Tangible Augmented Reality for Computer Games

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Abstract

In this paper we attempt to demonstrate that Tangible Augmented Reality is a highly effective environment for certain types of multiplayer computer games. We show the usefulness of this user interaction paradigm through both theoretical argumentation and presentation of our prototype system. During the development of this system we evaluated several variants of the interaction techniques necessary for the game, and we discuss the relative merits of some of them in this paper.

Keywords: Augmented Reality, Tangible User Interface, 3D-Interaction, User Interface Design

1 Introduction

Generally, a user interface consists of a screen, a keyboard and a mouse. This type of interaction evolved in the last decades and meanwhile belongs to the standard configuration of a computer system. The widespread use of this interface led to the assumption that it already represents the optimal way of communication between user and computer. However, this is not the case. On the contrary, it is a very abstract way of interaction. Compared to the natural environment of a person, there are two major disadvantages:

- Objects cannot be manipulated in a direct way – one has to use a mouse or a keyboard.

- The presentation of the objects is not three-dimensional, but two-dimensional.

Tangible Augmented Reality (see Section 2.2) tries to eliminate the gap between the interaction with a natural environment and the interaction with a computer system. Especially computer games benefit from a three-dimensional presentation and a direct way of interaction because this increases the realism of a game and simplifies its controls. Therefore, we developed a Tangible User Interface (see Section 2.1) for an existing Augmented Reality System (see Section 4.1). Several types of games and controls have been implemented to investigate the possibilities of a Tangible User Interface in the field of computer games.

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2 Background

2.1 Tangible User Interface

A Tangible User Interface (TUI) [4] uses objects of the natural environment as an interface to the computer. Thus, the real world and the virtual world are combined. This intuitive way of interaction simplifies the communication between man and machine, especially for unpractised users. Moreover, a TUI can be used by several persons because it is not restricted to one screen or one keyboard. Figure 1 illustrates the major difference betweeen a GUI and a TUI.
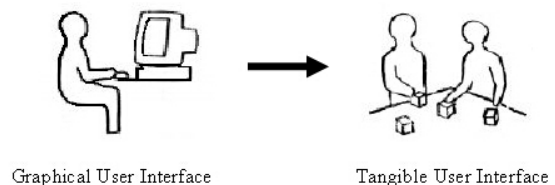

Graphical User Interface   Tangible User Interface

Figure 1: *A Tangible User Interface uses objects of the natural environment as an interface to the computer.*

2.2 Tangible Augmented Reality

Tangible Augmented Reality (TAR) [1] is a combination of an Augmented Reality System and a Tangible User Interface. A user interacts with virtual objects by manipulating real objects. There is no need to learn one of the common 3D interaction techniques [6] because the interaction with virtual objects is done in the same way as the interaction with real objects. A TAR-System therefore offers three-dimensional viewing of virtual objects and a very intuitive way of interaction with these objects. The most important attributes of a TAR-System:

- The user manipulates real objects to interact with virtual objects.

- Both hands can be used for interaction because the user does not have to hold a device.

- Several objects can be manipulated at once.

- Collaboration between several users is possible.

3 Related Work

3.1 Tiles

Tiles [1] is a TAR-System that has been developed for rapid prototyping for aircraft instrument panels. The TUI consist of a metal whiteboard, a book and several magnetic tiles containing virtual objects. The whiteboard acts as a working area where the tiles can be arranged in the desired order. The book serves as a menu with different virtual instrument models on each page. The tiles are divided into two types: data tiles and operator tiles. Data tiles contain virtual objects whereas operator tiles are used to perform basic operations such as deletion, copying and a help function. The system allows the collaboration of several users who sit in front of the whiteboard, rearranging tiles. See-through Headmounted Displays are used to present the virtual objects.

3.2 Shared Space

Shared Space [2] is a simple TAR-game developed for complete novices. Multiple users stand across a table with cards lying on it. Each user wears a see-through Headmounted Display with a video camera attached for optical tracking of the cards. The goal of the game is to collaboratively find the matching virtual models and place related models side by side. If this is done in the right way the pair of models is replaced by an animation of the two objects.

4 Tangible Augmented Reality for Computer Games

4.1 The Studierstube

The Studierstube [7, 9] is the Augmented Reality System that has been used to develop the tangible user interface presented in this paper. The standard input device is the Personal Interaction Panel (PIP) [8] – an implementation of the Pen & Tablet technique. For our purpose it was replaced by the interface described in Section 4.3. See-through HMDs are used as standard output devices.

4.2 ARToolKit

We used ARToolKit [3] for the optical tracking of objects of our Tangible User Interface. It is a cheap marker-based optical tracking system that can easily be integrated into an existing Augmented Reality System. For the tracking of the markers a video camera or a webcam is needed. A marker is a square piece of paper and can be produced using a normal printer. It has to contain a black frame with a unique symbol in it. Each marker has to be visible during the whole tracking process. However, if a user holds a marker in his or her hands it is often covered by thumbs or fingers. People or materials can also be located

between the markers and the camera and can therefore occlude markers as well.

4.3 The Tangible User Interface

The design goals of the new interface have been the following:

- Marker-based optical tracking is used for the manipulation of the virtual objects.

- The markers should always be visible to the camera.

- The users should not be restricted in their freedom of movement and action.

To avoid the occlusion of markers, it has to be guaranteed that persons or materials cannot get between the camera and the markers. This can be achieved by the use of a glass table. The camera is mounted underneath the table. The markers lie on the top of the table - upside down, so that they can be tracked by the camera. The virtual objects are displayed on the top of the corresponding markers. The users wear see-through HMDs to view the virtual objects.

The table top is made of plexiglass framed by wood and mounted on legs. The height of the legs can be altered so that players can stand or sit around the table. Figure 2 shows the table and the camera.
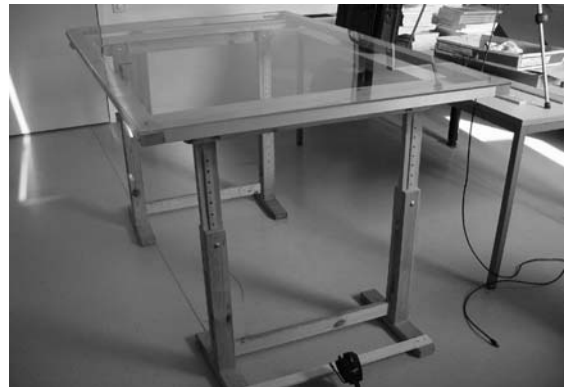

Figure 2: *The glass table.*

4.4 The Tabletop Game

The Tabletop Game is implemented as a two player game. The players sit or stand around the glass table. Each player has a catapult and a fixed number of balloons. The goal of the game is to shoot the opponent's balloons. The player who first manages to shoot all the opponent's balloons wins the game.

A player can control position and orientation of the catapult but not of the balloons. Additionally, each player owns a windmill which provides him with the capability to move the balloons out of the line of fire of the opponent.

The mode of interaction is that the balloons are drifting with the wind that is produced by the windmill.

To investigate which type of game suits best for a TAR system, various types of the game and the controls have been implemented.

4.5   Various Types of the Game

The user can choose between one of the following types of the game:

- action game

- strategy game

In the action game mode both players can move their pieces at the same time. The effects of a move can be seen immediately. The main focus of this mode are speed, a good aim and good spatial orientation capabilities of the players. Figure 3 shows a typical scene of the action game. The white squares on the top of the table are the markers. The pieces on the left side belong to the first player, whereas the ones on the right side belong to the second player. The score is displayed above the field. Every destroyed enemy balloon counts one point. However, hitting one of your own balloon entails a pentaly of one point.
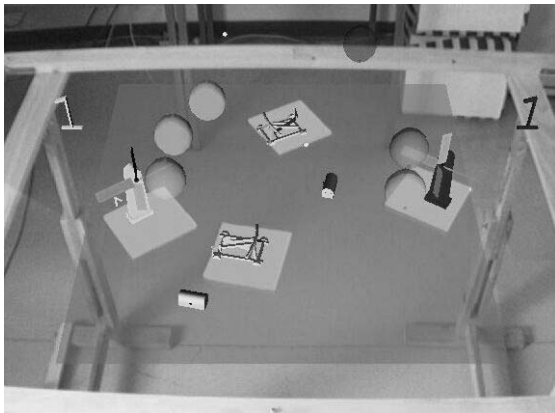

Figure 3: *The action game.*

The strategy game is turn based, which means that a player has the possibility to try out several moves before she/he actually chooses one.

In the contrary to the action game, the strategy game can be divided into different phases:

- The markers are placed in their corresponding starting positions.

- The players take turns in making their moves.

- The pieces are animated between two moves.

- The game ends after one player has lost all balloons.

To make sure that each player has equal chances, the markers are placed in predefined starting positions at the beginning of the game. After that, the first player starts the game by making her/his first move. However, the movement of the pieces is restricted. The distance between the starting point and the new position must not exceed a certain maximum value. Therefore, each piece is surrounded by a green circle that marks the region of movement. If a player moves a piece out of its corresponding region, the circle turns red and the virtual model stops to move. Only when the marker is brought back into the circle again, the player can continue her/his move. If a player has finished her/his move, she/he clicks a button that is located at the border of the field. There is an additional marker called menu marker that activates the button when it is moved onto it. Thereafter, the pieces are animated, that is the catapult fires off a bullet and the balloons that are located in the reach of a windmill drift with its wind. If a balloon is hit, it loses its air, falls off to the ground and afterwards disappears. Now, it is the second players turn.

The action game and the strategy game differ from their rules but not from the goal of the game. In the strategy game the player who first shoots all the enemy balloons wins the game, too.

4.6   Various Types of Control

The catapults and the windmills are controlled through markers, which means that moving a marker on the table results in a movement of the corresponding catapult or windmill. Since each of these pieces has a seperate marker, this system differs from conventional computer games where several pieces are controlled through a single input device and where the player has to specify the piece she/he likes to control. In the tabletop game this specification is simply done through choosing a marker.

However, it is not always desired to map the movement of a marker directly to the corresponding piece. Therefore, the Tabletop Game provides two different ways to change the position and the direction of a piece:

- Moving a marker immediately causes an alteration of the position and orientation of the corresponding piece.

- While a marker is being moved, the piece follows the marker with a constant speed.

An immediate change of the position of a piece is easy to comprehend, since a direct correlation between the marker and the corresponding piece can be recognized. However, it may in some cases seem unrealistic, if a marker, and thus the corresponding piece, is moved with high speed, since real catapults are not capable of moving at such high speeds, either. Therefore, another way to control the pieces has been implemented, where the piece follows its controlling marker with constant speed until it reaches its position.

4.7 Additional Features

To increase the degree of difficulty of the game it is possible to display a terrain. Then, it is more difficult to target at the balloons because the height of the catapult is not constant anymore. The terrain is randomly generated at the beginning of a game using the Diamond Square Algorithm [5]. During the game, the height value generated by the tracking software is replaced by the height of the terrain. Thus, the virtual objects are moving on the top of the terrain as shown in Figure 4.
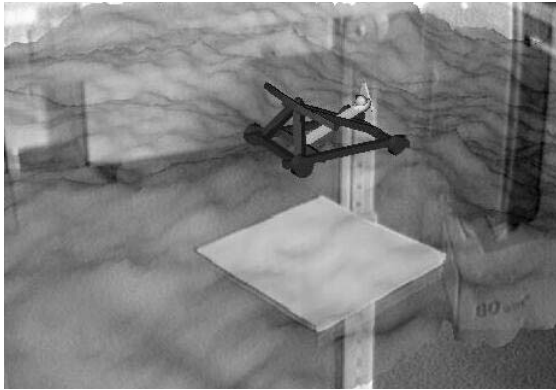

Figure 4: *The virtual objects are moving on the top of the terrain.*

To ease the positioning of the windmills, the air flow that is produced by a windmill can be visualized. This is realized using arrows that indicate both the space influenced by the windmills and the direction of the air flow. Depending on the size of the affected space, more or less arrows are displayed. One row consists of three arrows - one at each border and one in the middle of the row. The arrows are all placed at the same height because in the Tabletop Game the height of the air flow makes no difference to the movement of a balloon. If two regions of influence overlap, the direction of the air flow changes, as shown in Figure 5.

5 Results

Using our Tangible User Interface evokes the following advantages:

- Virtual objects become tangible.

- It is a wireless interaction.

- The amount of available input devices increases.

To interact with our system, a user does not have to learn an interaction technique because she/he can interact with the virtual world in the same way she/he does with a natural environment. The selection and manipulation of virtual objects happens through markers.
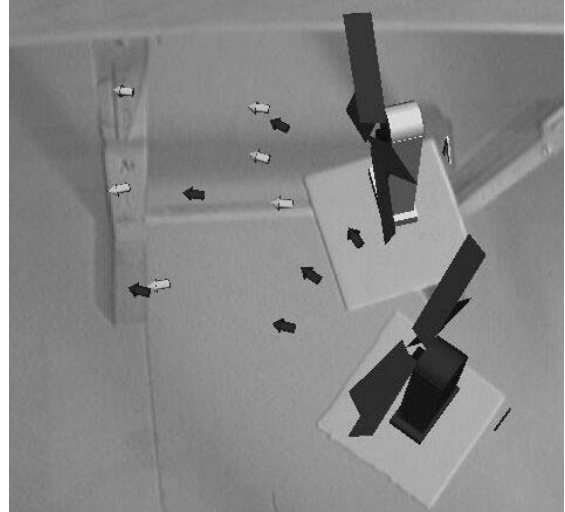

Figure 5: *If two regions of influence overlap, the direction of the air flow changes.*

Another advantage of the Tabletop Game is the absence of wires. Many VR input devices have to be physically connected to the computer system. For example, the usage of a Pen & Tablet technique leads to two additional wires between the user and the system. Thus, the freedom of movement of the user is quite limited. We avoided additional wires by using marker-based optical tracking.

Neither the operating system nor the number of ports limit the number of possible input devices. Just the number of markers that can be tracked by the camera is an upper bound to the number of input devices. If we want to increase the number of players in the Tabletop Game we just have to add an according number of markers. There is no need to buy and install additional input devices.

The use of a glass table solves the problem of occlusion of markers. Therefore, people and materials cannot unintentionally get between the camera and the markers.

The Tabletop Game Interface is suitable to both action games and strategy games. The special way of interaction allows the player to manipulate her/his pieces directly. This is the same way of interaction that she/he knows from real-world board games. Therefore, the Tabletop Game Interface represents a more intuitive and more natural way of interaction than conventional user interfaces. This supports the speed of the action game. However, the main focus of the strategy game lies on having a good overview over the pieces, so that the next move can be planned. Using the Tabletop Game Interface, the player can see the whole field and she/he can move around to see the pieces from different sides. She/He does not have to interact with a fixed view point like she/he would have to in a conventional computer game.

Virtual objects are displayed either on the position of the marker or follow the marker in a constant speed. The second technique has been implemented to simulate the realistic behaviour of a heavy object. During the evaluation

we found out that users prefer the first technique because the second one contradicts the fact that pieces are usually very light and can be moved very quickly. As long as the virtual objects are part of a game the first technique should be preferred.

The display of the terrain demonstrates the unconventional capabilities of a TAR-System. In a board game, it is usually not possible to include the third dimension into the movement of pieces. Playing chess, one can only move her/his pieces in two dimensions. In a TAR-System, this restriction does not exist.

6 Conclusions

The aim of the Tabletop Game Interface is to evoke the impression of playing with a real-world board game while enjoying the possiblities of a computer game. Thus, it unifies the advantages of computer games and board games. Computer games impress the player with appealing animations, whereas board games provide an easy way of interaction. The Tabletop Game offers both, animations and an intuitive way of interaction. Moreover, it is possible to include the third dimension in a natural way as can be seen through the interaction with the terrain and the balloons.

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