based on each player's resources
- Actual state of non-player "things" such as prices of various resources and how they could change
- Calculating, keeping and displaying information, or parts of it

6.2 Novel computer-augmented mechanics derived from existing mechanics

6.2.1 Active Board

Definition: The board by itself generates secret information and/or collects information regarding what is going on. Sometimes it displays this information.

Explanation: This mechanic is used by Mandryk et al (2002). It is derived from the mechanic Modular Boards, where the layout of the board either changes each time the game is set up (typically because it is made out of smaller tiles that can be combined in number of ways) or changes during play.

An example: The game *Giganten*[55] features oil wells that last for a certain number of rounds. A player may obtain this information and use it to decide if it's worth to drill there, but mustn't. When a player does drill, the information about how long the well lasts becomes public. Using an active board, this information could be given only to players who decide to peek, whether they drill or not. The only information displayed publicly in this case is when a well dries up.

The game could also keep track on, say, unit deployment on the board, and display certain information about this, or behave in a certain way when a certain condition is reached.

Technical suggestions: How this should be done is highly dependent on what information is to be displayed when and why.

6.2.2 Anonymous Trading

Definition: Via a special reader and special tokens, players can propose simple deals they would like to make. The outcome is calculated and shown.

Explanation: This mechanism is a variant of the traditional trading mechanism. Trading can come in many varieties; in some games one may only trade 1:1, on others one is only allowed to say only what one wants or what one can pay (e.g. *Res Publica*[56]), in some games almost everything (money, tokens, promises, positions, e.g. *Traders of Genoa*[57]) can be traded against anything else in any way.

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[55] Giganten by Wilko Manz, Kosmos 1999.

[56] Res Publica by Rainer Knizia & Avalanche Pres Ltd, Hexagames/Queen Games 2000

[57] Die Händler von Genua aka The traders of Genoa by Rüdiger Dorn, Alea (German ed.)/Rio Grande Games (English ed.) 2001

A significant aspect of trading is not only to decide what to buy or sell and to which price, but to whom. It can be all right to make a certain deal with one player but not with another; the second player may gain too much of an advantage though the deal, or might even win, whereas it is "safe" to make the deal with the first player. This may be a feature in a game. But it might as well be a feature to have some kind of anonymous trading, i.e. that you anonymously turn in your trading wishes; what you want **and** what you can pay, let an embedded computer match the deals and come up with the result. In the example below, players state (to the computer) which kinds of pieces they are willing to sell and which ones they want to buy and what they will pay for that. The computer calculates this, and gives some output in form of text, images on a screen or LEDs, creating an outcome like:

```
* Blue gives 1 tower to Red and pays 1 gold to Green (for 1 castle).
* Red gives 1 store to Green and pays 2 gold to Blue (for 1 tower).
* Green gives 1 castle to Blue and pays 1 gold to Red (for 1 store).
* Yellow didn't trade.
```

In this case it is quite obvious who traded what with whom and for how much. But the output might just as well be:

```
* Blue gives 1 tower to Red and gets 1 gold from Red.
* Red gives 1 store to Green and pays 1 gold to Blue.
* Green gives 1 castle to Blue.
* Yellow didn't trade.
```

In both cases, the haggling part is totally gone. Instead, trading would be a lot about trying to foresee who wants to trade what, and if they are willing to pay with something you want, and also which trade is the most important. This would only work for less complex types of trading though. As soon as trading becomes negotiation-like[58] it would only be tedious and tiresome to state all one's possible bids.

Technical suggestions: Here, both the technical problem and the interaction problem lies in how to enter one's trading wishes. Also, the computer must of course have some rules on how to perform trades, let's say that it will always sell a piece to the player that is willing to pay the most for it, and that the order of suggested trades is significant (i.e. if a player only has one gold and is willing to pay it for either a castle or a store, he will buy the store if that wish was entered first).

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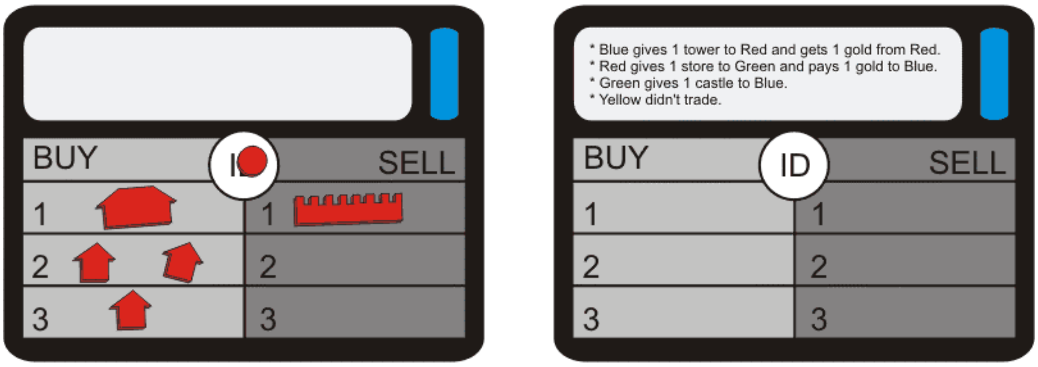
[58] As in: "I'll trade you two silver for that green!" "No, that's too little. I want either three silver or one silver and one blue!" "I can actually pay you two nice juicy blues and a silver, but then you'll have to give me two green ones").

The cheapest way would be to have one "trading display" (see below) that is passed around by the players. It should have a couple of areas where tokens could be placed; e.g. one for what the player primarily wants to buy, and one for his or her second wish, and then one for what he or she would like to pay, or if money isn't involved areas for the items that the player wishes to give away. The tokens could be recognized using RFID technology, weight sensing, capacitive proximity sensing or some other suitable technology. Each player would also need a special set of trading tokens.

One could also imagine suggesting several deals, e.g. "one castle for one store" or "one tower for one store". In that case, the areas should be divided into "buy-sell"-pairs. In either case, the player also has to put a identity chip somewhere. Also, there has to be a way to tell the computer to calculate the input.



A trading display shown in two states; to the left a player is entering trading wishes by simply putting tokens on the areas, to the right someone has pressed the upper right button and the display is showing the outcome of the trade.

Why not use buttons also for entering the wishes? Well, this doesn't make the interaction as natural, and it would also be necessary to provide feedback regarding which information had been entered.

6.2.3 Complex Commodities

Definition: The price of a certain commodity relies heavily on prices of other commodities. The relations are complex and prices are calculated by the computer and then displayed.

Explanation: This mechanic is based upon the mechanic Commodity Speculation, combined with Active Board. It can be used in stock market-based games and the like; prices of certain commodities/stocks could change in a semi-predictable way. In it's simplest form, this does not need any technology; a set of dice would do. But, what if the prices depended on each other; say that the price of oil goes up, so does gas. Or a semi-random weather may affect which crops grow and which don't. Such complex behaviors would be tedious to determine with die-rolls and calculations, but easy to simulate with a simple computer program.

Technical suggestions: The board would need some input to trigger the calculation. This could be accomplished by using any button, or triggering any sensor with a certain component. The outcome could be shown on either a display, on a screen or by a range of LEDs to show the current prices/growth rates.

6.2.4 Computerized Clues

Definition: The computer distributes clues about certain information in the game, known only by itself. At certain stages in the game all information may be revealed.

Explanation: This is of course a variant of Clue-giving used by Mandryk et al (2002). In some games, e.g. *Clue*[59] players exchange information with each other, a mechanic called Clue-giving. But one could also imagine a game where clues are given by the computer, similar to how Stop Thief works (see Previous work).

This can be explained using the example of *Dragon's Gold*[60], a game where players cooperate to kill dragons and then negotiate about how the dragons' treasure should be divided amongst them. There are always four dragons on the table, and most of the contents of their treasures (made out of tokens representing gemstones in different colors and silver and gold) are public. But they needn't be. The treasures could be entirely hidden, and the computer could display information only about which one of the four treasures that is the largest one, which one of them that contains most green/blue/etc gemstones, which one is worth the most points and so forth.

Technical suggestions: The tokens could either be physical, being drawn blindly and hidden somewhere where sensors could recognize them, or they could exist only as bits in the computer – this does not prevent players from having physical tokens anyway, to gather, trade or pay with later on in the game. The output could be shown on a display, on a screen or as multicolored LEDs on the board.

6.2.5 Secret Bidding

Definition: Players may bid secretly on an item. Only the player who wins the bid, and the sum that is bid is displayed.

Explanation: This mechanic is of course derived from the standard Auction/Bidding mechanic. Now, using ubiquitous computing would be extra useful if the secret bidding is to be kept *really* secret.

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[59] Clue, aka Cluedo by Anthony E. Pratt, Parker Brothers/Hasbro 1946

[60] L'or des Dragons aka Drachengold aka Dragon's Gold by Bruno Faidutti, Descartes Editeur, 2001

Technical suggestions: Each player places his bid and an ID-marker ("Blue player" etc) on a special tag reader that is passed around, and the reader then announces who won the bet and what he/she is going to pay. The bids of the other players remain secret.

6.2.6 Secret Partnerships

Definition: Players are divided in teams, without knowing with whom. The combined actions of a team lead to certain consequences in the game (calculated and displayed by the game itself), wherefore it is important to figure out who is on which team.
Explanation: This mechanic is derived from the traditional game mechanic Partnerships. A variant of it is used by Mandryk et al (2002). In most games, partnerships are explicit. Two people know that they form a team, and which other players are joined in other teams. But a game could certainly have an element of trying to find out who is actually teaming with whom, and who is one's own conspirator.

In it's simplest form, and combined with the mechanic Computerized Clues (see above), each player plays an X or an O, and the computer then gives output regarding the amount of X-s and O-s in each team, or how one team looks or that none of the players that played X-s in this round are on the same team, etc. Of course the game should be more complex than this, getting the players to secretly maneuver to find out information about the teams, since the configuration of teams affects what happens in the game. The goal in the game itself does not have to be to find out who's on one's side, it might still be to achieve as many points as possible.
Technical suggestions: How this should be done is highly dependent on what the rest of the game is about.

6.3 Entirely new, computer augmented mechanics

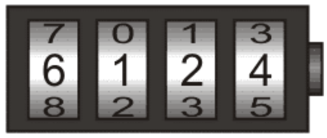
These mechanics are not derived from a certain mechanic, or can be used to enhance many types of mechanics.

6.3.1 Active Dice

Definition: The probability of the outcome of a die roll may be skewed or may depend on the outcome of previous rolls.
Explanation: If only one die is used in game, their is always a certain probability for a certain outcome. If two or more dice are used, the outcome of the roll also has a certain probability, that normally (but not always) follows a bell-shaped curve. But if one wants a

skewed probability, this can be hard to obtain with regular dice. One might also want the probability of a die roll to depend on the outcome of the previous roll, or on the state in the game. This can again be solved with ubiquitous computing.

Technical suggestions: Unfortunately it would be hard to build this into regular dice, since they are small and need to be robust. Perhaps it is possible to build a kind of dice that is made out of slot machine-like wheels, whose outcome is randomized (within given constraints) by a small microchip and regulated by small motor, electromagnets or something similar. It could have a button on the side to initiate a roll.



This might seem a bit overdone when one could simply use a display or a screen, but there might be an emotional value in keeping the physical feeling of the die roll, a notion that is of importance to an interaction designer.

If the outcome of the die roll should depend on the state of the game, this state must of course be able to measure, and the information has o be transferred to the dice. This would be easily accomplished with the SuperBoard.

6.3.2 Active Surface

Definition: The surface of the board changes its properties during the game.

Explanation: This is the mechanic is used in *The MarbleGame*. It needn't be moving sticks below a cloth though, it could be changing colors (as in *The Hatchery*) or entire sections moving, becoming hot or cold or lit or whatever. If metallic pieces are used, parts of the board could suddenly become magnetic (using electro magnets), effectively capturing or moving the pieces.

Technical suggestions: How this should be done is highly dependent on the way the surface should be active.

6.3.3 Active Tiles

Definition: Tiles recognize which other tiles are next to them and react to this.

Explanation: If tiles can recognize each other they can be made to change appearance or behavior depending on which tile is put next to them. Say that three blue tiles put next to each other form a river, which is impossible to cross. Now, if the tiles "know" that they form a river, they can prevent pieces to move over them by beeping for instance.

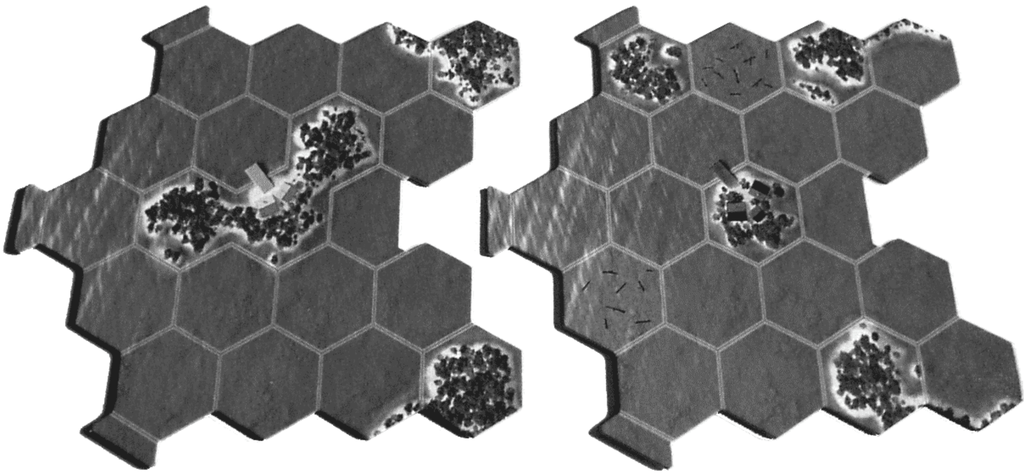
Here's another example (not necessarily good for the game, but illustrating the point). The game *Mississippi Queen*[61] is about paddleboats race along a river, that displays during the

[61] Mississippi Queen by Werner Hodel, German edition by Goldsieber Spiele, English edition by Rio Grande Games, 1997.

game. The upcoming appearance of the river (i.e. how it bends, if and where there are islands etc.) is unknown to all players; a new foremost river tile is drawn as soon as the first boat reaches the presently foremost tile. The current river stretches from the last tile where there is still a boat, to the foremost tile. This has a balancing effect on the game; the leading player does not have the benefit of knowing what the river looks like in front of him, and cannot plan his steering in beforehand, whereas the player who is last in place has a full view and can plan ahead.

But, using sensors, a designer could introduce a capricious river. The river tiles could communicate, thus knowing how long the present river is and if at least one player is lagging behind. Depending on the length, new river tiles could contain more obstacles on some of their fields, such as floating logs, thus balancing the game even more.

The present/non-present behavior could be programmed in such a way that it'd be possible for the players to make an educated guess, being able to take chances crossing the possibly log clogged field, hoping that the logs would have disappeared (or drifted?) once the player gets there.



Two Mississippi Queen tiles, one being from the expansion set The Black Rose.
Note the ´two fields containing floating logs on the rightmost tile.

Technical suggestions: Tiles may very well be able to recognize each other, for instance as in the Triangles project (Gorbet et al. 1998) Each of the triangles had a microprocessor inside and magnetic edge connectors. The connectors make it possible to physically connect the triangles, and through them digital information can be carried since they pass electricity. Information about which pieces are connected to which is sent to a computer that keeps track of the configuration. Output (i.e. the status of a tile) can be shown by LEDs, or sometimes by sound (e.g. when moving a piece over a forbidden tile).

6.3.4 Espionage

Definition: Players have the opportunity to get more or less accurate information about another player's resources, but may give away information regarding their own resources in the process.

Explanation: In many games it is critical to know which resources (money, building blocks whatever) the opponents have. Some games have built-in spying features (e.g. playing a thief and a magician on the same dragon in *Dragon's gold*[62] allows you to peek behind an opponents screen and see his or her gathered treasure).

However, spying in the real world, isn't as uncomplicated. Now, what if one could spy on other players in a more realistic way? Depending on what sum one paid, one would get more or less accurate information. There might also be a built-in risk in spying; information about one's own resources may leak to the opponent.

Technical suggestions: This could again be accomplished with RFID-technology, but in a more complicated way than the other mechanics in this section. The problem is that one's own RFID-tag reader must pick up the information about on whom one wants to spy and for how much, transfer it to the other players RFID-tag reader that checks the resources and in turn returns some more or less correct information to one's own tag reader that displays it. This means that the tag readers have to be connected either by cable or in some wireless way.

If one does not want to provide all the "extra" features (paying various sums and running the risks of getting inaccurate information and/or giving up one's own information) there are easier solutions. Each piece in the game can be more or less (preferably less) magnetic, and that one could spy on another player's resources by measuring the strength of the magnetic field that his or her components emit. Or perhaps different components could have different weights and one could demand to weigh another player's resources.

6.3.5 Ubiquitous Information

Definition: The game keeps track of when certain conditions are fulfilled and acts on it. It is very hard, or impossible for the players to know if a condition is fulfilled or not.

Explanation: This is a mechanic similar to Keeping Track, and it can be for instance be applied with any one of the following Goal mechanics: Area Enclosure, Matching, Set Collection, and Pattern Building.

Let's say that a game has a certain winning condition (or a condition that triggers a new phase in the game); it could be that the money earned in the game exceeds a certain sum, or that every player has gathered at least x tokens, or that the sum of blue tokens gathered

[62] L'or des Dragons aka Drachengold aka Dragon's Gold by Bruno Faidutti, Descartes Editeur, 2001

exceeds the sum of white tokens, or that a certain percentage of the board's squares are occupied etc. If it is hard, or impossible (e.g. if the distribution of tokens is done secretly or semi-secretly) for any player to have access to all information regarding the fulfillment of the condition, this mechanic is applicable.

Technical suggestions: This can be made possible if using RFID-technology or some other kinds of sensors, e.g. light sensors or compression sensors that can keep track of the deployment of items on the board.

6.4 Supportive "mechanics"

Actually, these aren't mechanics per se, since mechanics are more about what we do in a game; what options, goals and prohibits there are. Instead, the suggested "mechanics" below handle visualization of information

6.4.1 Informative Board

Definition: The board keeps track of information that is due to change during the game in a pre-defined way and always displays the current information.

Explanation: In a complex game many things (such as prices of commodities, number of action points, numbers of a certain item, what is allowed to do and not etc.) change over time or during play. Typically one says that the game goes through certain phases that may last for a certain number of rounds or that are triggered by a certain event. Now, if one could indicate to the game what phase it is in, it could output information on current prices etc; thus displaying information that would otherwise come from more or less complex tables or would have to be kept in mind by the players themselves. There aren't that many games as complex as this today, but if using an informative board, they could be.

Technical suggestions: How this should be done is highly dependent on what triggers the phases and which kind of information that shall be displayed. If the phases depend on the number of rounds it would be easy to have a switch or something similar to input this information to the game.

6.4.2 Keeping Track

Definition: The game keeps track of a players resources and displays them to him or her.

Explanation: In many games – especially auction/bidding games – players want to keep track on how much money the do have, and in some games this can be difficult if there are a lot of bills and these bills have different values. This is even more complicated and important if no change is given, meaning that players want to pay exactly what they bid, since they'd lose the excess. The same technology can of course be used for keeping track of other things.

Technical suggestions: In this case one might want to keep track by using the RFID-technology (described above). Each bill or coin would have an RFID-tag containing its value and the tag reader would read their value and add it all up to the correct sum, which is shown on a small calculator-like screen on the reader. It could also carry a small program that calculates which exact sums can be bid.

7 DISCUSSION

7.1 Evaluating methods

It was not hard to find information on ubiquitous computing and interaction design, but it was surprising that I couldn't find more examples of previous work; only one truly computer augmented board game was found, namely *False Prophets* (Mandryk et al 2002). The other games mentioned in the Background section were either board games turned into some other form, or board games that didn't use a high degree of computational power. Either, the searching was done in the wrong places, or this area of research has been highly neglected until now. It is notable that *False Prophets* was presented in late April 2002, this being several months after this thesis work was begun.

It was very useful to try to design a game system that should be set in the future, as was done with *The Hatchery*, simply because it removed some of the everyday constraints, making it easier to think "out of the box". As it turned out, one of the three groups came up with a game that they actually prototyped and tried out. Also, *The Hatchery* could be built today, even if the costs would be quite high.

Together with the research on sensors, microcontrollers etc, it also served the purpose to realize what is possible to accomplish.

To have more than one group coming up with initial rules for *The MarbleGame* worked very well when it comes to the number of ideas that were generated. But, since there was a five-hour time-limit (due to outer constraints set by GothCon; each session is 5 hours) many of the rules submitted were quite rough and had not been playtested very much. In that respect a longer time would have been desirable. On the other hand is five hours of intense brainstorming just about as much as one can take. As mentioned, the design situation was somewhat crippled by me being an insufficient computer when using the Wizard of Oz-method. In retrospect it might have been better to have a fully functional prototype, but then again the rules that were made up would have been highly influenced by the implemented functions of the prototype.

Overall, this was a satisfying way to generate ideas and highly different sets of rules, even if the method needs some elaboration. It may very well be developed as a method of its own, being a kind of non-steering participative design method, that can be used to get ideas regarding the interaction design of any non-existing product. However it is important that the prototype is flexible enough, as well as the product being developed. Making the setting into a contest make the participants work harder than they perhaps would do in a more normal situation.

The ideal would of course be to have several groups that work at a lower pace but for a longer time, perhaps with slightly different permutations of the game materials. Unfortunately, this can be very expensive and it can be hard to find that many participants.

The sessions with the teams were also very interesting for me as an interaction designer, since every design decision that was made when creating the prototype mattered. For instance, the board itself was made out of two shelves joint by two hinges. This caused the board to sag somewhat along the joint in the middle, meaning that if no sticks were raised, the marbles tended to roll towards the center. Some teams considered this to be a feature, while others remedied it by placing a cut off PET-bottle underneath for support. By having a rim made out of four parts instead of one piece (which was due to sheer laziness, initially the plan was to join them by putting them onto an edge) the teams came up with a lot of creative ideas on how to use them and place them. E.g. one team tried to make an arch of them. The sagging board didn't influence the rules in any significant way, but the construction of the rim may very well have done that! Seeing the impact of the decisions that had been made at an earlier stage, again imprinted in me that one person, even if being skilled, cannot foresee all aspects of human behavior and creativity, or the entire impact that the real-word situation will have on the design.

When carrying on with the development of *the MarbleGame*, there was a slight problem when developing the game using Evolutionary Design; shall one use one or more expert groups in the process? If one uses only one group of play testers, the benefit is that they can overlook the entire process, comparing new versions with older ones, sometimes reviving rules that have been tossed out at an early stage but suddenly seem to fit again when other rules have changed. But it can be hard to keep the same expert group together playing the game over and over again; it does get boring after a while, especially since the initial versions are likely to have many flaws. Also, the group can get stuck within a set of ideas and notions.

On the other hand, if using different groups one has to find a larger number of willing subjects. They will contribute with more ideas, and since each player plays in his or her own style, a wider range of possible gameplays will occur. On the other hand, each new group will spend a lot of energy on re-inventing older mechanisms that have already been thrown out since they didn't work. It will also be harder for them to get an overview; they can of course only analyze their own session.

The drawbacks of each of these methods can of course be balanced by the game designer, but one must still be aware of the different effects. I used a combination of these methods, since two people – myself and another person – took part in all of the play testing.

This was not a deliberate decision, I just had to adjust to which people were willing to playtest and when (initially a lot more play testing had been planned, but it was hard to find participants and possibilities). However, mixing the groups turned out to be very lucky, since it merged the benefits of using both new and old play testers. It seems like this led to a better result in a shorter time.

This finding is interesting, since it is sometimes is recommended that users shouldn't test a system more than once; the second time around they will learn the system faster since it is already known to them, and this will give the false impression that the system now is easier to use. Also, older users may be biased towards older designs. But, when doing like this, none of the users will have an overview of the sequence of changes, and will not be able to compare them and how they work, respectively, just as when using different play testers for each evolution of a game. Thus it may be worth trying a blend of new and experienced users in any iterative interaction design process.

7.2 Evaluating work

To my disappointment, there was neither time or resources left to carry on with this design experiment by building a full-scale prototype of *The MarbleGame* and compare it with a non-computerized prototype to see which one players preferred. Also, building a computerized prototype would have been more of an interaction design challenge, plus that the interaction design ideas would have been tested and evaluated instead of just proposed.

However, having 36 sticks run by 36 step motors, and deciding that the easiest way to state what stick(s) should move (from an interaction point of view) was to push a corresponding button, leads to a quite complex electrical design, with some 500 wires that had to be drawn in the correct way. I'm not very experienced with building these kinds of things, and there was no one to ask for assistance, and thus this possible part of the work could never be carried out. This was not an appreciated outcome, but there was nothing to do about it.

Out of the eight interaction design methods mentioned in the method section, only four were used (Participatory design, User studies, Prototyping and The Wizard of Oz-method). Myself being a gamer I didn't see the need for using scenario writing, personas or various and formal user studies; even if much of *The MarbleGame* was developed in cooperation with users, they were mainly studied by using observation and informal interviews. Out of the others, Relabelling Design wasn't used because I couldn't figure out how to apply it on board game design.

In retrospect I regret that I didn't create some extreme characters and tried to design a game for them; this method has proven to be useful for me more than once, and it might have helped me to come up with a more complex basic idea for *The MarbleGame* than ordinary brainstorming did.

Another thing that might have been made differently would have been to try to come up with some computer-augmented mechanics before designing *The MarbleGame*, instead of first designing it and then use those experiences to come up with mechanics. If done the other way around, some additional unique mechanics could have been integrated in the game, thus being tested.

It might seem unnecessary to have gone through the whole Evolutionary game design-process to improve *The MarbleGame*, but when going through the process of creating such a concept together with the users, it becomes very clear where each function comes from (how it has evolved), why it is necessary, when it is used, what purpose it serves and how, which significance it has to compared with the other functions and how it is seen by the users. Knowing this clearly simplifies the work when it comes to create an elaborate and well working interaction design. Also, without doing this, I would never have stumbled across the thought of blending new and experienced users in an iterative process.

In the same way it was necessary to enter deeply into game design, since domain knowledge will always lead to better interaction design. There is also a similarity between board game design and complex interaction design that didn't strike me until afterwards. It has to do with the way some game designers (among them Dan Glimne) look upon a game being an unfinished work of art that can only be completed when being played, and gets completed in new way over and over again, in different ways. This cannot be said about a book, and the writing of a book, or about a car and the design of it. When it is done it is done. This of course depends on the stable physical nature of these things. But when it comes to a game, most if its character is hidden in the rules, and it is hard to predict how the rules and the players will interact, and thus what the outcome will be like.

The same can be said about interaction design. It too, consists of more or less physical things in combination with the invisible, ungraspable qualities of computational power, and it too serves to create an experience in cooperation with the user, being incomplete without the user.

To conclude, game designers deal much with the experience of the game, as do interaction designers with the experience of a product. In both cases a living system is designed, a system that isn't alive without someone using it. But when it is used, its various parts must concur with each other as well as with the user's actions and still be able to keep together, and keep it's own distinct characteristic.

7.3 Reflections on board games using ubiquitous computing

One might wonder why there's a point in enhancing board games with ubiquitous computing; why not simply turn the board game into a computer games instead? Well, for another project[63] that was a part of the HCI-course at the IT-University in Gothenburg, a small survey was made, asking when, where, why and with whom people played board games, and what they liked and disliked with playing board games. They were also asked whether and why (or why not) they played computer games. 52 Swedish people took part (31 men, 21 women), 83% of them were between 20 and 35; the rest were older. The group featured only six hard core gamers. It turned out that most of the interviwees played board games mainly as a social activity together with friends and family. Games were normally played in someone's home, in the context of a party, a dinner party, vacation or holidays. It seemed important to know at least some of the people that were playing, even if some pointed out that gaming can be an excellent way of meeting new people. Computer games, on the other hand, were played to get intellectual stimulation, or as a way to relax and get some time for oneself. This clearly points out that board games and computer games are not played for the same reasons.

Unfortunately, a board game containing ubiquitous computing will be more vulnerable than a traditional game. It will most likely need electricity, and therefore it cannot be played anywhere anytime. If parts break or stop to work, it will be hard to fix or replace them. This would not be a problem if the games themselves were cheap – one would simply buy a new one – but probably they will cost somewhat more to produce; a blend of electrical components, microcontrollers and the like are more expensive than plastic, wooden pieces and cardboard. The latter is a problem that will pass though; electronic equipment will get cheaper and cheaper. Many of the proposed mechanics could use RFID technology, but today RFID readers are fairly expensive, sine they are not mass-produced. But if the gaming industry would demand this, they would be, and prices would decrease dramatically.

Instead of fiddling with unique electrical designs for each game, one could imagine a ready-made device, a SuperBoard, consisting of both input and output devices as well as of a microcontroller or even a more advanced computer. It could consist of a digitalized board (a flat touch screen in practice), that could show any board. Capacitive proximity sensors could be hidden below it to keep track on items on the board. When buying a game one would

[63] "Drakguldet" ("Dragon's gold") – a study on how to turn the board game Drachengold into a networked computer game and still keep the feeling of spending some time with one's friends

only get components like rules, markers, cards and money, some of them with embedded tags, but not the board itself. Instead one would get a chip carrying the logic for it. The chip could then be inserted into the board and the actual board would magically appear, along with some "behavior" stated by the rules. In this sense, the SuperBoard would be the board games' equivalent to what a console is to computer games. This would make the games less vulnerable and cheaper, but would restrict the possibilities when designing a game.

It should be mentioned that ubiquitous computing does not necessarily make a game better; some games simply don't need these extra features, but it can certainly help us to create new games, maybe even new kinds of games. However, such improvements will lead to a more "computerized" feeling of the game; mixing wooden pieces and a board decorated with pretty images with a number display and some LEDs may not necessarily turn out well from an aesthetic point of view. A new aesthetic style might be needed. Also, using these technologies sometimes requires a formalized gameplay; one has to put certain items on a certain place for instance. Making this feel natural will in this case be a new challenge for both board and game designers, and good deal of interaction design will be needed, concentration both on making the game easy to play and enjoyable to play, look at, touch and feel.

In short, the interaction designer has to make sure that the computer should be invisible for the players in the sense that they never have to think about the fact that they are interacting with a computer; they should never be uncertain of how to "input data" (i.e. put an RFID-tagged item on the tag reader), or how to interpret output data (i.e. that a value is displayed somewhere or that a LED lights up), and they should never have to hesitate bout the outcome of their actions. Also, they shouldn't feel appalled by the look, feel and experience of the board and the components; they should be enjoyable, blending in with the players notion of what a game should be like in all respects.

Consequently, such a game will need a lot more testing; not only do the rules and how they work together with the components need play testing; but also one has to test acceptance as well as interaction principles as well as making the technology fool-proof so that RFID-readers can't make unexpected or strange readings, LEDs won't go on and off in unexpected manners if a magnetic piece is put close to them, that the microchip really keeps track of the winning conditions one has set etc. When something similar is done with a computer system it is called **performance testing** or **load testing**; one simply confronts the system with heavy traffic, lots of simultaneous request and harsh treatment (i.e. deliberately trying to crash the system by entering wrong data).

Also, the process of developing a board game that uses ubiquitous computing will be more complex. For instance the choices made when developing the prototypes, and the skill of a "wizard" may highly affect the outcome of the game, as seen in the case with *The MarbleGame*. The initial play testing of such a game would have to rely heavily on Wizard of Oz-testing, or on crude computer game versions of the game and probably one would have different phases in the design, starting out with evolutionary game design with a "wizard" and a non-computerized prototype, thereafter interaction design of the first computerized prototype, followed by combined evolutionary game design and interaction design, perhaps parallel with performance and acceptance testing.

Then again, thorough design isn't a bad thing; there are several board games on the market today, that suffer severely from bad design.

As mentioned, the new, computer augmented mechanics in this thesis deal with tasks that are somehow related to keeping, calculating, collecting or displaying information; where items are on the board and if they are allowed to be there, how resources are distributed among the players, keeping, how long a certain resource will last or who is actually teaming with whom, and the actual state of non-player "things" such as prices of various resources and how they could change.

What makes this interesting from an interaction designer's point of view is not only what the mechanics can do for the game and its rules, but also how they affect the experience of the game and the interaction between players. For instance, the mechanics Anonymous Trading, Secret Bidding and Ubiquitous Information hide information from the players, meaning that playing the game becomes a matter of deceiving the other players; what one perhaps will trade, if one thinks that one can do something that leads to the meeting of certain secret conditions etc. The mechanism Espionage does this too in a sense, since one can trick another player to believe that one knows a lot about his or her resources – or about someone else's resources for that matter.

The mechanics Active Board, Active Items, Informative Board and Keeping Track on the other hand, make information more visible and easier to interpret. Thus, players do not have to spend as much emotional energy on figuring out certain information, which means that a player can direct their attention towards what the other players are doing and what implication that may have on his or her own strategy. Mechanics similar to this are Active Dice, Active Surface and Complex Commodities, since these also free player's from tedious work, giving them time to concentrate on the game and each other.

Then there is Computerized Clues and Secret Partnerships that work in a way that is exactly opposite of the mechanics mentioned above. Here, the computer suddenly becomes a prominent, but still invisible part of the game, and much of the play focuses on interpreting the information from it, and perhaps input information that one hopes will make it harder for other players to draw as advanced conclusions as oneself. The previous informative game has turned into a mind game.

Given all these implications, one can conclude that clearly, there are advantages with adding ubiquitous computing into board games. The game designer gets access to a new set of mechanics, and in extension a way to influence gameplay and the entire experience of playing the game. The techniques can be used to make games easier to play; illegal moves may be impossible or at least indicated, mode changes can be made (more) visible and tedious "maintenance" such as die rolling or moving markers (to indicate a changed price for example), may be eliminated. (Then again, some people like to do this!). Therefore, it is my firm opinion that the benefits of using ubiquitous computing in a board game – thus providing new mechanics and new experiences, making the game easier but yet more intriguing to play – widely exceeds the disadvantages.

7.4 Future work

Future work would include to build a fully functional prototype of *The MarbleGame* and/or *The Hatchery*, playtest the rules on it and evaluate the entire game.

Something else that needs to be done is to explore the whole sequence of designing a game using ubiquitous computing, to see which design methods are appropriate (or need to be invented!), in which order different steps should be made (i.e. how early should one build a computerized, or semi-computerized prototype), and how this affect the design process.

Also the possibilities of various sensors and other components may be more thoroughly explored, leading to various suggestions of how they can be used in board games to achieve new mechanics or enhance old ones. These mechanics, together with the ones mentioned here should be realized and evaluated.

It could also be valuable to explore the effects of using a blend of experienced and new users when carrying out user tests in an iterative design process.

8 CONCLUSION

The aim of this thesis has been to explore how to join the social activity and fun of a board game with the computers' possibility to add simultaneous and continuous action and the sensors' abilities to detect changes in the environment. The aim has been to enrich board games, using ubiquitous computing and interaction design as a way to achieve this, coming up with new board game mechanics that rely on embedded technology.

By collecting information on various sensors, motors, microcontrollers, input and output devices as well as some other electrical components, combining this with an extensive knowledge about board games, and applying ubiquitous computing and interaction design onto the design of two board games, a set of new mechanics for board games have been devised. These are unique, since they use aspects of ubiquitous computing to work.

The conclusion is that enhancing board games with ubiquitous computing is a promising new field since it combines the social interaction of board games with the qualities of computer games' possibility to add simultaneous and continuous action as well as compute complex data. There are four main benefits:

- **Information can be made more visible**, using various output devices such as light, sound and displays, making the game easier to play, thus giving game designers the possibility to design more complex games.
- **Resources can be linked in multiple ways**. Tedious die-rolling and similar "maintenance" that is normally used to keep track of such relations, can be taken care of by the computer and shown as output, and in addition the relations can be made more complex: "If the price of A rises the price of B will go down half as much if, and only if, the price of C still is higher than the price of A."
- **Information may be kept secret from all or some players**, opening up for mechanics that include secret winning conditions, anonymous trading and voting, secret partnerships, espionage etc.
- **The various components in a game (board, tokens, tiles and dice) may interact and react.** These components can be made "active", reacting on each other and on what happens in the game, triggering different outputs and outcomes.

These various ways to collect, compute, display or hide information will also influence the experience of the game, and the ways players interact with each other.

Components that can be used to achieve this are microprocessors, a wide variety of sensors, ID-tag systems and more common items such as motors. The electrical components will at present make such a game fairly expensive, but these costs will go down eventually.

Unfortunately, a game that uses ubiquitous computing will be more vulnerable than an ordinary game; it will need electricity and lost components will not be as easy to replace. Such games will also require thorough interaction design to become easy and delightful to use, and will have a more complex design process than ordinary board games. Also, ubiquitous computing cannot be used to improve every game; some games simply don't benefit from it.

However, using ubiquitous computing can certainly help when creating new games; it may even imply new kinds of games. It provides new mechanics and new experiences, making games easier but yet more intriguing to play. In my opinion, the benefits of taking ubiquitous computing into account when designing a board game and perhaps using it exceeds the disadvantages.

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APPENDIX 1: COMMON BOARD GAME MECHANICS

Action Point Allowance

This means that each player has a fixed number of points to spend on various actions each turn. It can also mean that each player has some extra tokens that can be used once to give the player extra action points.

Urland[64] is a game where each player has a clan of primitive reptiles. The goal is to get as many creatures as possible, and to get them on land. Each player has two action points each turn, and there are four possible actions to choose from, that each cost one point, They are: breeding, moving from one ocean to another, crawling onto land or to take back creatures onto the hand.

Area-Enclosure

A goal, or sub goal in the game is to enclose an area, as for instance in the ancient game *Go*, where points are earned this way.

Area-Impulse

The board consists of a map, and on each impulse players activate areas and move units into them to accomplish movement and combat. This is a typical wargame mechanic, but it has also been used in racing games and other types of fighting games.

Auction/bidding

Here, players have some limited resource that they use to vie with for other things. Normally, this is money or something else with a (numerical) value that can be compared. Therefore, a typical component associated with this mechanism is money. There are different kinds of bidding:

- Secret bidding: Everyone places their only bid secretly (i.e. by hiding a sum in their hand) and all bids are revealed simultaneously.
- Open bidding: The bid can go around the table one time, or until everyone passes. In some games you are out once you pass, in some games you can join in again next round.

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[64] Urland by Doris Matthäus & Frank Nestel, Doris & Frank 2001

- Free bidding: The bidding is not done in a sequence around the table, instead, anyone can bid anytime.
- Fixed price: In some auctions a fixed price is set and the first one to accept it (going around the table) gets it.

Modern Art[65] is a very typical bidding game. In it, all of the above bidding mechanisms are used on various occasioins. Paintings are bought and sold, and the value of a painting by a certain artist varies due to the demand.

Betting/Wagering

This is a very common mechanic in racing games. Players bet money on the outcome of the game, or of a subgame (a race for instance) in the game. A typical component associated with this mechanism is money.

Campaign/Battle Card Driven

This is another wargame mechanic, meaning that battles and sometimes general events come in form of cards. This is pretty much the same mechanic as Event Card Interaction.

Clue-giving

This mechanic can be used in the type of games where someone is hunted, in mystery games or in trivia games. The game itself gives clues to the location or solution (e.g. a quiz card can contain a number of clues) or players give clues to each other.

Co-operative Play

Here, players have to cooperate to reach a result. In the case of the *Lord of The Rings*[66] - game this is extreme; the players unite to beat the game. They may not look at each other's cards, but are allowed to tell the other players about them. Sometimes cards can be exchanged. In other games with this mechanic the cooperation isn't normally as emphasized.

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[65] Modern Art by Reiner Knizia, German edition by Hans im Glück, English edition by Mayfair Games 1996

[66] Lord of the Rings / Der Herr der Ringe, by Reiner Knizia / Hasbro, German edition by Kosmos, English edition by Parker, 2000.

Commodity Speculation

Players buy or produce commodities and speculate in that their value will rise. A typical example is the Swedish game *Ostindiska Kompaniet*[67] where commodities are brought from Sweden via Spain to East India and vice versa and sold wherever the price is highest.

Event card interaction

In the game there are cards with certain events. The entire game could be a card game, but the cards can just as well be a minor part of the game. A typical game component is of course cards.

Crayon Rail System

An almost typical traingame mechanic, where the rails are drawn directly on the board.

Drawing/Drafting

This simply means that cards (or chips, or something else) are drawn and "luck of the draw" is a significant part of the game. Many simple card games rely heavily on drawing. This mechanic is also sometimes called drafting.

Hand/Resource Management

Players are given a collection of cards that are used to accomplish a set of goals, but the cards are either hard to get, or one gets a limited number.

Hex-and-Counter

Any game (mostly wargames) that is played by moving cardboard counters (normally representing some kind of armed force) on a board that features a map with a superimposed hexagonal grid.

Matching

Players shall match various items, for instance trying to match (recognize) the design of a card with the design of another card, as in the game *Scan*[68]. It can also be to place a tile somewhere wher it matches surrounding tiles.

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[67] Ostindiska Kompaniet by Dan Glimne, G&RRR 1992.

[68] Scan, Parker Brothers 1970

Memory

Just what it sounds like. Certain information is shortly revealed, and the players have to remember it afterwards.

Modular Board

This means that the board of the game either changes during the game, or that it can be put together in different ways. A typical example is the game *Settlers of Catan*[69] where the board consists of 19 hexagonal land tiles and. At setup these tiles are mixed and laid out, each time in a different configuration. There are water and harbor tiles as well. Other ways to use modular boards is to have extra parts of the board that cover parts of the original board, or are added next to it, during the game, as in *Mississippi Queen*[70], where paddleboats travel along a river. The river/board evolves by adding an extra river tile every once in a while.

This has proven to be a very powerful mechanic since it prevents the players from optimizing how to play on a particular board; with a new board every time, the game is more about the game itself, rather than empirically knowing which space or way on the board is the best.

Negotiation

Again, this is just what it sounds like. Players have to negotiate to reach a result. A typical example is the game *Dragon's Gold*[71]. The players cooperate to kill dragons but when a dragon has died the cooperation ends, and the players start to negotiate about how the dragon's treasure should be divided amongst them. They have 30 seconds to reach an agreement.

Open Card Selection

In the game, there are some cards that are open for everyone to see. They could be purchasable, or achievable in some way, or they could belong to a certain player.

Partnerships

The extreme on one end is playing in teams or in pairs, which is common in card games and family games. On the other end, it means that players have to cooperate in some way with

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[69] Originally "Die Siedler von Catan" by Klaus Teuber, Mayfair Games 1995

[70] Mississippi Queen by Werner Hodel, German edition by Goldsieber Spiele, English edition by Rio Grande Games, 1997.

[71] L'or des Dragons aka Drachengold aka Dragon's Gold by Bruno Faidutti, Descartes Editeur, 2001

another player to be successful, as in *Dragon's Gold*; (see Negotiation above) if one does not help the others to kill a dragon, one won't get a part of its treasure.

Pattern Building

Players try to lay out various patterns on the board. A good example is Noghts and crosses, or *Take it Easy*[72], a game where the players have tiles which have different types of colored/numbered lines crossing in three directions. The object is to place the tiles in such a way, that a line of a certain color continues to run across as many tiles as possible, which is complicated by the fact that when putting down a tile, one wants all the three lines on it to match with the ones on adjacent tiles.

Pick-up and Deliver

This is when players have to physically move items around the game board to fill demands or fulfill game requirements. A good example is, again, *Ostindiska Kompaniet*[73]. Commodities are transported across the seas in ships, and are bought ("picked up") and sold ("delivered") in different cities. The ships – controlled by the players – can sink, drift away in storms or be boarded by pirates, which makes the deliver-part harder than it sounds.

Rock-Paper-Scissors

This mechanic is based on the children's game with the same name[74]. It means that players try to outwit each other by guessing what the other ones will do, and by tricking other players to take a wrong guess on one's own action. Of course this is more or less present in almost any game.

The original game is very simple; after a count to three both players make one out of three gestures, depicting rock, paper or scissors. Rock beats scissors, scissors beat paper and paper beats rock.

Role-Playing

Role-playing means that players somehow need to act. Many board games with role-playing mechanics are about negotiation, and in that case they are often combined with a voting mechanism. For instance, the game *Werewolf*[75] circles around the task to find the two werewolves (played by two players) that keep slaying the other players. It is a vivid game full

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[72] Take it Easy by Peter Burley, FX Schmid 1994.

[73] Ostindiska Kompaniet by Dan Glimne, G&RRR 1992.

[74] "Sten, sax, påse" in Swedish.

[75] This is a public domain game also known as Mafia or Werewolves.

of accusations and counter accusations, speculations and insults, and even if the game is actually played by voting, it falls flat without role playing.

Roll and Move

This is one of the simplest game mechanics. The most wide spread roll-and-move-game must be the game *Ludo*[76] where players roll a six sided die and move one of their pieces along the track on the board.

Secret Unit Deployment

In a game with this mechanism, all players may not know everything about the other players on-board resources. *Stratego*[77] is such a game. It's a war game, and in the setup each player deploys his or her game pieces, which are soldiers of different ranks and bombs. At first, none of the other players know how the other one has deployed his or her forces, but during the game this is slowly revealed.

Set Collection

Here, the players try to collect set of elements, usually the more of the same kind the better. For instance, if you manage to get all streets in the same block in *Monopoly*[78], you can charge a higher rent if someone lands there.

Simultaneous Action Selection

This means that each player picks his or her action(s) for the upcoming turn secretly, and then everyone's actions are revealed at the same time. In the game *RoboRally*[79] the players program how robots move on a hostile board. A turn consists of five actions and these are programmed secretly. Then, the first action of each player/robot is revealed and performed more or less simultaneously. After that comes the second action and so on until all actions have been performed and the next turn starts.

Singing

Exactly what it sounds(!) like.

[76] An ancient game also known as Pachisi and, in Sweden, Fia med knuff

[77] A classic game with a somewhat complicated origin. The first time it was published under this name, was in Holland in 1947.

[78] Another classic, first published by Parker 1935.

[79] RoboRally by Richard Garfield, Wizards of the Coast 1994

Stock Holding

In this kind of game, players buy stock to get interest, and perhaps sell again when they can make some extra money out of it. Normally, no player has an exclusive control over a certain element. In the game *Acquire*[80] the players acquire(!) stocks in different hotel chains. They do not get any money until a chain merges with another one; the two players owning the most stocks in the smaller chain can sell their shares to get cash, or trade them in for stocks in the larger chain. (See also Tile Placement below.)

Storytelling

A mechanic that builds on that players try to create a story. An example is the game *Once Upon A Time*[81] in which the players create a story together, using cards that show typical elements from fairy tales. Players must get rid of the cards in their hand, but can only do so by weaving them into the story that is being told.

Tile Placement

Tile placement games feature non-moving tiles played on the board by the players. Often the whole game, or a larger part of it, revolves around the placing of the tiles.
In *Acquire* (see Stock Holding above) the players place tiles that lead to that hotel chains grow – their stock become more valuable – or merge.

Trading

This is as simple as it sounds. One ore more commodities can be traded against others. Trading can be made either with the bank or with other players. When trading with the bank, the exchange rate is normally fixed, or at least defined by rules such as "in phase 1 the rate is one x for 2 y's, but in phase 2…" When trading with other players the rate is often negotiated according to supply and demand.

One of the most striking examples of a trading game is the world wide bestseller *Settlers of Catan*[82] where the players colonize an island. It costs different sets of commodities to build certain things (i.e. it costs one wood and one brick commodity to build a road), and to get these, the players sometimes have to trade. They can also trade with the bank at the high rate of 4:1.

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[80] Acquire by Sid Sackson, 3M 1962

[81] Once Upon a Time by Andrew Rilstone, James Wallace and Richard Lambert, Atlas Games 1998.

[82] Originally "Die Siedler von Catan" by Klaus Teuber, Mayfair Games 1995

Trick Taking

This is very common in card games. Normally everyone plays a card and whoever plays the highest card wins the trick. Typical components for this are some kind of cards that have some kind of ranking/value.

Unit Deployment

This means that players at some point in the game get to deploy their units/markers/game pieces onto the board. In most games, this is normally done at the beginning of the game, but some games are almost entirely about unit deployment, where the units are used to control different areas/functions on the board. For instance, in the game *Big Shot*[83] players place units as they like on the board, to gain control of or even win, as many areas (in this case districts in a town) as possible. Each player has units in one color but the units come in groups of four, and they can be any combination of colors. Therefore, the game is not only about placing one's own units in a good way, but also about misplacing or using other players units.

Variable Player Powers

Anyone who is into role-playing will know this mechanic. It's simply about that each player, or at least some players get certain powers/privileges that can affect the game, usually from a variable setup. The game *Evo*[84] is a good example. In this game, each player controls a species of dinosaurs and throughout the game each species gain different sets of mutations that give them special abilities in the pre-historic world featured by the board.

Voting

This too, is just what it sounds like. Players try to reach an agreement by voting, and the decision most in favor wins. In some games, players have veto rights, can place extra votes by using cards, markers or something similar, or they have the power to invert the result.

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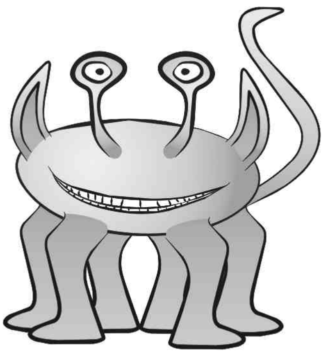
[83] Big Shot by Alex Randolph, Ravensburger 2001

[84] Evo by Philippe Keyaerts, Descartes Editeur 2001

APPENDIX 2: MULTI MONSTER MADNESS AND THE HATCHERY

This game system and its game was created by me in cooperation with Mads Haahr, Niels Reijers and Jussi Holopainen. We in beforehand stated that players' reasons for playing should be earning money, having fun, express creativity, and to collect cards, in that order.

Game system – Multi Monster Madness



Let's look into the future, but just a couple of years. Let's say that screens are cheap, and that a small 5 x 10 x 0,5 cm computer with a touch screen costs only a dollar or euro. Now, imagine that these flat computers can be used as cards in a game, cards that carry data about their own behaviors and possibilities, cards that can recognize other cards and interact with them depending on how the players move them and orient them physically.

This was the main idea for a hypothetical collectible card game that was named Multi Monster Mania. This card game features four different types of cards; games, places, modifiers for other cards (weather, tools, weapons etc) and, most important of all, monster cards. Monsters come in a lot of varieties. They have their own genetic properties determining for instance the number and types of arms, legs, eyes and so on, what kind of skin and color it has and so forth. Depending on their physical appearance, they also have physical statistics which are used to calculate how good a monster is at certain skills that could be important in a game, e.g. running and carrying a ball if it is an American football game.

All this data is carried in the card, as well as the biography of the monster; games played, training activities, offspring (players can breed monsters!) etc. The cards communicate wireless with a game card to get the rules of a game, and they can also sense if another card is put next to them. In some games the physical orientation of a card may matter; monsters put head-to-head against each other are enemies whereas monsters put alongside of each other are teammates.

Sometimes the screens on two cards merge, so that a monster can move back and forth between two cards. This, among other ideas and features, are discussed elsewhere.

A game: The Hatchery

This is a rough layout of the game idea for *The Hatchery*. You will note that no exact points or costs have been set, and that some rules state what "might" be done. This is because the game has never been play tested; it is a theoretical construction to describe the possibilities of gaming in a world with Multi Monster Maness cards. Also, it shows quite clearly how computers and sensors can be used to provide new game mechanics.

Object of game

This game is played with teams of monsters. Each team has four eggs in their chamber in an egg-hatching factory. Also, each team has the same setup of eggs; one purple, one pale green, one pink and one turqoise. How fast eggs grow or shrink depends on the environment in the entire factory. This environment is visualized with a color – the closer this is to an egg's own color, the better it grows. Each player gets points for hatching his or her eggs, the sooner the better. Points can also be earned by cooperating with other players.

The color in the factory can be changed by feeding pellets into its heating system, and therefore the game is about the following things;

- Getting pellets and feeding them into the factory
- Cooperating to get more pellets and points.
- Saving shrinking eggs by temporarily taking them out of the hatching chamber.

The game ends when all eggs have been hatched, and whoever has the most points at this point wins.

Game pieces

- Each player chooses three monsters each from his or her stock
- As many hatching chamber as there are players (location cards)
- Four pellet fields: one red, one white, one blue, one green (location cards)
- Game field entrance (location cards)
- One rule card

Layout of game

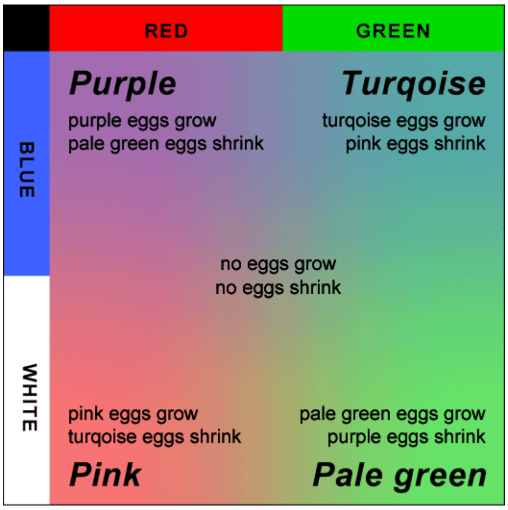
- The hatching chambers are put next to each other on the middle of the table. By doing this they connect.
- Each player puts his three monsters next to each other to indicate to the game that they are a team. After this, one of the monsters s put next to that team's hatching chamber to claim it as theirs. When doing that, four eggs of different colors appear

in that chamber. The monster can be taken away from the chamber again; it isn't stuck there for the rest of the game.

- The four pellet fields, the game field entrance and the rule card are also laid out on the table in some appropriate way, just like the monsters.

Important colors

Since the game is about changing the color of the hatchery chamber to match the eggs, colors and the change of colors are important in the game. The picture below shows how pellets affect the color status in the hatchery. Words written with bold capitals are pellet colors.



How monster stats affect the game

- Monsters with a lot of legs move fast
- Monsters with a lot of wings move even faster (twice as fast?)
- Monsters with a lot of arms can carry a corresponding number of pellets
- Monsters with a lot of arms can also harvest pellets with arms not currently used for holding other pellets
- Monsters with at least two arms can hold one and only one egg. When holding one egg, it can **not** hold any pellets, regardless of how many arms it has; it just clings to the egg with all arms. To pick up an egg all hands must be free (pellets must be given away to other monsters). A monster holding an egg may not move.
- Monsters with tentacles can steal and carry pellets, but not gather them.

Hatching eggs

This section describes what goes on in the egg-hatching factory. The changes of color, growth of eggs and deliverance of pellets is computed and thereafter shown on the cards by themselves.

- The entire factory has the same color. This color depends on the mixture of (colored) of pellets used currently (pellets get used over time, like if they were burned).
- The factory is fed with color pellets by putting one monster holding one or more pellets next to the players hatching room and then simply drag and drop the pellet(s) from the monster to the factory. It takes a certain amount of time to deliver the pellet(s).
- If no pellets are fed to the factory color will move towards gray (see color matrix
- Eggs develop (= grow) if their color is close to the color in the hatching factory.
- Eggs shrink if the color of the hatching factory is somewhere close to "opposite corner"
- Eggs neither grow nor shrink of the color is grayish (in the middle of the color matrix) or in the other end of its column or row.
- Eggs can be taken out of the hatching factory. When they are outside they neither grow nor shrink.
- Once an egg is hatched (has reached the hatching size) it is sort of "done" and will no longer be affected by the color in the factory.

Moving & distributing pellets

There are six different, virtual places in the game. A monster is "at" a place if its card is placed next to a location card (such as red field etc). The possible locations for a monster are:

- Next to the red field (in case any border of the field-card is still free).
- Next to the white field (in case any border of the field-card is still free).
- Next to the blue field (in case any border of the field-card is still free).
- Next to the green field (in case any border of the field-card is still free).
- Next to the hatching chamber (a monster can only be place next to its own hatching chamber and there are two places).
- Next to the field entrance.
- In void – any place else on the table.

Movement is measured in time – it takes a certain monster a certain time to get to a certain location. From a computers point of view the locations reside in a virtual space where every location is exactly the same distance away from any other location (the cards making up the factory counting as one location), including the void area.

Depending on how many legs or wings a monster has, it will move faster through the virtual space. To practically move a monster you move its card from one location to another. The time it takes for it to actually get there is computed by the card and a little status bar is counting down on the card.

- A monster without legs or wings cannot move at all.
- A monster can carry as many pellets with it as it has arms.
- A monster may use all his arms to carry another monster of the same team. The monster being carried can still hold pellets.

Pellets can be moved from one monster to another by putting the cards next to each other and drag and drop the pellets between the cards. This can be done with any two monsters regardless of team. See trading below

Getting pellets

Gathering

Pellets can be gathered at the pellet fields (one field per color). They are gathered by placing a monster card next to the field. The monster starts picking up one pellet per free hand. This takes a certain amount of time. Probably it takes a little longer to pick up three pellets at once, but not at all as not as long as 3 * 1 pellet. A little status bar on the monster card visualizes the time.

Note that tentacles can't be used for gathering pellets, only for holding/carrying

Note that pellets actually **grow** in the field which means that there is not an unlimited supply at all times. It takes x seconds for a pellet to appear, and all this is of course calculated by the pellet field card itself.

Trading

Two players can agree to trade pellets with each other. They just place the two monsters carrying the pellets they want to trade next to each other and drag and drop pellets between the cards. It **is** allowed to break a promise by not "paying" for a pellet that has been dragged to your monster.

Stealing

If a monster with a tentacle is placed next to a monster of an opposite team carrying pellet(s) the tentacle monster will steal a random pellet from the other one (maybe one per tentacle, or this my be too powerful?).

Cooperating

At the start of the game each monster will get the special ability to create a pellet of one certain color if fed two pellets of two other determined) colors. For instance the monster Bob would produce exactly one white pellet if fed exactly one red and one green pellet. The monster Michelle would in a similar way produce a blue pellet being fed a red and a white.

However the two monsters feeding the producing monster (which they do by being put next to it) have to belong to **two different teams**. Any monster not belonging to the producing monster gets victory points. The producing monster gets the pellet.

Getting more monsters on the team

A player may get extra monsters (from his or her deck) into the game by paying either 4 pellets of the same color or 3 pellets, all of different colors, at the game field entrance (location card).

Winning – getting points

Parameters for calculating score:

- A player scores points whenever his or her eggs hatch (the sooner the better).
- A player scores points whenever he or she has managed to hatch all his or her eggs (the sooner the better).
- A player scores points for cooperating with other teams (se cooperation above).
- A player scores points for number of pellets held at end of game?

The game ends when all the eggs in all chambers have been hatched. A player is stays in the game even if all his or her eggs have been hatched; he or she can still influence the color in the factory by feeding pellets to it, or earn points by cooperating with other players. The score is kept secret throughout the game – or maybe not.

Possible improvements

Having discussed the original ideas with an hard core board gamer, the following improvements have been suggested.

Cooperating

This was actually one of the original ideas, but it was written out of the rules to decrease complexity. Monsters can still produce pellets, but need other resources than pellets to accomplish this, for instance resource A & B. Resource A can be found in the own team whereas resource B must come from another team. Also, monsters produce two (or even more?) pellets. This will increase cooperation.

Field entrance as waste basket

The field entrance can have two functions. Either pellets can be dumped there to disappear from the game, which will give players even more influence of the color in the hothouse, especially if pellets grow very slow in the fields. Or, a certain combination of pellets can be used to **switch** one monster on the board (belonging to one's team) against another monster from the deck (instead of adding one).

Eggs like being nursed

If a monster is docked next to its teams hatching chamber, the eggs in that chamber feel better and grow faster. The growing rate improves if two monsters dock. This effect will prevent all eggs of one color (i.e. pink) to grow at the same rate if, say, the factory environment is pink.

Varying color in hatching factory

Another way to make a difference in how fast eggs grow is if the color in the factory varies slightly between the hatching chambers. If one monster feeds one green pellet into his chamber, this would affect the color in that chamber in the corresponding way. In surrounding chambers, the color should change in a similar way, but calculating with ½ pellet instead of 1. Two chambers away the effect is calculated with ¼ pellet. If this idea is used, it is important that the hatching chambers put on each end of the row are also connected virtually, so that color can spread from one of them to another.

APPENDIX 3: RULES FOR THE RULE-WRITING CONTEST

Welcome to GothCon XXVI and the "Build your own board game" contest. When this paper is handed out to you, you have exactly five hours time to create your game. Good luck!

Game material

- 1 board, including four cornered rims and clips to keep them in place
- 30 marbles; 6 red, 6 yellow, 6 green, 6 blue, 2 black, 2 white, 2 black-and-white
- 2 larger marbles
- 12 wooden pellets; 3 red, 3 yellow, 3 green, 3 blue
- 4 wooden eggs, 1 red, 1 yellow, 1 green, 1 blue
- 4 game pieces; 1 red, 1 yellow, 1 green, 1 blue
- 48 white cards, numbered from 1 to 6, eight of each number
- 16 gray cards; four marked with "A", four with "B", four with "C", four with "D"
- 12 dark gray cards with four different symbols; three of each

Rules for making up rules :)

- The following game materials **have** to be used
    - The board
    - Some – but not necessarily all – cards
    - At least one marble or pellet or egg, preferably more
    - At least one die

- Game designers are encouraged to apply computer characteristics to the game. To promote this, game designers **may not** move sticks up or down during game testing; this will be made by Sus Lundgren, acting as the computer.

- It is advisable to make a game for no more than four players, since there are four members in the jury.

- Each team may only turn in rules for one game. The rules may however contain variants.

- The rules shall contain the name of the game, the names of the game designers, what materials are needed, how the game is set up, how to win, and of course how to play. Also, it should be stated whether Sus Lundgren may or may not develop the rules further.
- Each team has exactly five hours to turn in complete rules for a game, in form of a digital file. A computer will be provided for this, and Sus Lundgren can be asked to help out with this. Drawings to clarify rules may be turned in as drawings on paper, as long as there are references to them in the text.

Judgment of the games

The best game is chosen by a jury. The jury consists of four people; some of them devoted gamers, some not.

- Sus Lundgren is **not** a member of the jury and will not interfere with its decision. She will take part in their work though, by still acting as the computer as stated in the rules.
- The jury will spend one hour on each game, including reading and understanding the rules. They will play the game as many times as possible within the given time, starting out with the basic rules, then adding the variants the second time around.
- Only the winning game will be selected; all others end up in second place.
- The winning team will be announced at GothCon's ending ceremony.

Copyright notes

- The games that are created when the game material and the rules are combined, are co-productions between Sus Lundgren and each team.
- Sus Lundgren reserves the right to publish the rules for all games in her master thesis. Game designers will of course get all the credit for the rules.
- GothCon reserves the right to publish all game rules in connection with its website.

APPENDIX 4: FORM TO MEASURE GAME EXPERIENCE

Team: ____

Participant 1: ____ Age: _________

Participant 2: ____ Age: _________

Participant 3: ____ Age: _________

Participant 4: ____ Age: _________

Participant 5: ____ Age: _________

Games	1	2	3	4	5
Monopoly					
Chess					
Trivial Pursuit					
Balderdash					
Othello/Reversi					
Ludo/Fia med knuff					
Jägersro					
Yatzy					
Uno					
Risk					
Pictionary					
Canasta					
Poker					
Bridge					
Chinese checkers					
Svälta Räv					
Settlers of Catan					

El Grande					
Carcassonne					
Torres					
Tikal					
Elfenland					
Mississippi Queen					
Hare & Turtoise					
RoboRally					
Richochet Robots					
Diplomacy					
Civilization					
History of the World					
Britannia					
Chinatown					
Union Pacific					
Drachengold/Dragon's gold					
Ohne furcht und Adel					
Ra					
Total					
Overall total					

APPENDIX 5: RULES FOR OPERATION PHOENIX

Rules written by David Hagman & Jenny Nordgren

Introduction to the game

In a distant future, our galaxy is controlled by four strong alliances. Each alliance is desperately trying to find and colonize a black planet, called the Paradise Planet, before the others. The problem is that the planet seems to be moving and jumping through the universe in unpredictable ways. Thus, each alliance has a number of ships out looking for the Paradise Planet. While gaining more knowledge and power, each fraction discovers more ways to influence the course of events in deep space.

Goal

Each fraction's goal is to land all its ships on the Paradise Planet, thus gaining the control of it; leading to power and glory for ever.

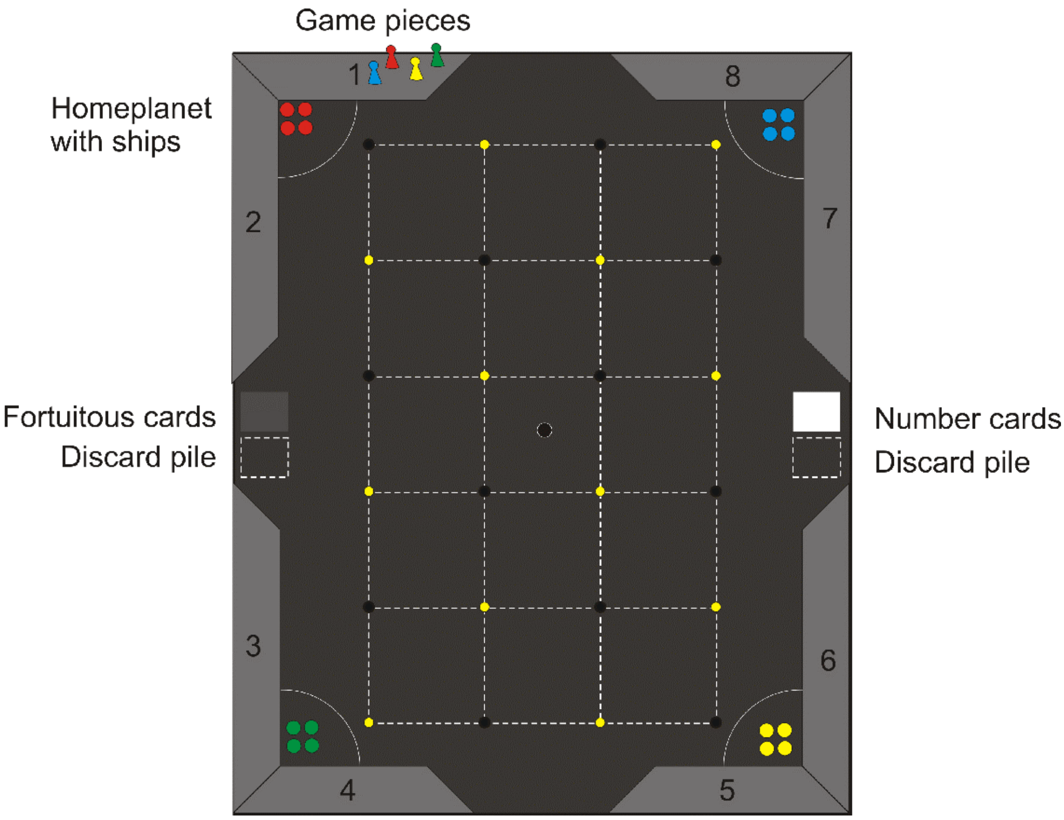
Game components

- 1 board, including four cornered rims and clips to keep them in place
- 25 marbles; 6 red, 6 yellow, 6 green, 6 blue, 1 black
- 4 game pieces; 1 red, 1 yellow, 1 green, 1 blue
- 48 white cards, numbered from 1 to 6, eight of each number
- 3 gray cards marked with "B", "C", and "D"
- 12 gray cards; four marked with "A", four with "B", four with "C"
- 12 dark action cards with four different symbols; three of each
- One randomizer (die, computer, game designer or whatever) for the range 1 – 8 and one for the range 1 - 15

Setting up the game

1. Put the rims on the board and fasten them with the clips
2. All sticks should be as lowered as possible
3. Cards and game pieces should be placed like the drawing below; the game pieces should be put on a rim, the black marble in the middle square, each player's marbles

in the corner closest to them etc. Each player should start with four ships (=marbles). If a longer game is desired, , players may get six ships each.



How to play

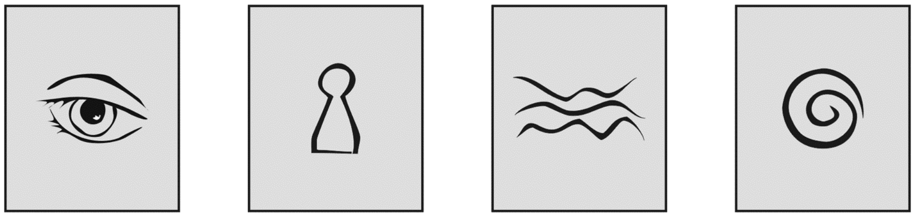
The fifteen squares on the board symbolizes the Milky Way, the black marble is the Paradise Planet and the marbles of each player represent his or her ships. Each player draws a number card, and whoever gets the highest number is the start player.

In short, each players turn consists of four phases (see below):

1. Playing action cards (except Influence)
2. Moving the game piece
3. Moving a ship
4. Moving sticks – distorting space

Playing action cards

After the very first round, a player **may** choose to play one of his or her action cards. All cards except Disturbance must be played in this phase. A player may never have more than two cards on his or her hand. If a third is drawn, the player may choose which ones to keep. The cards are from left to right:



1. The all-seeing eye: Draw a card from any other player.
2. Influence: The game piece is moved twice as long in the next phase.
3. Disturbance: This card is played when another player has drawn a number card but not yet moved any stick(s). You choose which stick(s) are to be moved and how.
4. Wormhole: Switch places between one of one's own ships(marbles) and the Paradise Planet.

Moving the game piece

How the game pieces move along the rim represent each fraction's progress when it comes to politics and science. There are two steps on each rim, making the whole track eight steps long.

- The player moves his or her game piece as many steps as he/she has ships in the Milky Way (= on the board).
- When a game piece completes one lap, meaning that it is back on square one again, it's player receives a gray card.
- A player will also receive a gray card if one of his or her ships (marbles) are pushed/moved/roll out of the Milky Way, **due to the actions of another player**. The unlucky marble has to start over again from its home planet.

Moving a ship

Ships can only be moved in one of the following ways:

- By being moved in this phase
- By being affected when the space is distorted by any player
- By being affected by the Wormhole action card.

In this phase, the player may activate one of his/her ships by moving it from the home planet into the closest corner square of the Milky Way. He/she may also move a ship from any square to an adjacent square (not diagonally). He/she may put the ship anywhere in the square and if the ship rolls away from the square (any way, including diagonally) because space is distorted, this is perfectly alright. It is not allowed to drop ships in a square; they are to be put on the cloth, not distorting it, an let loose.

If a ship leaves the board

If a ship is pushed/moved/roll out of the Milky Way, **due to the actions of another player**, it's owner will receive an action card. The unlucky ship has to start over again from its home planet.

Moving sticks – distorting space

The player draws a number card and may then move a stick up- or downwards that many steps. The steps can also be divided amongst several sticks, who don't have to be moved in the same direction. All steps have to be used.

Encountering the Paradise Planet

Whenever a ship enters, **and stops in**, the same square as the Paradise Planet or vice versa, it is determined if it succeeds to land on the planet or not. The player draws a letter card.

- A: The ship fails, and is moved out of the square to one of the eight surroundning squares (this is randomized). If the space is distorted in this square, and the ship rolls back to the square with the Paradise Planet, a new card is drawn.
- B and C: The ship succeeds and is taken out of the game.

Moving the Paradise Planet

The Paradise Planet can only be moved in one of the following ways:

- By being affected when the space is distorted by any player
- By being affected by the Wormhole card.

When every player has completed his turn, the Paradise Planet mysteriously moves to any random one of the fifteen squares. If the space is distorted,

How to win

A soon as someone's last ship has succeeded in landing on the Paradise Planet, the game is over, and that player has won.

APPENDIX 6: EVOLUTIONARY DESIGN OF THE MARBLEGAME

The initial rules

The entire rules can be found in Appendix 5. In short, the object of this game is to get rid of one's four marbles (spaceships) by somehow moving them to the square of a black (neutral) marble, called the Paradise Planet, or moving it to their square. Whenever this happens, luck of the draw decides if the ship leaves the game or not. If not, it is replaced on another square, chosen by the outcome of a die roll. Players may play action cards to trigger certain events. Action cards are gathered by completing a lap around an eight-step track made out of the rim. Each players **turn** consist of four **phases**:

- **Action card-phase:** Action cards can be used for steeling one card from any opponent, moving one's game piece twice as far, moving the sticks in someone else's turn, switching places between one of one's own marbles and the black marble.
- **Game piece movement-phase:** Moving the game piece along the track as many steps as one has marbles on the board
- **Marble movement phase:** Either moving a marble that is already on the board to any adjacent square (not diagonally), putting it down anywhere in the square **or** introducing a new marble in that player's starting square.
- **Stick movement phase:** Draw a number card and assign the same number of steps to one or more step, moving them upwards or downwards. Sticks remain in that position.

At the end of each **round** (i.e. when all players have had their turns), the Paradise Planet moves to a random square that is determined via a die roll.

The first iteration

Before the second prototype was built an expert group played the Operation Phoenix game on the existing prototype, their task being to evaluate the rules and the prototype, and to suggest improvements.

Things that worked

- The Influence-card (stealing someone's stick movement).

- The Action card-phase.
- The Marble movement-phase.
- The Stick movement-phase.

Problems

- Where does the Paradise Planet go if it for some reason is pushed off/rolls out of the Milky Way? It can't just be randomized back, unless you want it to be a tactical maneuver to push it off, hoping it will reappear in a more suitable square.
- If many marbles are in the same square, this creates a pit, that draws even more marbles. The group of marbles is hard to move and almost possible to split.
- Moving the Paradise Planet when each player has taken a turn means that it will always be moved between the last and first person, which is disadvantageous for the first player. This could be solved with bidding for turn order, or by moving the Paradise Planet at more random occasions.
- Players had trouble remembering the game piece movement-phase.
- Players had trouble remembering the radom movement of the Paradise Planet at the end of each round.

Possible improvements

- The numbers on the number cards should be non-evenly distributed, preferably along a bell curve.
- Players should be allowed to have more than two fortuitous cards, or to have two disposable cards in hand, and then a "queue" of possible surplus cards.
- In the computer-enhanced prototype: If a stick is raised a lot, surrounding sticks my rise somewhat as well.
- Having an fortuitous card for moving stick(s) two extra steps.
- Having an fortuitous card for moving a ship two extra steps.
- Having an fortuitous card for moving the Paradise Planet
- Having a function for resetting the board.
- Bidding for turn order and/or for how the Paradise Planet should move.
- Raising the edges so much that marbles never can roll out of the MilkyWay
- Having a larger board with more squares.
- Having four Paradise Planets, one for each player.

Changes

- Having 6 x 6 sticks instead.

- Each round should start with a bidding phase to resolve turn order.
- To get rid of a marble, it has to hit the Paradise Planet; getting into the same square shouldn't be enough. If a marble stops in the same square, however without touching the Paradise Planet, it is punished by having to start over again.
- If a marble lies exactly in the middle point of four squares (this can occur if that stick is lowered so that there's a valley there) it may be moved to any one of those four squares if the player chooses to move it manually instead of with the sticks.
- The Paradise Planet should not be moved at the end of rounds.
- Dice should be used to resolve the number of steps a stick should be moved. There should be two six-sided dice (numbered 4,4,3,3,2,1 and 4,3,2,2,1,1 respectively), creating a bell-shaped curve of the outcome, with a range from 2 – 8 and an average of 5.
- Each player should get two action cards at the beginning of the game.
- There should be a new set of action cards:
    - **Worm hole** – the player gets to switch places between one of his/her ships and the Paradise Planet. Played in the Action card-phase.
    - **Hyper drive** – the player gets to move one of his/her ships two steps. Diagonal movement is allowed. Played in the marble movement-phase.
    - **Telepathy** – the player gets to move the Paradise Planet two steps. Diagonal movement is allowed. Played in the Action card-phase.
    - **Espionage** – the player gets to look at one opponent's cards, and then has to switch one of his/her (other) cards against one of the opponent's. Played in the Action card-phase.
    - **Influence** – the player gets to move the sticks in someone else's turn, instead of that player. Played in the stick-movement-phase, before the die roll.
    - **Scientific progress** – the player gets to move his/her game piece a double distance. Played in the game piece movement-phase.
    - **Flatlands** – resets the board. Played in the Action card-phase.

The second iteration

The second time around, the game was played on the new and improved second prototype. Play testers were myself and three experienced gamers.

Things that worked

- The Influence-card (stealing someone's stick movement).

- The Action card-phase.
- The Marble movement-phase.
- The Stick movement-phase.
- The bidding for turn order.
- Having more sticks and squares.
- The Flatlands-card.
- Elimination of marbles.

Problems

- The action cards seemed to be to hard to get. No one ever had more than two action cards, and those were played in the beginning of the game.
- It seems that the entire moving of game pieces is rather useless and uninteresting. It was used as a balancing force in the game, since it made it harder for a leading player to get cards – but this is also true for a player who is lagging behind.
- The Worm hole-card turned out to be a very powerful card in this particular tryout, since one player simply introduced all his ships to his starting square and finally played the card.
- The Hyper drive-card and the Telepathy-card turned out to be too powerful.
- The Espionage-card did not work. It was considered to be boring, and it was argued that the price was to high; paying one card to receive another of your choice seemed good in theory, but since none of the players ever had more than two cards, it was not as good as it sounded. Also, the player kept this until they had no other cards, then using it to simply steal a card, since they had no cards left to switch with.
- The Scientific progress-card didn't work since it simply is played to get another card, which makes it rather useless.

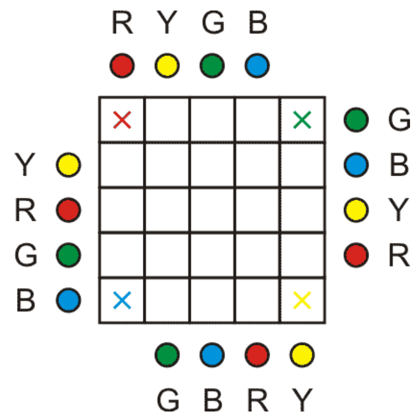
Possible improvements

- The thing that affects the game the most is moving the sticks, and therefore there should be more ways – or action cards – to affect this.
- The possible outcome of the dice could be altered so that the range becomes even smaller, perhaps 4 – 6.
- If one rolls a low number, one could choose to save the outcome, using it to add that number of steps onto a later roll.
- Players may not have a particular starting square; either each player could have one marble staring from each corner, or the starting square for each player could change throughout the game.

- Perhaps cards could be distributed in some other way, maybe whenever someone gets rid of a ship. This would exclude the game pieces.
- The current position of the game piece could affect where new ships come into play.
- The Worm Hole-card could be used for switching the Paradise Planet and the ship of an opponent, or one's own ship and that of an opponent.
- The Hyper drive-card and the Telepathy-card should only allow a player to move the marble one step, diagonal movement still allowed.
- Throw out the Espionage-card and the Scientific progress-card.
- Add one or more cards that influences the movement of the sticks.

Changes

- At the setup, the Paradise Planet is placed in the middle square, and those marbles that are closest to a corner is placed in that square (see the crosses on the figure below).
- Each player's marbles enter the board from different positions, laid out as below. The layout was made to be as balanced as possible. The player's may choose freely which one of his or her marbles should enter play; they needn't be played in any special order. The rim can be adapted to this, so that it has correspondingly colored pits to put the marbles in. This means that when setting up the game, each player will have one marble in a corner square, and the remaining three in the other three pits.



- A roll of 2 or 3 may be saved, using it to add that exact number of steps onto a later roll.
- The two dice should be numbered 3,3,2,2,2,1 creating an irregular bell-shaped curve of the outcome, with a range from 2 – 6 and an average of 4,33. It will be more unlikely to roll 2 than 6, but also more unlikely to roll 6 than 2 or 3. The reason for this is to promote the saving of rolls.
- If a marble needs to start over because it stopped in the same square as the Paradise Planet without touching it, the player may choose to restart it from any one of his or her non-occupied starting positions. This choice has to be made immediately when the marble is taken off the board.

- Each player should get two action cards at the beginning of the game.
- At the end of each round where marbles have been eliminated, each player who did not get rid of at least one marble gets one action card.
- The game pieces are taken out of the game.
- There should be a new set of action cards:
    - **Influence** – the player gets to move the sticks in someone else's turn, instead of that player. The influential player may not chose to save any steps. Played in the stick-movement-phase, before the die roll.
    - **Theft** – the player gets to "steal" two steps from someone else's die roll. The two steps are saved by the stealing player, who can use them to add that number of steps onto a later roll. Played in the stick-movement-phase, after the die roll if the other player' decides not to save (in case of a roll of 2 or 3).
    - **Flatlands** – resets the board. Played in the Action card-phase.
    - **Worm hole** – the player gets to switch places between one of his/her ships and the Paradise Planet. The Worm Hole may not be used if the Paradise Planet will take out more than two of any player's marbles. Played in the marble movement-phase, instead of normal movement.
    - **Hyper drive** – the player gets to move one of his/her ships one step. Diagonal movement is allowed. Played in the marble movement-phase, instead of normal movement.
    - **Telekinesis** – the player gets to move the Paradise Planet one step. Diagonal movement is **not** allowed. Played in the marble movement-phase, instead of normal movement.

The third iteration

The third time around, the game was played by myself and another experienced gamer. We used the second prototype.

Things that worked

- The Influence-card (stealing someone's stick movement).
- The Action card-phase.
- The Marble movement-phase.
- The Stick movement-phase.
- The bidding for turn order.
- Elimination of marbles.

- The Flatlands-card.
- The Theft card.
- The Telekinesis card.
- The Hyper drive card.
- The configuration of the dice.
- The new starting points for marbles.
- Having marbles on the board from the beginning gave the game a quicker start.
- The distribution of action cards.

Problems

- The influence card suddenly became far too powerful.
- The rule that the Worm Hole card may only be played if it takes out no more than two marbles felt awkward. It was written this way to make the card less powerful, but with the spread out starting positions, it looses a lot of its power anyway.
- The few saved rolls were never used.
- The game is very short.

Possible improvements

- Throw out the Influence card.
- Revert the Worm Hole card to its initial status.
- Elongate the game by playing with six marbles instead of four.
- Not allowing the players to choose which one of his or her marbles that is to be put onto the board; this should be determined by a die roll.

Changes

- Throw out the Influence card.
- The rule for the Worm hole card is as follows: the player gets to switch places between one of his/her ships and the Paradise Planet. Played in the marble movement-phase, instead of normal movement.
- The game should be played with six marbles. In the marble movement-phase a player thus may choose to
    - Move a marble that is on the board, or
    - Move a marble from a pit onto the adjacent square, or
    - Move a hitherto non-used marble into any one of his or her empty pits.

APPENDIX 7: FINAL RULES FOR THE MARBLEGAME

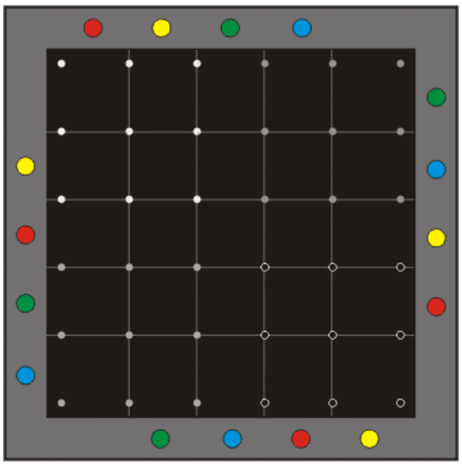
When describing the rules blow, no consideration has been made to explain how to interact with a computerized prototype. These are the plain rules.

Introduction to the game

This game features marbles rolling on an ever changing surface. The object is simply get rid of all one's marbles by hitting a black target marble, but throughout the game various action cards can be used to change the course of the game.

Game components

- 1 board, including four cornered rims and clips to keep them in place
- 25 marbles; 6 red, 6 yellow, 6 green, 6 blue, 1 black
- 12 white cards with the text "2"
- 12 white cards with the text "3"
- Four sets of bidding cards, labeled "1", "2", "3", "4", "5" and "6".
- 4 gray cards marked with "A","B", "C", and "D"
- 22 dark gray action cards four each of the types Theft, Telekinesis, Hyperdrive and Wormhole, two of the type Flatland.
- Two six-sided dice numbered 3,3,2,2,2,1



Setting up the game

- All sticks should be as lowered as possible.
- Put the rim on the board and fasten it with the clips.
- Place the black marble on the center square.
- Place marbles of corresponding colors in the colored pits on the rim.
- Give each player two action cards

How to play

Each round consists of three phases:

- A bidding phase to resolve turn order
- Each player takes their turn. Each turn also consists of three phases:
    - Moving a marble
    - Moving one or more sticks
    - Playing action cards
- Players that didn't manage to get rid of any marbles draw an action card each.

The bidding phase

At the beginning of the game, players get six bidding cards. When bidding for turn order, they secretly choose one or two cards to bid with. The cards are revealed simultaneously, and whoever has bid the highest sum gets the card labeled "A" to indicate that he or she is the first player in this round. The player who has bid the second highest sum gets the "B" card and so forth.

If two players bid the same sum, the one of them that who played eafter the other one in the last round gets to go first.

When four rounds have been played, players get back their spent cards and start over with a full set.

A turn

A turn consists of the following three phases:

Moving a marble

A player has three choices when it comes to moving a marble:

- To move a marble that is on the board, one square, diagonal movement **not** allowed. When moving the marble to another square it may be put **anywhere** in that square.

- To move a marble from a pit onto the adjacent square, putting it **anywhere** in that square.
- To move a hitherto non-used or restarting marble into any one of his or her empty pits.

Sometimes marbles are found in pits formed on the board, lying in the intersection between four squares. In this case, and if choosing to move that particular marble in the marble movement phase, the marble my be moved to any one of these four squares.

Moving one or more sticks

Before a player moves one or more sticks, he or she first rolls the dice and adds the numbers. The sum is the number of steps (upwards or downwards) that the player may distribute to one or more sticks. The primary aim of stick movement is of course to get one's own marbles to hit the black marble, but one can also use it to impede other players. The player again has three choices:

- To distribute the rolled number of steps to one or more sticks as is, moving them.
- To cancel the stick movement, instead saving the steps. This may only be done if the sum of the die roll was two or three. No sticks are moved, and the player takes one of the cards labeled "2" or "3" respectively.
- To add extra steps to the sum, spending previously saved steps by paying the card symbolizing this. After that, he or she distributes the steps to one or more sticks. The sticks are moved.

It is allowed to assign upward movement to one stock and downward movement to another.

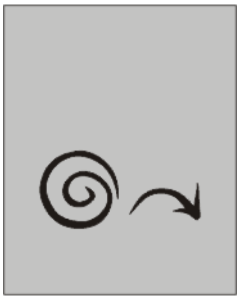
Playing action cards

In his turn, a player may play one or more action cards. He only exception from this is the theft card, that is played during another players turn. Exactly when a card can be played, depends on which card it is. The cards are:

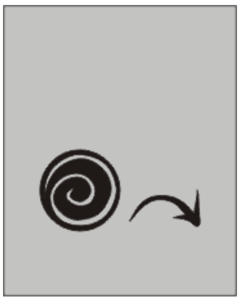
Theft – the player gets to "steal" two steps from someone else's die roll. The two steps are saved by the stealing player, who can use them to add that number of steps onto a later roll. Played in the stick-movement-phase, after the die roll if the other player decides not to save the steps.

Flatlands – resets the board. Played before marble movement..

Worm hole – the player gets to switch places between one of his/her marbles and the black marble. Played in the marble movement-phase, instead of normal movement.



Hyper drive –the player gets to move one of his/her marbles one step. Diagonal movement is allowed. Played in the marble movement-phase, instead of normal movement.



Telekinesis – the player gets to move the black marble one step. Diagonal movement is **not** allowed. Played in the marble movement-phase, instead of normal movement

Hitting or missing the black marble

As soon as a marble hits the black marble or vice versa, it is taken out of the game, and the player is somewhat closer to the goal of the game. A marble may hit the black marble by being moved next to it, by rolling into it, or by being hit by the black marble itself, rolling or being moved. **But** if a marble enters and **stops in** the same square as the one where the black marble resides, without hitting it or being hit by it, that marble has to start over again.

If there are any empty pits of that player's color on the rim, the marble is put in any one of them (player's choice); if all are occupied it is removed entirely from the board, and has to restart by being put in a n empty pit during marble movement.

Moving the black marble

The black marble may move due to stick movement or when the Action cards Wormhole or Telekinesis are being played (see above).

Getting new action cards

At the end of each round (i.e. when all players have had their turns) each player who hasn't managed to get rid of any marbles gets one action card.

How to win

The player(s) who first manages to get rid of all his or her marbles, wins the game.