Mobility and Social Interaction as Core Gameplay Elements in Multi-Player Augmented Reality

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ABSTRACT

In this paper, we present an Augmented Reality game that strongly exploits mobility and social interaction between players as core gameplay elements. We have implemented this game on handheld devices and conducted a qualitative user study, investigating the level of mobility and social involvement of players. We discuss the results from this user study, describing the problems experienced by players and how we tackled them.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems – *Artificial, augmented, and virtual realities*; K.8.0 [**Personal Computing**]: General – *Games*;

General Terms

Design, Experimentation, Human Factors.

Keywords

Augmented Reality Games, Mobility, Handheld Augmented Reality.

1. INTRODUCTION

An advantage of playing games in the real world is that navigation in the environment and communication between players are performed in natural ways. The interface with the real world is intuitive and well known to players of any age, sex and technical expertise. People get involved socially and physically with the same mechanics they regularly use also in non-gaming contexts. On the other hand, computer games have the advantage of allowing sophisticated, animated content, which is sometimes fantastic or even impossible in the real world. Computer games can challenge players independently from the availability of human opponents. A computer is also an unbiased game controller that can enforce complex game rules and verify multiplayer game actions.

DIMEA'08, September 10–12, 2008, Athens, Greece.

A natural strength of Augmented Reality (AR) games is that real-world interaction and computer-controlled content can be mixed seamlessly. This is especially true when unobtrusive devices are adopted, as in the case of handheld game consoles and mobile phones. Players can easily combine device-mediated and real-world interaction paradigms in a single homogeneous game experience.

We present a team-based competitive AR game that requires players to physically explore the game environment and to communicate face-to-face with other players. We implemented the game on lightweight handheld game devices and conducted an explorative user study with a group of technically as well as non-technically educated players. We believe that the results from this study can be of help for researchers working on AR in mobility contexts as well as for companies working on commercial AR games.

This paper is structured as follows: section 2 compares our project to related work and presents our motivation for the project; section 3 presents the game, its gameplay and what is necessary to set up the game in a new environment; section 4 gives details on the implementation; section 5 presents first empirical observations on the gameplay; section 6 introduces a qualitative user study that we carried out and results which derived from it. Finally we draw conclusions and discuss future work.

2. MOTIVATION AND RELATED WORK

The proposed game draws inspiration from various categories of computer-based and computer-less gaming; we try to mix elements from various categories into an original gameplay suitable for casual players.

A core element of this game is *mobility*: players are forced to physically explore the environment looking for game locations. Mobility elements can already be found in non-computer games such as "hide and seek" and treasure hunts. Another gameplay element that is shared with treasure hunts is the spatial search for hidden items: in our game, virtual cows are scattered around the real environment and players are required to look for them. Most AR games on mobile devices, such as AR Tennis [6], the Invisible Train [11] or the work done by Rohs [8], are portable rather than mobile. They exploit mobility only around a central game board, instead of integrating the real environment into the game. Some marker-based edutainment games, such as the Eduventure [5] and MARQ [9], strongly foster explorative mobility of the players inside the environment. In the educational games the locations have usually the role of disconnected checkpoints that make up a storyline for the players, rather than being interconnected and part of an evolving collaborative and competitive environment.

Several location-based *non-AR* games have already introduced physical player mobility as a key gameplay element. “Treasure” [1], “Pirates!” [3] and “Can You See Me Now?” [2] are examples of such games. In these games, the game space is usually presented to players as on-device virtual maps. Physical actions in the real environment affect these virtual maps and must be mentally mapped by players onto the real environment. Epidemic menace [7] employs AR for players who are wearing a backpack setup, while players using smartphones can only access a virtual view. An advantage of AR is that the representation of the virtual game world can be presented to players as part of the real world through a *world-registered 3D game interface*. The device registers the real world in 3D with the computer-generated visualizations of the game state into a single, merged view. Even more, marker tracking provides update rates of ~20Hz, which are about an order of magnitude larger than via GPS and hence allow much faster gameplay. It is important to point out that we do not consider our game to be location-based: albeit players are required to interact with specific locations, such locations do not have any real-world meaning. Instead they are given meaning by the augmentation, i.e., there is no real stable or pasture in our physical game environment.

Another core element of the game is *social interaction*: Players are all physically in the same environment equipped only with an unobtrusive handheld device. Social mechanics of real-world games can be preserved, e.g. face-to-face communication and pointing at objects. Some computer games already exploit this, e.g., party games based on the Sony EyeToy or on the Nintendo Wii (e.g. Nintendo’s Mario Party). Some AR games such as ARQuake [10] and Human PacMan [4] exploit physical movement of players. However, their use of heavyweight backpack AR setups plus the low number of available devices severely affects mobility and social interaction.

A final core element of the game is that it is a *computer game*, which makes it possible to introduce autonomous game entities and to enforce computer-managed game mechanics. Furthermore, every player’s device can provide a personalized view of the game state. E.g., information can be hidden, so that players are encouraged to explore.

3. DESCRIPTION OF THE GAME

We designed a team-based game in which players have to physically explore the real environment, look for some hidden items, and collect them into a safe location belonging to their team. The interaction with the game is mediated by an AR interface, but real-world social mechanics between players are preserved. Our game can be quickly deployed in a new environment, as explained at the end of this section.

3.1 Game concept and gameplay

The game characters are cows and UFOs. The virtual game space is composed by a set of locations, divided into a number of pastures and exactly two stables. All game locations are outfitted with fiducial markers. Two game locations with an open line of sight in physical reality are also connected in the game world with a footpath for cows. 3D arrows are used in the AR interface as navigational clues to indicate footpaths between locations.

Figure 1. The interaction between the players and the virtual game space is mediated by an AR interface.

Two opposing teams, each composed by an arbitrary number of players, are required to play the game. Every team is uniquely assigned one of the two stables. The goal of players is to save cows by bringing them into their stable. The team that saves more cows wins the game. The interaction between players and the virtual game space is mediated by an AR interface presented on the handheld devices (Figure 1). Every player is assigned one device and is forced to physically move in the real environment to reach specific fiducial markers. Whenever a fiducial marker is visible to a player’s device, the AR interface becomes available and the player can interact with the items at that game location. Players can only use two simple game actions: order one of the cows to move from its current location to a directly connected one; or order an UFO to shoot and kill all cows at the current location. Stables are the only safe spots in the game, where cows cannot be shot or moved. When ordering a cow to move, players select the arrow corresponding to the target location using the cursor buttons: One press of the PLAY button then orders the cow to move to the selected location. Whenever a cow is ordered to move, it instantly disappears and reappears on the target location. UFOs are ordered to shoot by a single press of the STOP button. When UFOs are ordered to shoot the cows, an animation of a laser beam is visualized for a few seconds. The complete user interface is presented in detail in Figure 2.

At the beginning of the game cows and UFOs are randomly scattered on the pastures in the virtual game space. Players must physically explore the environment searching for fiducial markers, where cows and UFOs are located. A 2D map providing an overview of the real game environment is available on the handheld devices and also indicates the position of all pastures and stables.

Single-player mechanics are dictated by the game. Players must physically move to a real-world location, interact with the contents which are on that location, physically move to another location, etc. In contrast, multi-player mechanics cannot be fully predicted because they strongly depend on communication between the players, on their experience with the game and their familiarity with the other players. Possible team strategies can be either constructive (e.g., sending “scouts” to look for cows in distant locations) or destructive (e.g., shooting all cows in the surroundings of the stable belonging to the other team). More than one player can simultaneously interact with one location, and precedence is given to the actions that are triggered first.

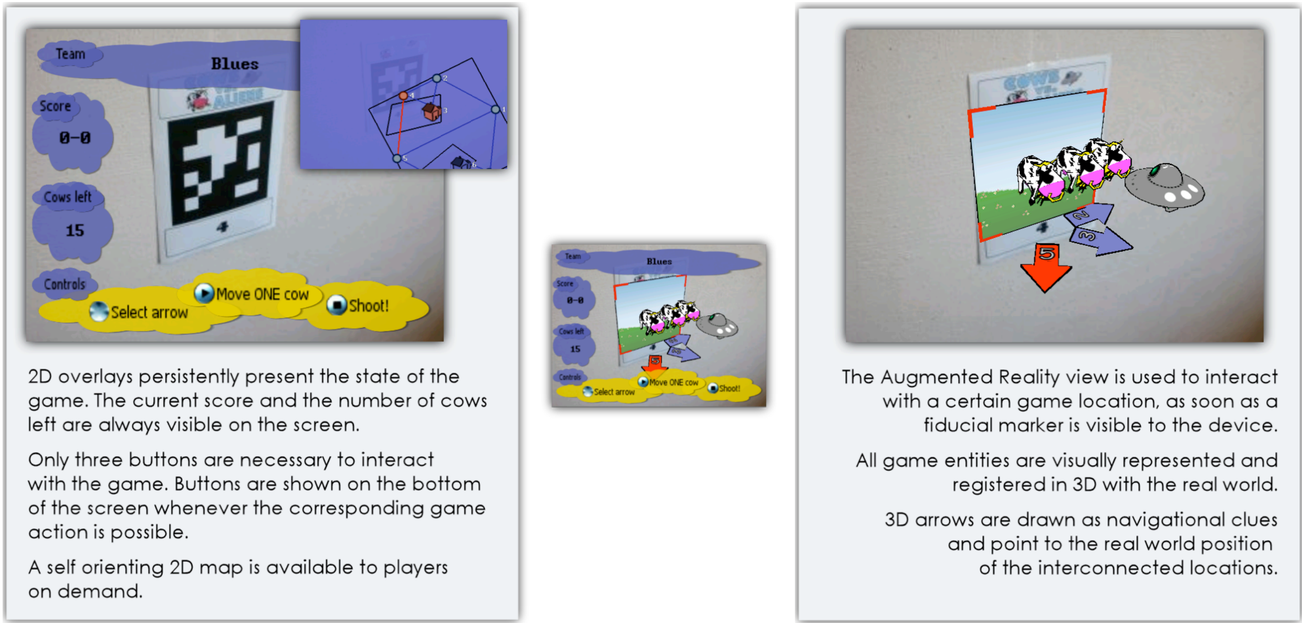


Figure 2. The User Interface combines real-world elements and virtual computer-generated contents in a single merged view.

3.2 Setting up the game

Fast deployment and easy adaptability to new environments are necessary requirements for a game to be deployable outside research environments. Setting up our game in a new environment is performed quickly as described in the following paragraphs.

The real environment where the game takes place must be outfitted with a number of fiducial markers positioned on walls. The fiducial markers naturally form a graph of locations connected by line-of-sight relationships. A coarse 2D map of the walls in the game environment is manually drawn on a desktop computer (see Figure 3). Next the positions of the fiducial markers are specified, by graphically placing them on the 2D map that was just created. After this setup phase, players can immediately start the game. The 2D map of the environment can then be used for any number of games. Whenever players decide to shuffle the markers or to change their position, they can update marker positions accordingly on the digital map.

The following section will describe our implementation of the game, consisting of a desktop tool for offline editing and run-time game management and of a handheld run-time application.

4. IMPLEMENTATION

The game has been implemented with a client-server architecture composed of a central server machine running Windows and several handheld client devices. The handheld devices are Gizmondo game consoles, robust and low cost devices running Windows CE. They are 3D hardware accelerated, have built-in Bluetooth support, but lack support for WiFi.

At the present time the game is limited to seven players because this is the maximum number of devices that can concurrently join a single Bluetooth network. Another constraint is the range of Bluetooth connections of around 10 meters, depending also on the power of transmitters and on the amount of occlusion in the environment. Since the game is typically deployed in a few adjacent rooms, these limitations are not considered relevant in our specific case. The game is a native Windows CE application, therefore it can also run on PDAs and smartphones based on the same operating system and possibly equipped with WiFi.

The central server maintains the complete game state in a database. As in most other multiplayer games, certain game events occur independently of the players, while others are triggered by concurrent actions of multiple players. A server-side game controller application has been implemented to handle these events that cannot rely on a specific single client. This controller also runs on the server machine and is persistently connected to the database. Changes in the database trigger callbacks in the game controller, which internally updates the overall game state and finally shares the new state with the clients by writing the results back to the database. Both client-side and server-side modifications incurring on the database are consistently and automatically visible by every game client. Another purpose of the game controller is to work as a console that allows configuring the game before startup: game sessions can be suspended and restarted. All game state transitions are visualized in the console (shown in Figure 3). Finally, the map of the environment and the location of all markers are also specified using this tool.

The client application is based on the Studierstube ES framework and all client-server communication is handled using Muddleware. The game uses Studierstube Tracker for marker tracking. The overall update rate on the client devices is between 15 and 20 frames per second, depending on the 3D content visible. More details on the underlying software framework have been presented in [9].

5. FIRST PLAYABILITY OBSERVATIONS

Within related work (presented in section 2) there is no previous game that includes all the gameplay elements that are present in our game. We could not fully rely on previous experience and we therefore adopted an iterative design approach. We showcased the game at a social event at our institute. Roughly 60-70 visitors

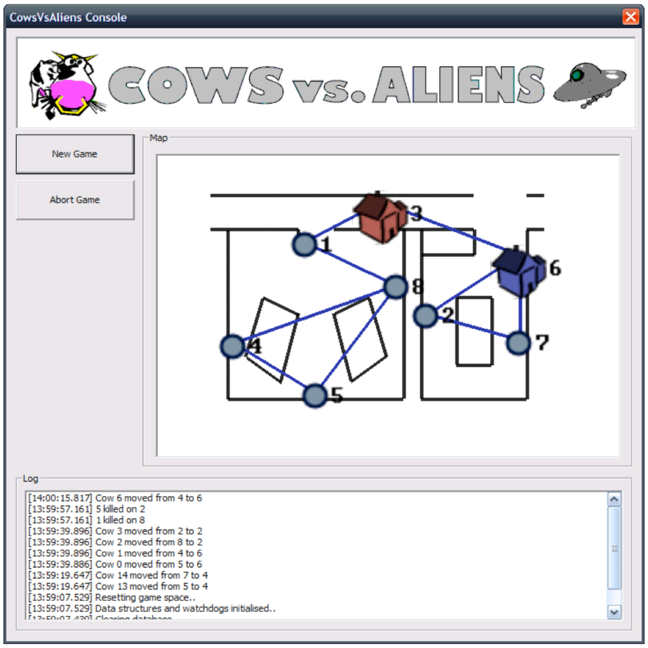


Figure 3. Screenshot of the server-side console, also showing a map for a sample game setup.

enjoyed the game. Even though a large majority of the visitors were students (with a natural interest in technology), some players had little to no experience with computer games and related technology. The visitors came randomly to our demo setup (composed of a single room equipped with 8 fiducial markers) during a time interval of more than 2 hours; more than 50 games were played with group size varying from 2 to 6 players. During this event we observed players and drew first conclusions on the playability of the game.

We noticed that players were easily and quickly able to cope with the mapping between the virtual game space and the real environment, maybe also because of the reduced size of the environment. Some players had to be taught on the necessity of keeping the fiducial marker always in the field of view of the device in order to have an augmented view of the world. We tackled this issue in subsequent versions of the game by drawing a viewfinder frame as in regular photo cameras. Nearly all players were able to effectively interact with the game. They understood the mechanics of moving the cows into the direction of choice and walking to the corresponding location in the real environment. Some players were even running and pushing to get to the game locations before players of the other team. We also noticed that players exploited face-to-face communication for giving commands, teasing opponents, commenting the outcomes of a game and the new tactics they had adopted.

We noticed that players often had a blurred understanding of the game state and the available actions they could invoke. E.g., some players were trying to collect cows with their devices in order to drop them onto another location, not understanding that cows were moving autonomously. In general, our first test runs revealed that many players had problems understanding some of the game rules, mostly because they were too complex. Fast paced gameplay and fast turnaround of players during demo sessions adversely affected concentration. Hence, it was not possible to give detailed introductions to the game rules to all players. We also noticed that UFOs were hardly ever used, probably because the focus was put first on moving cows. Counter tactics based on UFOs are more subtle and were only developed by players who had gained some experience.

We decided to refine the gameplay to better support casual gamers and to focus on physical mobility and in-team communication. One old rule required players to lock the cows and the UFOs with a specific button press, before they could be given orders. The unlocking mechanism was based on timeouts. Many players found this locking mechanism not intuitive therefore we removed it. We simplified the gameplay so that players need only three buttons to interact with the game. In the old user interface all the seven buttons were used and some were triggering different actions depending on the context: This complexity was found to hinder playability. The gameplay we presented in section 3.1 is the final refined version.

6. USER STUDY

We conducted a qualitative user study on the refined version of the game to discover further playability issues and to investigate the level of mobility and social involvement of players during a gaming session. Two groups of six players each, with varying technical expertise and different interest in games, were asked to play our game and to express their opinions through questionnaires and focus groups. The user study and its results are presented in this section.

6.1 Hypotheses

Our hypotheses for the study were:

- The UI interface is clear to the players. They are able to quickly understand who is winning and which actions they can perform in the game.
- Players are able to understand the mapping between virtual game locations and real world fiducial markers, how they are connected and how cows move among these.
- Handheld devices do not limit players' ability to navigate the environment. Also, the devices do not limit social interaction, allowing face-to-face communication between players.
- Players enjoy the game and interact socially with other players developing team tactics after they have gained experience.

6.2 Participants

The participants of our user study were two groups of young adults with mixed interest on computer games and mixed knowledge on AR systems. None of them had seen or played the game before. Each group was composed of six players, for a total of twelve subjects (6 male and 6 female) with an average age of 26. Users had varying gaming background. While some of them never play computer games, others play at least once a week. On average subjects played only once every few months. No "hardcore gamers" (playing every day) were invited for the study. Few users had previous experience with AR systems, while the other players had seen an AR application only once or never. The distribution of the population of users is shown in Table 1. All players within a group knew each other beforehand and had already played some non-computer games together. Only a half of the players had also played computer games together.

A pilot evaluation was conducted on a group of four users with good expertise on AR and resulted into minor changes to the user interface and to one section of the questionnaire.

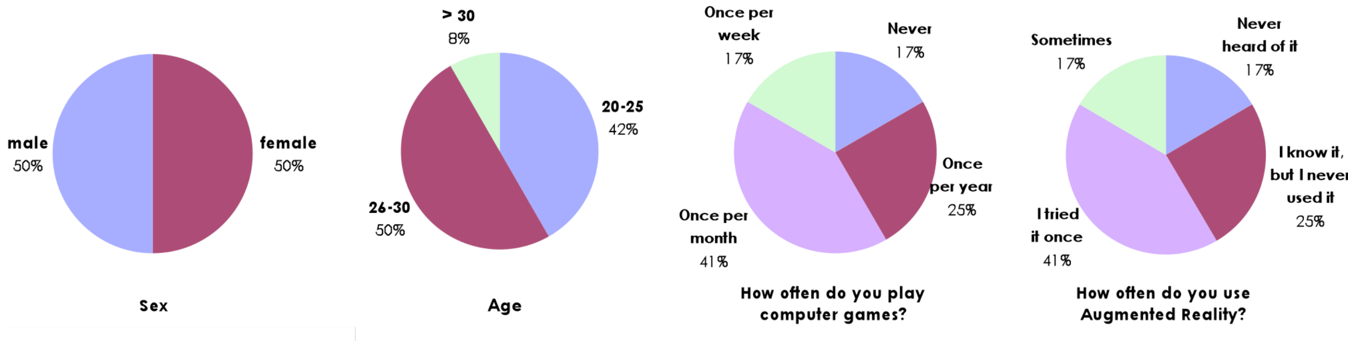


Table 1. Distribution of sex, age and technical expertise over the population of users who participated in our evaluation.

6.3 Procedure

The same procedure was adopted for both groups: Users were divided in two teams of three players each. The two teams were asked to compete in the game for a total time of ~25 minutes, which resulted to 10-15 games. Two physical playgrounds had been prepared: a single-room setup and a setup composed of two rooms connected by a corridor. Both setups used a total of eight fiducial markers, but the arrangement of them was completely different. All users played both setups, each approximately for half of the duration of the study.

Before the study all users were asked to fill in a short questionnaire to measure subject variables like age, sex, how often users played computer games, how experienced they were with AR systems and if they had previous gaming experiences with other members from the group. The results of this questionnaire were used to split into separate teams those players who had previous game experiences with each other or had good technical expertise.

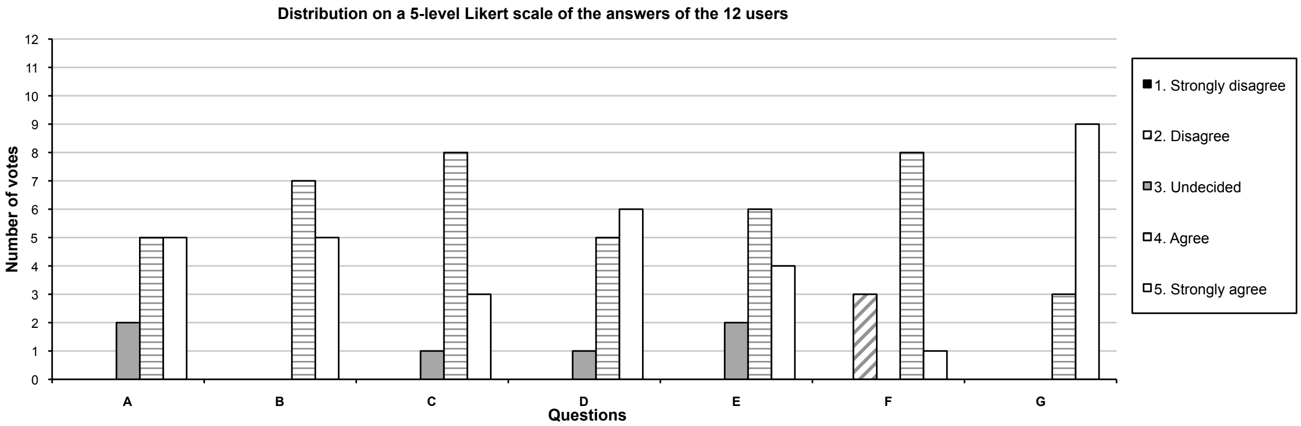
In both the setups the study was carried out with the same procedure: users were first handed their devices and asked to explore the environment for two minutes. After the orientation phase users were asked to play some games, while the evaluators were observing the occurrences of particular user behaviors without interfering: stress and frustration because of problems with the device-mediated interaction, confusion while trying to navigate the real environment and to map it with the virtual game space, as well as cooperation and face-to-face communication between players. Except for a few empty batteries at the beginning of our study, no technical problems happened.

After playing both setups all users were asked to fill in an anonymous questionnaire based on a 5-point Likert scale, expressing their agreement on general claims on the playability, the mapping between real environment and game space, the communication between players and within the team, the experience gained after some games. Table 2 presents the questions and the distribution of the answers. We then invited all six players to a focus group, structured on questions that were following the statements in the questionnaire. In the focus groups we left more room for the subjects to express their own opinions and to tell in-game anecdotes, investigating also more in detail the achieved levels of social interaction between players. We used the results of the questionnaires to confirm that most players shared the opinions collected during the focus groups rather than being influenced by a single strong personality.

6.4 Results

A main concern of most players was related to the high speed of the game: The maximum duration of a game was in fact less than three minutes, with an average game duration of around one

Figure 4. Social and physical interaction during a game session. Left: players talk to each other to figure out who saved the last cows. Right: one player slows down an opponent by covering the camera of his device with one hand.



	average	median	variance	deviation	error
A. The more games you play the easier it is to play.	4.250	4.000	0.568	0.754	0.218
B. The more games you play the more complex team tactics you can develop.	4.417	4.000	0.265	0.515	0.149
C. After you have played some games, it is easy to play in different rooms.	4.167	4.000	0.333	0.577	0.167
D. Using the game device did not cause fatigue.	4.417	4.500	0.447	0.669	0.193
E. It was always clear where to search for cows in the real environment.	4.167	4.000	0.515	0.718	0.207
F. The location where cows were moving to was always clear.	3.583	4.000	0.992	0.996	0.288
G. The game is entertaining.	4.750	5.000	0.205	0.452	0.131

Table 2. Distributions on a 5-level Likert scale of the answers of the 12 users who participated to our user study.

minute. Many users complained about the impossibility of developing in-game tactics because of the *"hectic"* pace of the game. One user pointed out: *"you have a chance to create a tactic before the game, but if the tactic fails you don't have the chance to adjust it"*. It was noticeable during in-game observation that, after some games, players were starting to develop team strategies, instructing each other on what to do; this was noticed to happen mostly between games but rarely during a game. The answers taken from the questionnaires support our hypothesis that players gain experience during the games and start developing team tactics (see Table 2, questions A-C); from the interviews it emerged that these tactics are limited to pre-game tactics.

Another common consideration on the game concerned the size of the environment where it should be played. Most of the players agreed that one or two rooms are not big enough for this game. The necessity for a big environment was partially related to the necessity of slowing down the game. This was also suggested as a possibility to create massive multiplayer games in a strongly spatially distributed setup, which would allow more complex and structured team tactics.

One player mentioned the idea of arranging evening gaming sessions with friends: *"if one has a flat that is big enough"*. *"And if you don't start smashing everything down"*, as pointed out another player. The physical presence of players introduced in fact physical interaction mechanics (i.e. pushing each other, running faster than the others) which raised some concerns about safety from our side. When asked, users claimed that the pushing was always friendly and just for fun. We consider these behaviors comparable to those normally happening during sports or other mobility-based games (e.g. capture the flag).

Another interesting physical interaction between players arose from the limitations of the optical marker tracking: we noticed that some players were trying to block the line-of-sight from the devices of opponents to the markers (Figure 4), thus limiting their interactions with the game world. The good tracking range (the 15-centimeter markers could be detected from a distance of ~4 meters) was exploited by some players for sneaking behind the shoulders of opponents in order to "steal" their cows. This was also seen as a drawback for small setups since it was easy to move cows between locations without physically approaching each marker; one player in fact claimed: *"I just realized that the device could see the markers from the middle of the room so I didn't move anymore"*.

All players agreed that using the device was not a source of fatigue (probably also due to the short duration of games), as confirmed by the questionnaire (see Table 2, questions D). Players also agreed on the fact that it was always clear how to hold the device in front of a fiducial marker in order to interact with the game world. Some players claimed that the 3-button interaction was simple enough so that they were able to use the device without looking at the buttons, after they had played for a while. Several players stated that the simple user interface allowed them to easily navigate the real environment while using the device at the same time.

All players agreed that it was always clear to them where to look for cows in the real world. For almost all players it was also always easy to understand, how the virtual game space and the markers in the real environment were corresponding (see Table 2, questions E-F). Users expressed that it was no problem to understand how cows were moving in the real environment, as long as they were the only person at a location. Yet, some players pointed out that they got confused when competing with another player at the same game location. In general the high pace of the game was seen as problem: in the rush of a game it was not always clear who had moved cows and where they had gone. Some players proposed to introduce smooth animations of cows moving from and to locations, as a visual feedback for changes in the state of the game; this was also suggested as a mean for slowing down the pace of the game.

Problems of understanding the global state of the game were raised both from focus groups and from questionnaires. Players blamed mainly the in-game stress for this problem, rather than the user interface. One player claimed: *"I just concentrated on how to move the cows… when somebody lost I then looked at the score"*.

In general all players found the game fun to play, which is supported by strong agreement on the entertainment factor of the game, coming from the questionnaire (see Table 2, question G). Players seem convinced that slowing down the pace of the game, enlarging the gaming environment and introducing multi-sensorial feedback (e.g. sound and vibration) could be a good path for making the game state clearer. It would also support more subtle and complex tactics and in general an even more enjoyable game experience.

7. CONCLUSIONS AND FUTURE WORK

The user study showed a general enthusiasm for our game, which was enjoyed by young adults with varying interest in gaming. A very simple user interface, with persistent on-screen information and interaction mechanisms based on only three buttons, resulted in an enjoyable player experience. Even though a lot of effort had gone into an evolutionary design process, the user interface was still not considered simple enough and users asked for multi-sensorial feedback and 3D animations instead of simple color coding.

We adopted several navigational clues: a purely virtual map, 3D AR arrows and printed markers on the walls. With the help of these clues, players were able to understand the correspondences between the virtual game space and the real environment in which they were moving. Although this is a demanding task, it was performed easily by the players even under conditions of stress due to physical pushing and fast movement in the real environment. The physical interaction between players was also supported by the robust, compact and lightweight design of the handheld devices. Still, some players asked for wrist straps to prevent accidental dropping of devices.

It is important to stress that the players did not have the feeling that they were trying something experimental. They did not complain about any technical problems or limitations, except for some network slowdowns due to insufficient Bluetooth coverage. The subjects felt secure with the presented technology up to the point that some of them proposed the idea of further gaming sessions with friends in their flat, which confirms the robustness of the software as well as hardware platform.

We have observed, also from the comments of the users, that the fast pace of the game strongly prevents in-game social interaction, restricting the interaction to between-game discussions. We plan to comply with the general request for slower game mechanics, in order to favor continuous interaction between players. We would like to achieve this by introducing smooth 3D animations: In the next version that we plan to implement, cows will require several seconds to move from one location to another. We believe that this will allow subtler team mechanics. This would also increase the value of AR, because cows moving from one location to another could be visualized directly within the environment. Technological progress in the field of marker-less tracking will strongly help this next development of the game. We plan to increase the player awareness of the game state by implementing multi-sensorial feedback and by improving the informative value of the overview map. Experiments with much larger environments and bigger teams are also considered for future work. Adopting long-range robust communication technologies is an obvious necessity for such experiments.

8. ACKNOWLEDGEMENTS

This project was sponsored by the Austrian Science Fund FWF (Y193, W1209-N15) and the EU (FP6-2004-IST-4-27571). We would like to thank Albert Walzer for creating the 3D content of the game and Roberto Ranon for his valuable comments.

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