A Proposal of a Shadow Detection Architecture Interface for Games Using Portable Projectors

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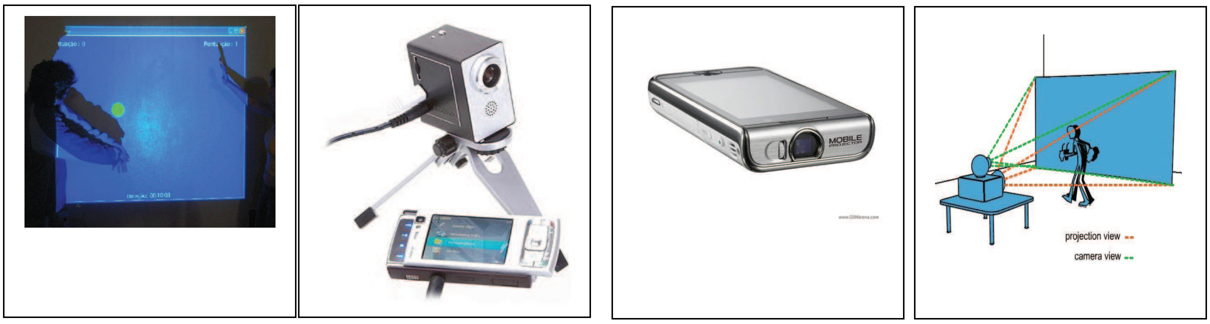

Figure 1: The figures above illustrate: the game Shadow Volleyball (first figure, left), the use of a “pocket projector” connected to a mobile phone, the Sansung W7900 mobile projector phone and the projector and camera setup used during the tests.

Abstract

With the advent of “Pocket Projectors” - projectors based on LED [Rojas 2004], OLED [Miller 2009] or laser light emission [Captain 2008], with sizes similar to smartphones and the emergence of mobile phones capable of video projection, the “projector phones” [Ricker 2008], a new interface and a new way to play games became possible. By using computer vision techniques, the shadow generated by the human interaction with images projected by portable projectors can be used to control game elements and respond to game events. The player can interact with the projection using his shadow and the game interface can react accordingly.

This article proposes a interface for game control that react to commands based on the detection of shadows generated by players interacting with a projection from a portable or a common projector. This article also describes experiments made during the development of prototypes that respond to interactions represented by shadows.

Keywords: Computer Vision, User Interface, Computer Games, Mobile Phones, Game Development, Game Frameworks.

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1. Introduction

In the video game world, two aspects of the market have become extremely relevant in recent years: games based on controllers that identify movement; concept enshrined by the Nintendo Wii, who will face a strong competitor with Microsoft's Project Natal [Microsoft 2009], and the popularization of mobile phones with color screens, making room for the massive growth in numbers of games for mobile phones. Both phenomena of portability and interaction caused a revolution in the game market, making room for more casual players and for games that need physical interaction.

Games for handheld devices and games that can be controlled by hand and body movement are popular, but until recently, they were a self-exclusion phenomenon; games with control based on body movement are not practical for portable devices and games for portable devices usually does not work well with body movements. Recently, the incorporation of accelerometer chips in mobile phones gave the ability to control games moving the phone. These movements are still limited to small turns and shakes since the player needs to see the screen to play properly. The advent of “Pocket Projectors” can change this barriers. With mobile phones connected to projectors, there is no need to look at the screen of the device, the player can look at its projection. However, while there is the possibility of wireless transmission from the mobile phone to the projector, little can be done for the detection of full or broad body movements of the player holding the phone for effective control.

With this scenario, the authors propose a new and unique paradigm of game interface using information captured from cameras of mobile phones, laptop cameras or USB cameras. This interface uses the shadow projected by the player over the image projected by the projector. This mechanism of interaction has several advantages over the current and future systems that detect motion based on analysis of body movement [Microsoft 2009]. Among the advantages, we can mention the possibility of multiplayer games with movements like jumps and crouches, which is possible when interacting with projections of more than two meters in height. The size of the projection can actually influence in the mechanic of games allowing more physically challenging games.

This paper is structured as follows: the second section describes related works. The third section presents the computer vision techniques employed. The fourth section describes how the physical design of the play environment can influence the gameplay. The fifth section details the shadow identification and its influence in gameplay. The sixth section presents some game concepts using shadows and details how the shadow detection can be used in the gameplay of these games. The last section concludes presenting opportunities for expanding the research, along with some final thoughts and considerations.

2. Related Works

The use of image processing to infer information from shadows is not new. The U.S. patent number 6624833 [Kumar 2003] proposes an interface where the shadow of gestures is used to estimate the relative distance of the hand of the controller to a surface, in order to provide spatial information of the position of the hand. The proposed method also considers the identification of gestures by the interface.

The presence of shadows and the increase and decrease in size of the shadow according to the user's movement, considering the focus of the light, is used by Shoemaker et al. [2007] for user interaction with large screens, too big to be reached by the user touch. Another work that use shadows and big screens, now interactive big screens, is the work described in [Apperley 2002], where the system uses the silhouette of each user interacting in a virtual meeting, where several users simultaneously use big interactive boards or screens. The article describe the use of virtual shadows projected behind the content handled by each participant, in order to allow participants to know the relative virtual position of each other, despite being geographically distant and using their on boards.

Finally, another work that deserves mention concerns the patent number 20070300182 [Bilow 2007], that uses the shadow and the contact point of an object (such as the finger of a user) on the surface of a touch sensitive display to allow positioning and orientation of the interface elements.

3. Implementation and Computer Vision Techniques

The proposed interface use computer vision techniques to obtain information of the environment to allow the game loop to handle user interaction based on the requirements of the game. Since the information of the environment is produced by the projector and captured by the camera, the correct placement of both influence in both the gameplay and the information captured.

During the tests, the best placement is presented in Figure 2. Is important to emphasize that there is no need for a perfect alignment between the projection and the camera's field of view.

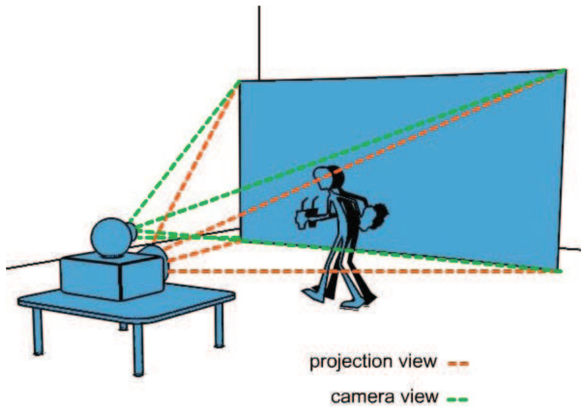

Figure 2: Camera and Projector Placement.

With the projector and camera positioned, the calibration process is started, which defines the region of interest of the game based on the color information of a rectangle generated by the projector.

To help identify the color, the RGB images acquired by the camera are converted to the HSV [Conci 2008] color space. The HSV model is a color system that helps the identification of a particular color and its variations in tone, which is very suitable for our purpose, since even if the background color is a pure, the light of the environment can still affect the information captured by the camera.

The shadow identification is done only in the region defined in the first step. Since just the shadow identification is necessary, the captured frames are converted do grayscale. After the conversion, the region is binarized, with a threshold low enough to detect only shadows. This step is necessary to address a phenomenon arising from the variation of illumination: noise, or more specifically, the false positives that can appear during the shadow detection.

In order to remove the noise, morphological erosion [Serra 1983] is applied. Only the pixel groups that contain the structural elements stay in the image. The groups that do not contain the elements are turned into black. After this, the image is prepared to be analyzed in order to calculate the bounding boxes of the detected shadows that will be used to calculate collisions.

The bounding boxes obtained are represented by Cartesian coordinates of the captured image region.

Hence, to make the collision calculations according to the actual projected image, it is necessary to transform the image of the captured Cartesian space to the Cartesian space of the game. To do that, the following equations are used:

X_screen=(screen_width/capture_width)*(x_capture–x_capture_min) (1)

Y_screen=(screen_height/capture_height)*(y_capture–y_capture_min) (2)

Where x_capture and y_capture represent the x and y coordinates of a pixel captured by the camera; x_capture_min and y_capture_min represent the coordinates of the minimum active area of the game; screen_width and screen_height represent the width and height of the screen of the game to be projected; capture_width and capture_height represent the width and height of the active region of the game captured; x_screen and y_screen represent the coordinates x and y of the pixel already transformed to the coordinates of the game screen to be projected.

4. Planning the Physical Environment

The basic structure of the proposed way of playing is a projector, a surface to receive the projection and a camera, which is used to "see" what happens inside the projection. Different camera positions related to the projector offers different possibilities of visual interpretation. For the proposed work, the camera is positioned close and above the projector (Figure 3). Depending on the projection cone, it may be necessary to move the camera a few centimeters above or below the projector to avoid regions where the element of the body that creates the shadow (a hand for example), cover the most of the shadow. In the experiments made, with some simple adjustments it was possible to remove any important "blind spot".

Depending on game design, the size and shape of the surface may also influence the gameplay.

The surface that receives the projection can be irregular, provided that it allows the player to project his shadow on it. Irregularities on the surface may not interfere much in the game, provided that the shape of the shadow does not change much. In some cases, the presence of irregularities on the surface provides a natural variety of gameplay, where the player needs to adapt to the irregular surface. Another important point is that the projection's surface doesn't need to be completely parallel to the projection. Projections on inclined surfaces such as a table can provide an interesting alternative for some games.

The space between the projector and the projection is also relevant. A large distance between the projector and the surface that receives the projection allows a bigger game space, forcing the player to move more during a match or allowing several players in the same space. Depending on the height of the projection, the game may require the player to jump, so that his shadow reaches certain areas.

5. Shadow and Gameplay

One of the first questions that arise in relation to the interface proposed relates to why not identify the body of the player instead of his projected shadow. The reason is simple; is easier for the player to follow the game through its projected shadow. The player looks at the shadow that he generate, which is in the play field . If the camera is used to detect the player it would be necessary a much larger space to play. Other problems and limitations concerning image detection are:

- Brightness of the environment: Low light can make the identification of color and shape harder. Since projector generates the shadow, environment light is not a big problem.
- Player size: A child near the projector can generate a shadow similar of the shadow of a adult. This can balance the game, giving the child a chance against an adult.
- Size of the projection: Depending on the surface that receives the projection, the projection may be much larger than the player or much smaller (the projection in a table, for a board game). Many games can be adapted to be played in both large and small projections. In these games, instead of using the body, the player can use objects such a pencil or pen. This flexibility is not easily achieved using other detection methods.

The shadow detection can give the following information for gameplay:

- X and Y coordinates of the projected shadow: the center of the bounding box around the shadow can be used to calculate X and Y.
- Z coordinate: the shadow increase and decrease in size can indicate a movement in Z.
- Shadow area: can be calculated by defining the minimal bounding box around the shadow.
- Shape of the shadow: simple shapes can be used to send commands for the gae
- Speed of the movement of the shadow: can be easily calculated for X, Y and Z coordinates.

6. A Game Example

Five game design proposals were developed during the study. One of the designs is a game called Shadow Volleyball.

In the Shadow Volleyball each player stands on one side of the projection, outside the projection field but close enough so your hands and forearms can reach the projection region. The projection should be taller than

2 meters to allow jumps. The match starts with one player moving his hand as in a normal volleyball game. A virtual ball is created and move towards the other player considering the strength and position of the player's initial movement. The opponent hit the ball with his shadow. The players needs only to move their arms, and may also jump or crouch to catch the ball.

The game calculates the size of the shadow in order to prevent the player to increase its shadow using the body to cover a larger area of the screen. Figure shows a gameplay of the game.

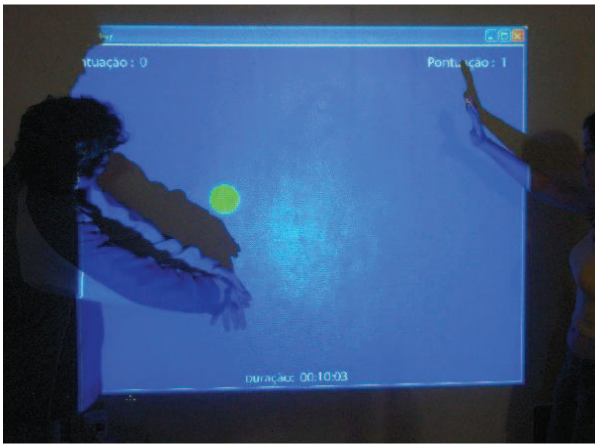

Figure 3: Shadow Volleyball.

7. Conclusions and Future Works

Due to the low cost of "Pocket Projectors" and despite the relatively low quality of the projected images, the appeals of low energy consumption and portability can make pocket projectors extremely popular in a short time. Coupled with the fact that mobile phones with projectors are already a reality, and the fact that most notebooks already have a build-in camera, it's possible to say that the hardware platform for games using shadow detection will be common very soon.

Another definitely important issue is the game experience that can be provided by the proposed interface. Initial experiments shows that the ability to interact with large projections excites the majority of players. Another motivating factor is the need to move the body to play. Unlike the Wii controller, which really does not need broad movements, the proposed interface can force players to move more their bodies.

As further work, the interface can be improved with the identification of the form of the shadow, allowing the creation of board games, where the projection of the shadow of physical pieces on the surface allow the computer to identify each piece and implement features of movement and functionality. Another field of study is the identification of gestures based on the shadow. Due to the flattening of the form done by the shadow, not all hand gestures can be adequately captured, however, due to the great definition achieved by the projection of the shadow, which hardly shows blurred regions, the detection of gestures can be more precise.

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