Designing Augmented Reality Board Games: The BattleBoard 3D experience

Troels L. Andersen, Sune Kristensen, Bjørn W. Nielsen, and Kaj Grønbæk
Department of Computer Science, Aarhus University
Åbogade 34, 8200 Århus N, Denmark.
E-mail: {tlange,sunek,bwn,kgronbak}@daimi.au.dk

Abstract

This paper discusses the design of BattleBoard 3D (BB3D) which is an ARToolkit based game prototype, featuring the use of LEGO bricks for the physical and digital pieces. BB3D is a novel type of an AR game augmenting traditional board games with features from computer games. The initial experiments involving kids indicate that it is promising with respect to add computer game excitement to board games and to add a social dimension to computer games. The paper discusses the concept for the game, implementation issues, the physical setting for the game, user interfaces, as well as tailorable pieces and warriors. Based on qualitative experiments with children, we discuss central design issues for future AR board games.

Keywords

Augmented reality, ARToolkit, design with children, game interfaces, multi-user board game, LEGO.

INTRODUCTION

Children's gaming habits have changed significantly during the past decades (Zagal et al., 2000), from board games over computer games to mobile phone gaming and other types of games involving pervasive computing. The social interaction has likewise changed from an intimate game experience in board games to a solitary game experience in the gaming arcades and behind the screens at home, and now multiplayer games over the Internet, multiplayer mobile phone games etc.

The goal of the BattleBoard 3D project is to combine the "best" features from classical board games and computer games. It's our thesis that by augmenting a board game the aesthetic game experience will be extended. In (Konzack, 1999) a report on children's use of computer games points out that a great amount of leisure time is used on these. In the fulfillment of this vision we turned to the technologies and perspectives of Augmented Reality.

The Augmented Reality (AR) research area (Azuma, 1997; Mackay, 1998; Milgram, 1994), focuses on linking digital information to physical objects, places (indoor and out-door), and spaces. AR aims at bringing IT-capabilities out of the traditional computer and embodying them in the physical environment that people work and live in. Typical applications are to link and display digital annotations on top of objects and places by means of identifying codes (barcode etc.). An example is the ARToolkit (Billinghurst et al., 2002) which have been used for creating the MagicBook and collaborative real world teleconferences. AR has different applications (Billinghurst et al., 2001) in industrial settings and entertainment. Recently there have been a few developments of AR games. This paper describes a new kind of AR game BB3D - featuring a mixture of digital and physical pieces made with LEGO[1].

The paper is organized as follows: First we describe the domains of computer games and board games as well as discusses the potentials of merging the two. Second we describe the conceptual design of BB3D and the technical implementation and the alternative setups for the game. Third we discuss the first experiences with children playing. Fifth, we compare BB3D to the AR games described in (Azuma, 1997; Rekimoto & Saitoh, 1999; Szalavári et al., 1998). Finally, we conclude the paper.

COMBINING COMPUTER GAMES AND BOARD GAMES

In this section we outline our vision for combining classical board games and computer technology in order to create new game experiences; the goal is to combine the dynamic nature of computer games with the social interaction related to board games.

The original source of inspiration for the BB3D project was a sequence in the movie Star Wars Episode IV where two characters are playing a game of Holo Chess. The different pieces of the chess game are alive,

[1] LEGO is the Trademark of LEGO Company, Billund, Denmark.

moving and making comments of the game, and when a strike is executed, a battle between the actual pieces is shown on the field of the board. Our idea was to make this scenario come through outside the world of fiction in the actual settings of multi-user board games.

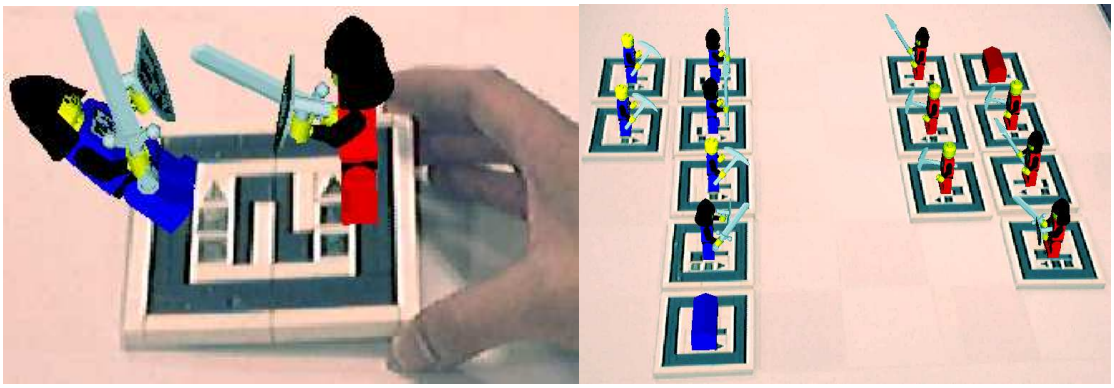


Figure 1a "A battle between pieces" **1b: "The Battle Board"**

In the BB3D project the physical pieces are associated with animations which show the virtual representation of pieces and the outcome of occasional battles. This kind of augmentation provokes new ways to interact with computers, which enable the user/player to maintain the same kind of interaction as known from classical board games – the interaction is purely based on physical interaction with tangible pieces. The use of computer interaction through physical objects to support learning has been described in (Milgram & Kishino, 1994). The objective for the development of BB3D is somewhat different – to combine the essential interactive features from classical board games with the aesthetic qualities from computer games.

The Characteristics of Games

Since it is our objective to augment classical board games, it is necessary to identify the characteristics of games. This identification accentuates the aspects of games that are relevant for the BB3D project and should not be considered a comprehensive survey.

Roger Caillois (1961) has described play as a set of four general genres: *Agôn:* A kind of play/game where competition is the center of focus. The skill of the player is essential in this genre because the player who has developed the best set of skills has the best chance of winning – the chess game belongs to this genre.

- *Alea:* is a game of luck. This kind of game is defined by chance. The human skills or strength can not determine the winner, but the roll of a dice can.
- *Mimicry:* is the play of make-believe. The ability to take on different kinds of characters is essential. It is closely related to fiction and acting, based on the ability to build up and maintain the illusion of make-believe.
- *Ilinx:* is a play with vertigo, a game of intoxication, and is basically a conflict between life and death. The play seeks a dangerous challenge to achieve an intoxicating feeling as is the case with bungee jumping.

The game of such game genres can be defined in terms of ludology that acknowledges different game factors: positions, resources, space and time, goal (sub-goals), obstacles, knowledge, rewards/penalties (Konzack, 2002). *Positions* are the positions from which the game is perceived – e.g. players, audience, or judges. *Resources* are the means by which the players are able to influence the game – the instruments of interaction. *Space* is divided into a virtual space and playground. Virtual space defines an imaginary space constructed by the player while playing. Playground defines the physical space for the game. *Time* is the time it takes to play an actual game. *Goal* describes the objective of the game, what is needed to win the game. *Obstacles* are the factors in a game that need to be defeated to achieve the main goal. It could be opponent pieces, lack of resources etc. *Knowledge* describes different kinds of information available during the game. The game roles are open information and the tactics and strategies of the opponent player are closed information. *Rewards/penalties* are the results of playing. A consequence of a game action could be loosing or achieving resources, a sudden need of solving a puzzle or gaining magic powers etc.

Classical Board Game Characteristics

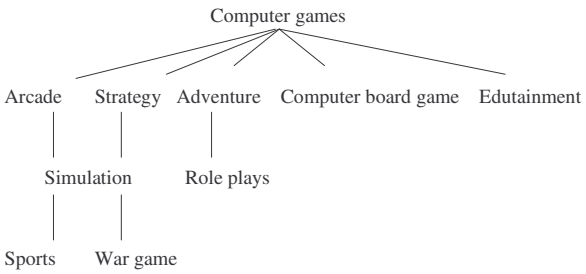
Classical board games in general fall into the genres described as *Agôn* and *Alea* in different mixtures depending on the type of game. A Chess game is a pure game of *Agôn* while a game of Backgammon can be defined as a mixture of these two genres. Other games such as Risk also incorporate elements from the *Mimicry* genre.

An important feature of classical board games is the physical placement of the players – described as the game positions. Position concerns the physical settings of the game, the social interaction between players and the physical surroundings. It was a vital concern in the development of BB3D, that the physical settings of the classical board game could be integrated in the physical settings of our augmented board game to ensure interaction based on physical objects with the two players on each side of the board.

The resources are the augmented parts in BB3D. Augmenting the resources can hopefully influence the player's experience of the space factor. The virtual – and the physical spaces are by augmentation extended to contain additional digital information. The goal of augmenting a board game is to extend the aesthetic experience of resources, space and the game in general.

The Characteristics of computer games

Computer games can be described in different genres. In (Konzack, 1999) a map describes the relation between a set of computer genres. This is not to be considered as the complete map of genres, the map changes over time, new genres emerge and others disappear. The following illustration is our translation from the Danish edition:



Model 1 "Genre map: quote (Konzack, 1999), p. 124."

In the following we give a brief description of the genres at the top level.

- *Arcade:* is a type of game that challenges the player's ability to react, the better reaction the more points you are rewarded. The goal is to capture the first place in the High Score list. The evolution of the games is set by changing levels with increasing obstacles. An example of an *Arcade* game could be: *Apple Tetris* (Kolling, 1996).
- *Strategy:* The scenario of such games is often based on historical conflicts. The game involves situation analysis and planning from the players to ensure the right strategy for winning. Strategy games often use narrative elements to visualize the game. Game example: *Civilization* (Meier, 1996).
- *Adventure:* are mission based games aimed at exploration. At the center of the game there is a quest which is the main goal. The player needs to solve different puzzles and collect different items in the act of solving this mission. Game example: *Thunderbay* (Grannel-Schaap & McDonnald, 1996).
- *Board game:* This genre is a description of computer games where a transformation from ordinary board games has taken place. Game example: *Draw Porker 1.0* (Gardener, 1994).
- *Edutainment:* These games have, as indicated, an educational purpose combined with an entertainment dimension. Example: *Barbie Fashion Designer* (Grant & Parker, 1996).

Common features for all these computer game genres are, in contrast to classical board games, that the rules are defined by the code of the software. The source code defines most of the game factors: position, resources, space etc. and thereby among other elements gives the option of a single player mode. The games are based on a digital representation of some kind of virtual scenario, which some times involves narrative elements, and the interaction is graphical through the computer. The digital representation also makes it possible to add sound effects. Computer games often use a large amount of sound, sound effects and music in order to support the action and narrative elements. Another feature central for Arcade, Strategy, Adventure and Edutainment is the progression in levels and scenarios, thus creating a dynamic game continuously introducing new challenges.

A genre that needs a more detailed discussion is the Computer board game, because it defines a type of game where a mixture of computer technology and classical board games is the goal. The genre is a classification of computer games that adapts ordinary board games into the computer environment, often transforming a social board game into a single player experience with a computer. This is different from BB3D where an augmentation of a traditional board game preserving the social interaction among the players is the objective.

The most obvious advantage of a computerized chess game is the adaptation of the single player mode; you are able to play against the computer and decide the skills of your opponent. You can change the skills of the computer player and thereby use the game as training ground for yourself. The representation of the games is a graphical interface which enables shifting representations. The game can additionally use points as a reward for winning, and thus incorporate the high score element known form the Arcade genre. A consequence of the graphical interface is the nature of interaction. By transforming a board game into a computer game the social interaction may disappear and the player interaction becomes more indirect through mouse, keyboard and screen. In BB3D we focus on maintaining both the social interaction and the direct manipulation of the pieces.

Combining board games and computer game features

The feature of interest in relation to classical board games is the social setting with two (or more) players sitting in front of each other, where the game interaction is based on the physical and direct interaction with pieces on the board. Here the social conditions between the players are essential while playing. During a classical board game you might be able to read the reactions from your opponent's face while playing. This is a kind of information, which is not available when playing against a computer or through a computer.

The prospect of augmenting classical board games is the addition of reward and level features from computer games. An augmentation of a classical board game could, e.g. result in the possibility to change level or change scenario by shifting between different graphical outputs. The games may also contain narrative or/and animation elements combined with sound effects to extend the experience of the board games. Adding reward systems e.g. based on points on a high score list, supplemented with level change, an augmented board game would contain many of the desirable features from computer games. But it will still be based on interaction through physical tangible pieces with the opponent on the other side of the board. BattleBoard 3D is a board game with additional computer game qualities; the next section describes the concept.

BATTLEBOARD 3D – THE CONCEPT AND DESIGN ISSUES

In this section we describe the game concept, followed by the design issues in developing the game, and finally a discussion of the implementation of BB3D.

The Setup

Two different versions of hardware setup have been tested so far. The first has a fixed camera recording the board and both players were using the same monitor to follow the game. The second setup used a prototype goggle. It was made by attaching a Web camera in front of the eyes of a VR helmet. One player used the goggles and the other player had a monitor which showed the picture from the fixed camera, see Figure 2. However it is currently necessary to have the application running on two different PCs in order to make two persons play each using a camera. This calls for synchronization of the player's PCs.

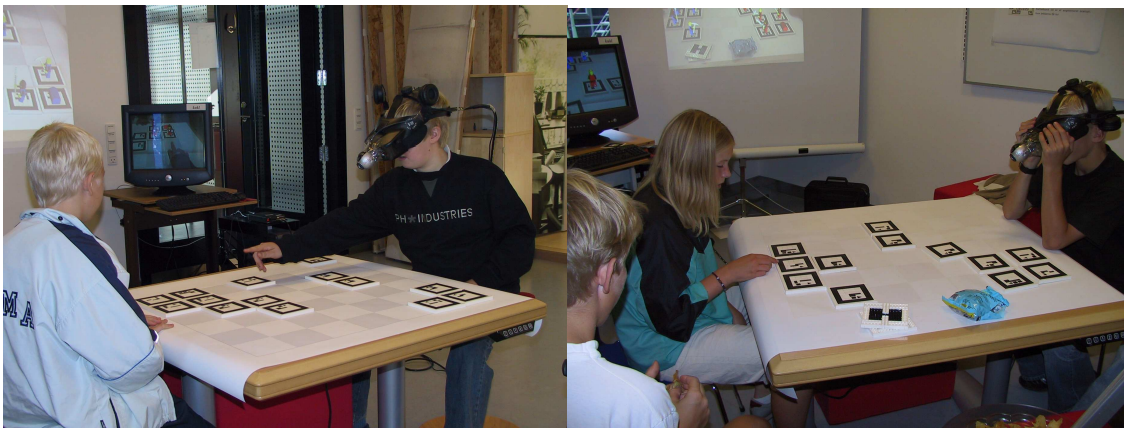


Figure 2. The BattleBoard 3D setup with pairs of children playing the game.

We have chosen the ARToolkit (Billinghurst et al., 2001) as our platform. ARToolkit makes it possible to use a webcam to detect a marker, which is a black square that contains a graphical symbol. The marker can be associated with 3D graphics placed on top of the marker when detected.

When the user application is running, ARToolkit is provided with a stream of pictures from a camera connected to a PC. The picture is analyzed to find black square frames (markers) and the information inside the frame is extracted. The position, relative to the camera in (x,y,z) coordinates, and number of each recognized marker is returned and the appropriate animation can be drawn on each marker. Finally the grabbed frame with the animations projected on it is returned and can be shown on the PC monitor or the display in a pair of goggles.

We saw an opportunity of letting the markers in ARToolkit work as pieces in a board game.

Design Issues for AR board games

In the following we will discuss the most central design issues for augmented board games and the rationale for the design choices we made for BB3D. BattleBoard 3D is a mixture of the genres *Agôn* and *Alea* and the Ludological conditions in connection with the game is described in the following.

Rules.

The first issue in designing BB3D was creating an objective of the game and a set of rules. Rules in a game should make the objective in the game difficult to achieve, but still feasible. Our aim was to make the rules simple but still exciting enough for children to play the game.

The primary goal was to create an objective in the game. In BB3D the objective is to capture the opponent's chest. The chest plays a similar role as the flag in Stratego. Like in Chess and Stratego we wanted to differentiate the pieces in strength and freedom of movement. Thus we created three levels of pieces increasing from level one to three in strength and freedom of move.

The decisive factor in the game is a calculation in the application, which determines the winner of the battle, depending on differences in levels of pieces. Explicitly this means that the piece with the highest level has the greatest chance of winning and if equal it's fifty-fifty. The game is played on a six times seven squared board and each player starts with seven pieces, one level three, two level two, three level one and a chest. The pieces are placed freely in the first two rows. Each piece can move a square per level, level one in each direction, level two and three horizontal and vertical, and the chest can't move.

The rules of BB3D were created for the purpose of implementing a prototype of our vision, but it is possible to make rules that fit any imaginable setup. A conclusion drawn upon the design of rules in BB3D is that augmented reality games should take advantage of features from both classical and computer games.

Physical pieces.

The physical pieces are essential in board games, and thus in AR board games. Our use of the ARToolkit causes some restrictions on the kind of pieces we could invent. They had to be flat and square with a thick edge. With that in mind we made two generations of pieces. First we made transparent plastic pieces with graphics on, and later we made the pieces out of LEGO bricks in order to make the triggering of a game more tactile, and to prepare the game for being extensible with new pieces constructed by children.

In the current design the physical pieces of each team are different. One team has information about the piece in the left side the other in the right side. Our experiences drawn from the first plastic pieces were that:

1. Every type of pieces should have unique patterns.
2. Patterns must be asymmetric to enable camera recognition and direction of the virtual model.
3. Simplicity in patterns is needed for human recognition.

From this perspective we started the process of building the physical pieces with LEGO bricks.

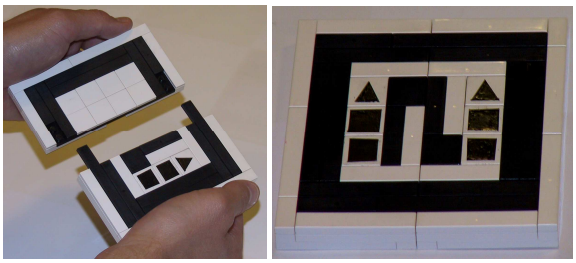


Figure 4 "Breaking a piece and an assembled piece"

Triggering a Battle.

Battles are central in board games like Chess and Stratego, but they are very quickly accomplished by the players resolving the battle in their heads and removing the loosing piece from the board. In an AR game it is possible to make the actual battle into an entertaining process of itself, like the battles in Computer games, thus the physical move of pieces should trigger the virtual battle. The idea behind triggering a battle is combining information from each team and hereby creating a new unique pattern called a battle marker. We chose to trigger battles by breaking pieces into halves and assemble them into a new combined battle marker, see Figure 4. However other choices were considered.

The issue of triggering a battle between pieces has revealed different choices. Effort was put into creating an efficient way to trigger a battle. In order to preserve the way a piece is moved in original board games, the first generation of pieces were printed on transparent slides. The slides were put on top of each other to create the new unique pattern and thereby triggering a battle. However, it was difficult to place the slides accurately on each other. Furthermore we couldn't avoid the reflection from the non printed areas of the slides. The sum of these problems made the virtual model very flickering and unstable in recognition of patterns.

Another approach in triggering a battle is utilizing the information that ARToolkit obtains of the pieces' position in space. Hence, it is possible to calculate the distance between pieces, and if they are within a specific proximity of each other, the battle is triggered. We haven't tried this approach on children, but we observe that breaking apart and assembling pieces is a disturbance to the rhythm of the game, and the proximity approach is something we will consider as future work.

Encoding of the pieces.

When physical pieces are linked to a virtual counter part, this link needs to be coded into the physical pieces. The first pieces with LEGO bricks were translations of the first generation of transparent plastic pieces. The pieces were sandblasted to avoid reflection and the first generation of squares and triangles were painted on the bricks. This resulted in a stable piece that didn't make the virtual model blink.

The reasons for using abstract patterns like triangles and squares on the pieces and not figurative depictions of the virtual pieces, which would make the human recognition easier, are the loss of flexibility. If you use figurative depictions of your virtual models, the possibility of using the same pieces for other board games and virtual models is lost. Additionally, it would be difficult to achieve sufficient differentiate of the depictions in camera recognition. Building new unique patterns with LEGO bricks would also be hard with depictions.

Because of the board game nature, the players inevitably have to touch the pieces when moving in the game. We realized that when the outer black square of the piece was broken e.g. by touch, the virtual model disappeared. ARToolkit is very sensitive in recognizing patterns and to compensate for it, we therefore decided to make an extra white square around the pieces. This made the pieces bigger, but it was a compromise, necessary in order to make the players touch the pieces. Additionally the players were able to pick up the pieces for a closer inspection. The final pieces are shown in figure 5.

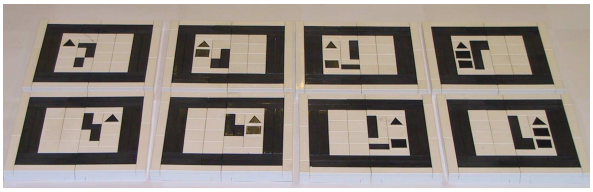


Figure 5 "All the final pieces"

Digital Pieces.

What makes AR board games special is that the physical pieces have a "live" alter ego in the computing environment. In our game the digital pieces could be any 3D model/animation the game designer or in the future the player wishes to use. This is one of the features that distinguish AR board games from traditional board games and add the entertaining and interactive element from computer games. The tailoring of scenario and possible replacement of the 3D models associated with the piece give the opportunity to play a new game with new digital pieces every time you play, or you may be rewarded with a new set of digital pieces if a certain level in the game has been won. Furthermore the battles don't have to be the same every time the game is played. It could be possible in the future for players to exchange, update or trade digital pieces over the internet. These features enable the aspects of surprise and challenges which are hard to achieve in a traditional static board game.

Implementation of BB3D

In our implementation of BB3D a battle marker is explicitly associated with two different animations, one for each outcome of the battle. When a battle marker is detected, a virtual dice is thrown to determine the outcome of the battle. After this the battle marker is attached to an animation for 10 seconds, where the winner defeats the looser. It is possible to have more than one of each marker presented at the board. If we decide that each warrior in the future should have its own energy level, it is necessary to have a unique marker for each fighter because each piece should only be associated with its own condition/state.

QUALITATIVE EXPERIMENTS WITH BATTLEBOARD3D

BB3D is meant as a game appealing to children. To achieve this, the game should be designed with input from children (Druin, 1998; Bruchman & Bandlow, 2002). The game was developed from the visions described earlier, and then we undertook a number of experiments involving children. This is not a quantitative evaluation, but rather exploratory experiments aimed at setting the direction for future development of this type of game. The experiments with BB3D were undertaken in two phases; first, experiments among ourselves and secondly, experiments involving children.

We conducted the children experiments with a group of 13 year old boys and girls playing the game, discussing the design and the perspectives of the BB3D. The goals of the experiments were to reveal issues concerning the game design in general, design of the physical pieces, the use of goggles versus screen display, and future evolvement. In both experiments the setup with goggles was used.

Playing the game

The first thing to remember when developing a game of any sort is that the developers should enjoy to play themselves, as Alan Dix (2003) indicates, if you don't enjoy your game neither will the user.

The first test of the game helped us find out whether the augmented game would be worth playing at all? We made a tournament table, such that several individuals could play a tournament against each others. We played tournaments among ourselves and colleagues, and it turned out that the game was rather amusing, although it had some weaknesses (e.g. unhandy goggles, breaking pieces disturbing the game flow).

The second round of experiments was more focused – how would a group of children respond to BB3D? Our prospective users were young teenagers who are brought up with online computer games, mobile phone games, console games etc. We therefore expected them to have high expectations for the game. After an introduction to the game, the children started playing a tournament. The children were fascinated by the fact that they could experience an animation from all angles and even pick up a piece and investigate the animated character from all sides, when using the goggles.

We also observed that the children brought the attitudes from board games into the game, e.g. they attacked the opponent piece by pushing the attacked piece from its current position as a gesture for the attack. We see this gesture as an accentuation of the interaction in classical board games. When striking in a chess game, the winning piece pushes the loosing piece in a similar way.

However, the use of goggles also caused some problems for the children. They found it difficult to navigate due to the distance between their eyes and the webcam recording the eye sight. This basically means that the player's arms seem to be 25 centimeters too short when using the prototype goggle. This resulted in fumbling when moving and breaking the pieces.

Furthermore, they found that breaking pieces apart was a suspense building element while waiting for the outcome of the battle, but at the same time they felt it as an interruption of the game flow.

The use of a screen to monitor the game gave the children a better over all view, but resulted in the children shifting focus between the screen and the actual board. An advantage when using the screen is the social interaction between the players. Hereby it is possible to look directly at the opponent and look him in the eyes, which is more difficult when wearing a pair of goggles. It gives the feeling of presence of the opponent, which characterizes the social interaction from traditional board games.

Reactions from the Children

After the tournament, we interviewed the children about central issues concerning the BB3D prototype. In general, the children found the mixed game entertaining and amusing.

The children also suggested some alternatives and additional elements to improve the game. Though problems prototype goggle was unhandy, they found it to be a key attraction to be able to see the 3D warriors from their

own personal perspective. Thus smaller goggles[2] are mandatory for the game. The children were found the battles between the virtual pieces exciting and adding value to the game compared to traditional board games, where a battle just is a move of a piece and a removal of the beaten piece. However, after a few games most animations had been repeated several times, and the children found that a greater variation of the animations was needed in order to maintain the interest for BB3D.

It was remarkable that the children's request for larger variation of animations showed that they perceived the game like a computer game raising their expectations for variations beyond the board game genre. Children would never expect variation in traditional board games, since all pieces in board games are static. When children meet a hybrid between computer games and board games, like BattleBoard3D, they meet the game with experiences and expectations from both types of games. An action adopted from ordinary board games is players slamming one piece into another when attacking, even though slamming does not trigger the battle per se.

The children suggested the possibility of choosing between different kinds of virtual pieces, which could have different behaviors, motivations and visual appearances. They saw potentials in building their own physical pieces in LEGO and hereby defining their own unique markers. Another opportunity would be the possibility of personalizing the board game building customized animations with some kind of 3D tool. They also suggested some kind of network by which they would be able to exchange their own homemade animations.

Some of the children thought that a competition on high score and a ranking system would add an extra dimension to the game. Furthermore some of the children meant that change of strength of the warriors according to the outcome of a battle would be useful. In other words a warrior should become more experienced if he won a battle and maybe get greater odds in the next battle. It was also suggested that if the winning warrior was wounded he should become weaker in the next battle.

The use of single player mode was discussed and some of the children found that the ability to play against the computer was a missing feature in the current prototype. A suggestion for implementing single player mode was to let the application show the moves of the computer in the goggles, as on a chess computer, where the moves of the computer player are shown on the board. Another approach would be a complete virtual opponent without physical appearance.

Reflections on the experiments

The experiments supported our initial objective of making a mixed game which maintained more social interaction than computer games and had more variation than traditional board games. Thus the experiments supported the hypotheses that the concept was feasible and entertaining. However, we got several requests for improvements to be made mainly to the technical aspect of the augmented board game. It will be necessary to utilize a different kind of goggle to minimize the fumbling when moving pieces. Another method for executing battles between warriors should be introduced, for instance moving the physical pieces towards each other, with the virtual characters facing each other, would be an easier and more intuitive way of triggering a battle. Even though we wished to stimulate the social interaction around the board game, there was a request to also support single player mode and to support several optional sets of digital warrior characters.

An adult test person suggested that the players should be able to have direct influence on the outcome of the battle e.g. a type of joystick which makes the player able to manipulate the warrior directly. This aspect would also be interesting to investigate further.

RELATED WORK

Only little research has addressed AR board gaming, specifically with ARToolkit. The foremost projects to our knowledge are the ones done by ARPEGROUP (2004). In comparison only a few more games have been created with other AR technologies. Mah Jongg and other Personal Interaction Panel (PIP) related games (Szalavári et al., 1998) are some of these. The difference in technology will not be the issue of this section.

This section compares BB3D to the above mentioned games, with respect to game domain. ARPEGROUP who have made four games, Augmented Wizard Duel, Cannon Fodder, AR Pong and Spheres of influence (only as concept, not implemented), all using the same setup, is familiar with BB3D. The difference is the use of sound which our game doesn't use. In addition to ARPEGROUP, we have a setup where the camera is attached to a VR helmet, which creates a personal view of the board.

One of the major dissimilarities is the way in which markers are used as pieces. ARPEGROUP uses different markers for every action and figures in their games, we instead created our pieces for combination. In

[2] We have performed initial tests with a small AR goggle, where the camera is only a few centimeters from the players' eyes.

Augmented Wizard Duel a dice with markers is thrown to make the action of casting different spells against each other. Cannon Fodder's action is triggered by moving your hand from the canon marker and thereby firing it against the goblins, who tries to reach the castle. Pong uses the positions of markers to determine if the ball is hit by the paddles or is out. Spheres of influence are supposed to use positions of markers to determine if creatures should fight, which is the same technique that we want to explore in the future.

Mah Jongg and other PIP related games are using yet another kind of approach. To interact with and create the actions in the games, a PIP, consisting of a pen and a panel is used. The PIP can be used for moving dices, cards, tiles etc. in games. This is different from BB3D, where players physically move the pieces in the game. The rationale behind PIP is the use of privacy in some games, which allows players only to view their own cards, tiles, etc. and only with a HMD. BB3D wasn't developed for privacy, and the use of public physical pieces doesn't support the privacy aspect, because of the human readable information on them. However, the use of multiple HMD's, which is envisioned for BB3D, may be used to show information which is private to the individual players.

Finally, Lundgren (2002) presents examples of augmented board games, where the augmentation consists of embedded sensors in the board pieces, thus keeping the game almost completely in the physical world without the computer game elements that BB3D mixes into the board game.

CONCLUSIONS

We have outlined the characteristics of board games and computer games and the prospects of combining these in a new type of AR games. We have described the design of the BattleBoard 3D Augmented Reality board game prototype utilizing LEGO for the physical and digital pieces. We demonstrated our concept by the implementation of BattleBoard 3D and described two rounds of experiments with the board game prototype. The experiments revealed both strengths and weaknesses of the concept, the interaction techniques, and the hardware setup, as well as ideas and issues for future AR game research. BattleBoard 3D has been described in relation to games in general as a mixture of the genres *Agôn* and *Alea* and the Ludological conditions in connection with our prototype has been outlined.

Basically, our experiments show that the children found the combinations of some of the social interaction around classical board games and dynamic computer games exiting and amusing. Our current design of the physical pieces has both some weak and some powerful features. The patterns on the pieces are designed to be human readable, and the pieces are designed to be picked up and moved freely on the board. However, the need for breaking up the pieces to trigger a battle breaks the game flow, but is also a suspense giving element. Further research in the area of how to trigger battles is necessary to find out which method is the most suitable. The pieces in BattleBoard 3D are larger than in ordinary board games, a wish for smaller pieces was put forward by the children. This aspect should be developed further. There are also a number of computer game features that could be integrated in BB3D, like levels, single player mode, and energy state for the digital figures.

The children expressed that the use of goggles resulted in a unique experience of the game, although a request for smaller goggles was put forward. The only way a player is given the illusion of playing with live pieces is when the goggles are used. A pair of video-see-through glasses would be more ideal than our prototype since they would make it possible to look right into the eyes of your opponent, which gives the physical presence that characterizes board games. Such glasses can be provided since several light weight AR glasses exists, but they need to be produced in larger volumes in order to get the prices on a level where kids can afford to buy.

Finally, our experiments have shown promise in this new type of AR board game, and we plan to make further experiments and systematic evaluations in order to develop the next generation of the game. We strongly believe that it will be possible to develop AR board games that can become light weight products for Playstation, Xbox, Game Cubes and the like, with cheap goggles and web cams just like the new gesture based EyeToy game for Playstation that has become feasible to sell at a low price, realistic for children to buy.

ACKNOWLEDGEMENTS

The project has been supported by ISIS Katrinebjerg, Center for Interactive Spaces. In the process of developing BB3D, we also received assistance from a number of people. Thanks to the ARToolkit Mailing List, CAVI at Aarhus University in general and LEGO Company for the supply of bricks. Finally, we wish to thank Andreas Lykke Olesen and Peter Skaarup for their assistance in animation and programming.

REFERENCES

ARPEGROUP, Augmented Reality Gaming Table, 2004, http://www.etc.cmu.edu/projects/ar/argt.html

Azuma R.T., “A Survey of Augmented Reality”. In Presence: Teleoperators and Virtual Environments 6, 4 (August 1997), 355-385.

Billinghurst, M., Kato, H. & Poupyrev, I. (2001). “The MagicBook - Moving Seamlessly between Reality and Virtuality”. Computer Graphics and Applications, 21(3), 2-4.

Billinghurst, M., Kato, H., Kiyokawa, K., Belcher, D., Poupyrev, I. (2002) “Experiments with Face to Face Collaborative AR Interfaces”. Virtual Reality Journal, Vol 4, No. 2, 2002.

Bruckman, Amy and Alisa Bandlow. "HCI For Kids." In Handbook of Human-Computer Interaction. Edited by Julie Jacko and Andrew Sears. NJ: Lawrence Erlbaum Associates, 2002.

Caillois, Roger, “Man, Play and Games”, New York 1961, pp. 12-26.

Dix, Allan, “Being Playful: Learning from Children” In Proceedings of the 2003 conference on Interaction Design and Children. Preston England July 2003.

Druin, Allison, The Design of Children's Technology; How We Design, What We Design and Why, Morgan Kaufmann Publishers, 1998. ISBN: 155860507X

Gardener, Dan (1994) “Draw Porker” Mineapolis

Grannel-Schaap, Karen A. & McDonald III, James E. (1996/97), “Thunderbay MUSH”.

Grant, Valerie & Parker, T. Grey (1996), “Barbie Fashion Designer”, Mattel Media.

Kolling, Bobby (1996) “Apple Tetris” Sharesoft.

Konzack, L., “Softwaregenrer” Aarhus University Press, 1999.

Konzack, L.: Computer Game Criticism: A Method for Computer Game Analysis. In Computer Games and Digital Cultures Conference Proceedings, Tampere Finland 2002, pp. 89-100.

Lundgren, S. (2002) Joining Bits and Pieces - How to make Entirely New Board Games using Embedded Computer Technology. MSc Thesis in Interaction Design. Department of Computing Science. IT UNIVERSITY OF GÖTEBORG, Göteborg, Sweden 2002

Mackay, W. Augmented Reality: Linking real and virtual worlds. A new paradigm for interacting with computers. In: Proceedings of AVI’98, ACM Conference on Advanced Visual Interfaces, ACM Press, New York, 1998.

Marshall, Paul & Sara Price & Yvonne Rogers, “Conceptualising tangibles to support learning” In Proceedings of the 2003 conference on Interaction Design and Children. Preston England July 2003.

Meier, Sid (1996) “Sid Meier´s Civilization, II” MicroProse.

P. Milgram & F.A. Kishino, “Taxonomy of Mixed Reality Visual Displays,” Institute of Electronics, Information, and Communication Engineers Trans. Information and Systems (IECE special issue on networked reality), vol. E77-D, no. 12, 1994, pp.1321-1329.

Piekarski, Wayne & Bruce Thomas: ARQuake, “The Outdoor Augmented Reality Gaming System”. In: Communications of the ACM Vol. 45 No. I January 2002, pp. 36-38.

Rekimoto, J. & Saitoh, M. Augmented Surfaces: A spatially Continuous Work Space for Hybrid Computing Environments. In: Proc. of CHI'99 Conference on Human Factors in Computing Systems (Pittsburgh, Pennsylvania USA) ACM/SIGCHI, New York, NY, 1999, pp. 378-385

Szalavári, Z., Eckstein, E. & Gervautz, M., “Collaborative Gaming in Augmented Reality.” In: Proceedings of VRST'98, pp.195-204, Taipei, Taiwan, November2-5,1998, http://www.cg.tuwien.ac.at/research/vr/gaming/

Zagal, J.P., Nussbaum, M., Rosas, R. A Model to Support the Design of Multiplayer Games, In Presence, Vol.9, No. 5, October 2000, 448-462

COPYRIGHT

[Troels L. Andersen, Sune Kristensen, Bjørn W. Nielsen, and Kaj Grønbæk] © 2004. The authors assign to OZCHI and educational and non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to OZCHI to publish this document in full in the Conference Papers and Proceedings. Those documents may be published on the World Wide Web, CD-ROM, in printed form, and on mirror sites on the World Wide Web. Any other usage is prohibited without the express permission of the authors.