Magic Wako - User Interaction in a Projector-based Augmented Reality Game

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***Abstract*—Augmented reality games offer a new level of player immersion into a game world. Upcoming pico projectors, which, are integrated into mobile phones, provide a way to make augmented reality games commonly available. This technologies aided by techniques such as image processing can serve as a way to creatively enhance existing games. Unless there is first work done on how projector based augmented reality applications in general can be controlled by users, investigation on augmented reality games control is little available. We present a projector based augmented reality game which, can be controlled by either real world or virtual world interaction methods. In two qualitative user explorations, one using a low-level prototype and one using a first implementation of the game, we identify user-related and technological challenges regarding interaction with the augmented reality game.**

Keywords-Projector phone; interaction metaphor; augmented reality; mixed reality game.

I. Introduction

Embedding pico projectors in mobile phones provides a complete new way to display information and new interaction techniques. The first integrated projector phones are now available. Such devices overcome the inherent display limitations of mobile phones, since larger displays can now be dynamically created on rather any surface. Projector phones also open up the range of possible interactions, since the user can interact with the mobile phone while looking at a projection or even using a combination of the mobile phone's screen and the projection in parallel. For users, this methodology eliminates the necessity to switch the focus of attention between the real object and the augmented video version on the mobile device's screen, which was inherent to the See-Through-Approach [1] for creating augmented reality applications.

Recently, using the physical world as playing field is becoming popular since this increases user immersion into the game world. Examples are dance mats or Kinect [2]. But, in these cases, the actual game world is still behind the screen. Hence, using augmented reality to play games in the real world can further increase gamer immersion.

This paper researches the interaction of users with augmented reality games focussing on a congruent setup of the mobile phone's camera and projector, were the field of view and the field of projection overlap [3]. This particular spatial configuration enables the user to interact directly with the projection without any limitations, and is open for the different interaction concepts described by Rukzio and Holleis [4]. However, the congruent setup also introduces problems, since the projected image can have an immediate effect on the processing of the captured camera image. Furthermore, the physical *process* of pressing a button on the device causes that it is shaken. This affects other input modalities which, are considering position and orientation.

This paper elaborates on how users perceive the interrelation of output and input channel and how they utilize this interrelation for their interaction in a game. For being able to observe players' behavior we created an augmented reality game called *Magic Wako*. This game offers an easy to learn gameplay associated with the necessity for fast, direct and gesture-rich interactions with a mobile projector.

The remainder of this paper is organized as follows. After discussing related work in the succeeding section, we present findings of our first low-level prototype. After that, we describe experiences from the first system implementation and insights from further user tests. Finally, we conclude and give an outlook on future work.

II. Related Work

The *Wear UR World* prototype [5] shows many everyday life examples how a portable projector can be used to augment everyday objects with additional information. As input modality, a wearable camera captures four-finger-gestures. For easier recognition, the fingers are equipped with colored markers. Baldauf and Froehlich [6] use the same gesture recognition approach but process the image on the mobile phone to make the setup more portable.

There have already been some games implemented which, use mobile projectors to interact with the real world. Pinhanez et al. [7] use the *Everywhere Display Projector* to let people build puzzle pictures with colored sweets. The projection shows gamers where to put a sweet on the ground. So, in this case the projector is controlling the user. In *Co-GAME*, gamers project paths onto any ground were a real-world robot toy is being guided towards a defined destination [8]. The robot is equipped with infrared LEDs that are tracked by a camera and steered by a server component. So, gamers control the game by moving themselves and the projector in their hands. *Flashlight jigsaw* is a multiplayer

puzzle game made for handheld projectors [9]. Players have to search on a public display for pieces of the puzzle by exploratively pointing at the screen with handheld controllers. Interaction metaphors are similar to *Magic Wako* without considering real-world objects. In *LittleProjected-Planet*, Loechtefeld et al. [10] use paintings on real world walls to let projected balls run through it. In this case, the individual manipulation of the real world creates the game world. At the same time, the information where the projector is pointing at is steering the game.

The presented game approaches do not deeply investigate user acceptance of the new input modality. However, Kawsar et al. [11] let users compare the See-Through approach against mobile projection in three different non-gaming applications. Afterwards, they conduct a qualitative study concerning user acceptance and usability issues of the interaction techniques. While preferring the larger displays of the projection approach, users figure out a higher degree of cognitive load due to more demanding hand-eye coordination. Blasko et al. [12] identify the stabilization of the projected image as the major challenge in the interaction with their wrist-worn projection display. However, we expect to find out additional challenges of projector phone interaction in the gaming context, as this requires faster and more spontaneous movements.

III. Prototype Design

We set up a first low-level prototype in order to find out about user requirements how to control the game.

A. Gameplay

MagicWako explores a new paradigm of gaming that aims at recreating the popular arcade game *Whac-A-Mole* [13]. In the original game, little moles (called Wakos) come out randomly from holes in the game board and disappear again after a short time. The aim of the game is to hit as many Wakos as possible. In our augmented reality version of that game, players have to search for the Wako with a mobile projector in their hand. The game is played on a physical playing field on which, virtual Wakos are projected by the mobile projector. As the field of projection does not cover the complete playing field, gamers have to explore the playing field to search for Wakos by moving the projector. Magic Wako differs from games presented in the previous work since firstly the projector is controlled by the user and not the other way around, and secondly only the controller and the gameboard are required to play the game; there is no need for additional world objects. Additionally, the game board can be replaces with any available object due to the initial color calibration.

B. Setup

We conducted a qualitative exploration with a low-level prototype and seven users. The aim was to find out how users would intuitively control the game with the new interaction paradigm and how they feel about it. Secondly, we wanted to know what problems might be caused by the interaction using a handheld projector for controlling an augmented reality game. The low-level prototype does not reflect the final system real conditions such as light, since the main focus is on the interaction of the control and not on the gameplay. This will be analyzed using the final implementation.

We presented the users the physical playing field, which, contained nine different colored circles made of cloth and explained the gaming rules. All users were familiar with computer games but never played an augmented reality game or used a mobile projector before. Users had to use an electric torch to simulate the projector (cf. Figure 1). Additionally, they were equipped with a mobile touchscreen phone, which, presented only one big button labeled ”Hit”. We simulated the Wakos by randomly putting and removing a card with an *X* on the circles of the playing field. Without further information on how the actual control of the game should work, for example how to hit the *X*, we asked users to play the game. We observed the players and afterwards interviewed them about their feeling of the game.

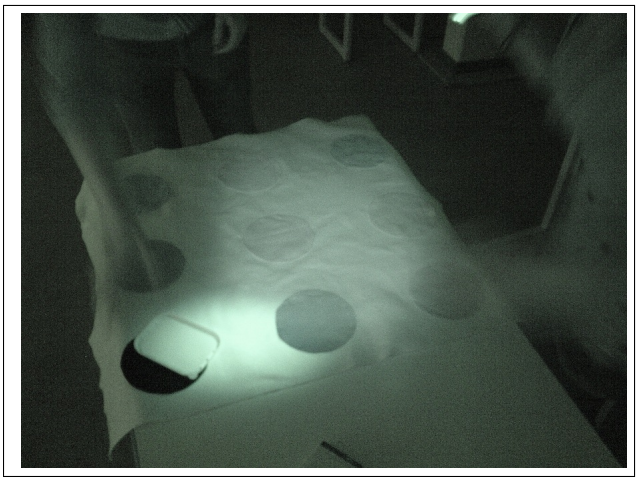

Figure 1. Torch setup for user evaluation

C. Ergonomic Findings

In the interviews, all users claimed the game to be comfortable and found the movement with the torch natural. Hence, we assume that the general approach of controlling the game is intuitive and was appropriate to be implemented in the first prototype. It seems that searching for objects with light in the real world is intuitively easy to understand even for users without experience in augmented reality games.

Three out of seven users pressed the ”Hit” button for hitting the *X*. Another three users tried to hit the physical *X* with their hand. One person wanted to use the torch itself to hit the *X*. The game setup is meant to be a hybrid between

a virtual and a physical game. According to that, it seems that about half of the users favored a virtual way of hitting - pressing a button. The other half of the users intuitively preferred to act in the physical world, be it with the hand or the torch itself. Hence, we plan to offer both possibilities to hit the Wako in the prototype and compare again.

We observed that especially users who tried to hit the *X* with their hand experienced problems to keep the torchlight steady while touching a far away circle with the other hand. When users leaned towards the playing field to hit a projected *X*, they tended to move the torch thus pointing to another position where the *X* was not present. Hitting the *X* by pressing the button relieved the users from leaning towards the playing field. Nevertheless, in an integrated projector phone setup, also the physical process of pressing the button would make the device shake a bit so that the current aim of the projection would change in that moment.

Five users pointed out the problem of carrying around the playing field and asked to be able to play the game on arbitrary surfaces.

IV. System

In this section, we present our first prototype of *Magic-Wako*. It was used as to find out more user-related and technical challenges for augmented reality games control. For this, we conducted another preliminary user study.

A. Decisions

As mentioned in the previous section, two possibilities to hit the Wako were taken into account. We implemented a first version of *Magic Wako* where the user had to hit the smartphone's screen laying in front of her. Providing this modality, the input process promises to have fewer impact on the position of the projector. Furthermore it is also possible to hold the Smartphone in the other hand and do the hitting with the thumb like it would be done with a button. However, we will add a module that can determine if a Wako is hit by a hand or another physical object in future work.

To detect the currently focussed real world object, we use a color recognition engine which, can determine the currently targeted circle. To meet the users' requirement of playing the game on other surfaces as our game board, a color calibration phase was added to the game. In calibration mode, users are asked to point at a color for 3 seconds. This color is saved as one of the game colors. In this way, players can initially specify the colors of the holes were the Wakos appear. This also allows a new range of playing fields, for example on people's colored shirts in front of an unicolored background.

B. Hardware Prototype

Due to the lack of appropriate integrated projector phones on the market, we connected an Adapt ADPP-305 projector to a Samsung Galaxy S smartphone. The Galaxy S offers a TV out port and high processor power for graphic computation. The ADPP-305 is a good trade-off between mobility (battery-powered), brightness (45 lumens) and size (fits in one hand). A wireless camera is attached to the projector to guarantee the congruent setup. The wireless camera provides colored images of 640x480 pixels. This quality is high enough in order not to raise problems with color detection, given regular indoor light conditions. The prototype's weight and size allow to operate with one hand.

One of the main problems encountered with this prototype concerned the connecting cables between the projector and the smarthpone. Firstly, there were several cables which confused the users on how to handle the device comfortably. Some of the users wore the cables around their neck. Secondly, as the users moved the prototype some of the cable jacks rotated making the projected image to be unavailable for a short period of time until the projector detected the input again. In a high-level prototype were the projector is integrated into the smartphone this would not be a problem.

Figure 2 shows the system architecture: The wireless camera collects an image of the game board and sends it to a server PC. The server computes the position and size of the Wako and sends this information to the smartphone, which, creates the final image to be displayed by the mobile projector using the stored current score and time left, too.

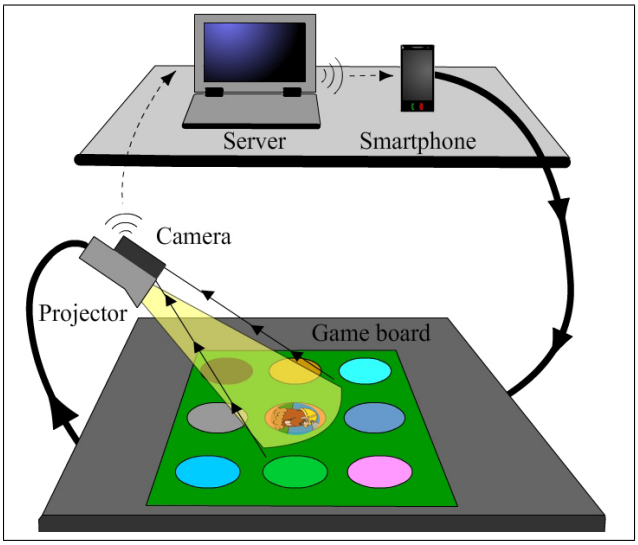

Figure 2. Game setup

Figure 3 shows a user who is playing with the first prototype.

C. Software Concepts

An image recognition module on the server detects the color of the circle where the user is pointing at by analyzing the current camera frame. The colors of a certain amount of pixels inside the shape are averaged. The actual algorithm was kept as easy as possible to execute it on a smartphone in

Figure 3. User plays with first prototype

later implementations. In the calibration phase, the images are analyzed for 3 seconds and the average value is stored for usage in the next game.

The server sends the position and size of the currently aimed spot to the game logic module on the smartphone. This module keeps track of the state of the game and passes all needed information to the image projection module, which, determines if, where and in which size the Wako shall be displayed. After this, the image is generated and displayed by the projector.

D. Lessons Learned

We conducted another qualitative exploration with the first version of *Magic Wako*. The aim was to confirm the observations of the low-level prototype testing. Additionally, we wanted to identify further user-related and technological challenges of this augmented reality game approach.

The exploration was conducted with six users which, did not take part in the first user test. They were equipped with the hardware prototype. After an introduction to the gameplay, users were asked to perform four tasks and provide feedback about the interaction: 1) Point at the top rightmost spot in the game board. 2) Point at all the spots at least once in the game. 3) Find the Wako during the game at least twice. 4) Hit the Wako during the game at least once. All the tasks were successfully performed by every user. All users managed to hit the Wako with increasing frequency towards the end of the game. It confirms that this way of handling the projector is natural and easy to learn. Additionally, every player told that the game is interesting and fun.

Three users asked for a device that is lightweighter and easier to handle. As pointed out in this section, the hardware prototype is a tradeoff because sufficient integrated hardware is currently not available. In an optimal setup, camera and projector would be integrated in the smartphone. This would reduce the size, weight and bulkiness of the hardware components. Also the server would not be necessary because all the computations could be performed on the smartphone. With regard to the shaking problem, it would have to be investigated if it is still a problem in this new setup. Alternatively a wireless button could be provided so that the user could hit it with her free hand. Although this time we explained that the Wako has to be hit by touching the mobile phone's screen, two users still tried to hit the Wako by hand. This confirms the need for a physical interaction with the game board as an alternative to the one with the smartphone.

In some cases when the Wako was projected on a circle, the color of the latter was altered by the projected light and the color detection did not work properly. This generated an annoying flickering of the projection. The color recognition algorithm was improved by increasing the similarity threshold between the detected color and the color stored during calibration. Projectors with a darker light work better because their projected image interferes less with the real world objects. At the same time, if the projection is too dark, the Wako is not properly visible. Unfortunately, background subtraction is not possible in this setup. The gameplay involves the user to navigate the field with the projector, which, constantly changes the image detected by the camera. This doesn't allow to distinguish whether the change in the detected image is due to the movement of the user or due to light changes caused by the projector.

Three users had problems to find a Wako because they were moving the camera and projector too fast thus preventing the image recognition module to work properly. The color detection process of one camera frame takes a few 100 ms. When color detection was completed, too fast users already pointed at another color. This resulted in a one-frame blinking of the Wako. That problem can be solved by optimizing the color recognition. Also a reduction of data communication steps can increase performance, for example by omitting the server between camera and smartphone.

V. Conclusion and Next Steps

Using augmented reality with a projector as a mean of game control has potential to intensify current trends in

gaming. During two qualitative explorations with a low-level prototype and a first implemented version of the augmented reality game *Magic Wako*, we could identify user-related and technological challenges. We also observed that our interaction approach of controlling the game through projector movements was easy to learn and widely accepted by users.

Our explorations indicate that both modalities, hitting the Wako by button press and hitting the Wako by hand or object, are requested by a significant group of users. There is slight evidence that hitting the Wakos physically seems to be more intuitive. We will further investigate the hitting modality in the next iteration. It will have to be taken into account the movement of the persons hand holding the control when they try to hit the wako phisically with their other hand. In future work, we are going to implement the possibility to hit the Wako by hand or by using objects in order to confirm this finding with a high-level prototype. This would solve the problem of having to push a button which caused the shaking of the device. Also in the next iteration it will be investigated what kind of user group prefers what modality. This input modality will probably cause bigger usability problems because the physical input process affects the projector handling a lot. We will try to solve these problems, for example, by applying image stabilization methods. The next iteration will include a larger group of testers since the number used in the previous two user studies is not sufficient to draw solid conclusions.

The ability to play the game on arbitrary surfaces is a further matter of investigation. In this context, reachability or mobility of objects offer new problems and possibilities. Also, further investigation on this matter will possibly lead to improvements or alternative implementations on the current image processing algorithm. These might include a new approach on distinguishing the colors where the Wakos come out such as background substraction.

If more sufficient integrated projector phones will be available in the future, this will meet one of our identified user requirements. However, it will also change the nature of a button press compared to our current prototype. By now, the physical process of touching the phone's screen does not influence the position of the projector, but this is different in an integrated projector phone. We will examine how strong this limits the user acceptance. A solution could be to compensate the projector movement recalculating the position of the projected image.

Further work will concern technological issues. The color recognition module will be optimized to deal with the problem of too fast user interaction. Also, the initial color calibration allows for the game to be played in an arbitrary surface that contains a variety of nine different colors. Test will be made in another setup than the one presented with the physical board with nine dots.

VI. Acknowledgements

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