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

Figure 1: The figures above illustrate: the game Shadow Volley (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 presents and describes an architecture interface for game development that responds to commands based on the detection of shadows generated by players interacting with a projection from a portable projector. This article also details experiments made during the development of games that respond to interactions produced 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 the supply of games for mobile. Both phenomena of portability and interaction caused a revolution in the game market, making room for more casual players and for games that "take the player of the sofa."

Games for hand held devices and games that use controllers based on movement are phenomena of popularity, but until recently, they were a self-exclusion phenomenon. A game with controls based on body movement is not practical for portable devices and games really attractive for portable devices do not involve the interaction based on full body movements.

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 of the phone since the player needs to see the screen to play properly. A game that actually uses the accelerometer of a mobile phone can't be a game that requires constant monitoring by the player of what happens on the screen of the device. The advent of "Pocket Projectors" changes this. With mobile phones wirelessly connected to projectors, there is no need to look at the screen of the device to monitor the action of the game. 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 of a game.

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 projection of the game, being made by a portable 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 more broad movements like jumps and crouches, in large physical spaces. This is possible when interacting with projections of more than two meters height, allowing a greater field for the game. The size of the projection is a factor that may influence the mechanics of games and increase the body movement of players, allowing more physical challenging games.

This paper is structured as follows: the second section describes related works. The third section presents the computer vision techniques employed and the proposed game loop for games based on shadow detection. The fourth section describes how is done the physical design of the gameplay area that will use the game engine based on shadow detection and how the gameplay environment can influence the games. 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 identification of shadows 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 about the research.

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 shadows 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 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 a surface of a touch sensitive display to allow positioning and orientation of the interface elements.

3. Implementation

The proposed mechanism use computer vision techniques to obtain the necessary information to allow the game loop to handle user interaction based on the requirements of the game.

Below are detailed the computer vision techniques employed and the game loop used for the prototypes cited in section six.

3.1 Computer Vision Techniques Used

This section describes the computer vision techniques used in the implementation of the architecture that supports the proposed mechanism. Early tests have shown that these techniques are fast enough for use in real time interactive games.

The initial process consists in the appropriate placement of the projector and the camera so the projection can be fully seen by the camera. Is important to emphasize that there is no need for a perfect alignment between the projection and the viewing cone of the camera, making easy for the user to prepare the environment for the game. Figure 2 shows one possible placement of camera and projector.

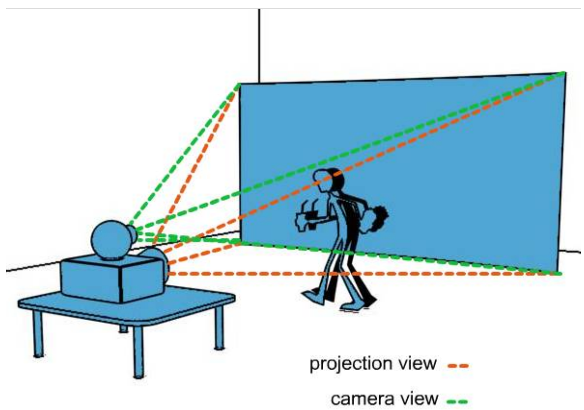

Figure 2: Camera and Projector Placement.

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

To help identify the color, it is appropriate to transform the RGB color space of the image acquired by the camera to the HSV color space. The HSV model is a color system that facilitates the identification of a particular color and its variations in tone which is very suitable for our purpose, because even if the background color is of a pure color, the light of the environment can still affect the information captured by the camera.

Once defined the criteria to decide which pixels are considered as the color of interest, the play field limits must be defined. For this, a pixel scan is performed from the center to the edges of the captured image. A total of four scans (center left, center to right-center to center up and down), are done. In each of these scans the algorithm tests if the pixels are blue. If not, it is considered that the limit of the region was reached. Once found the limits, the play area is defined and the match is started.

The shadow identification process is done only in the region of interest, defined priory. The image is converted to grayscale, and the color information is not relevant, since only the shadows will be considered. Then, the region is binarized, with a threshold low enough to consider only shadows. This step is necessary to address a phenomenon arising from the variation of illumination: the noise, or more specifically, the false positives that appear during the detection of the shadow.

In order to remove the noise, morphological erosion [Serra 1983] is applied. So, 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. At this moment, the image is prepared to be analyzed in order to calculate the bounding boxes of the detected shadows that will be used to calculate the collision.

The bounding boxes obtained are represented in Cartesian coordinates of the area of the captured image. Hence, to make the calculations of collision 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.

3.2 Game Loop for Shadow-Based Games

There are many kinds of tasks that a computer game should do: compute the graphics pipeline, artificial intelligence, physics, and network management, among others. These tasks can be categorized into three general classes: data acquisition, data processing, and presentation. The most basic game loop model, illustrated in Figure 3, is the simple coupled model in which all the stages run sequentially.

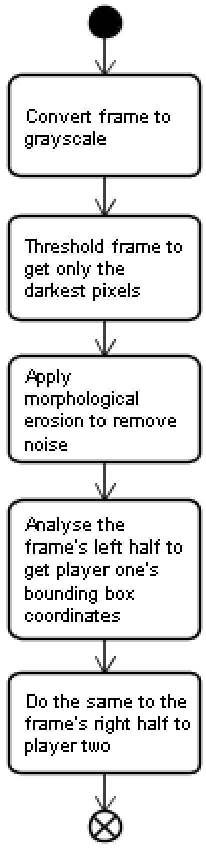

Figure 3: Simple coupled model.

The game loop proposed in this article consists of two different workflows: the first is executed while the calibration process is running; the second begins after the calibration and proceed until interrupted. These workflows can be defined as sequences of steps. The defined steps are: Initialize, GrabFrame, Calibrate, ProcessFrame, Update, Draw and Finalize.

Both workflows execute the same initialization (Initialize, GrabFrame) and finalization (Draw, Finalize) steps, they only differ in the intermediate steps, where the calibration workflow executes Calibrate step and the main execution workflow executes ProcessFrame and Update steps. The mentioned steps are described as following: Initialize – detects camera, creates the game window and executes anything that needs to be done once before the main loop; GrabFrame – gets frame from the camera; Calibrate – runs the procedure that tries to define the main game area (the blue rectangle); ProcessFrame – processes the frame using the described computer vision techniques to extract the data needed to interact with the game, as illustrated in the activity diagram in figure 4; Update – updates game objects status; Draw – draws the objects in the game window; Finalize – executes control processes, like memory management to prepare for the next iteration. Figure 4 illustrates the activity diagram that represents the game loop.

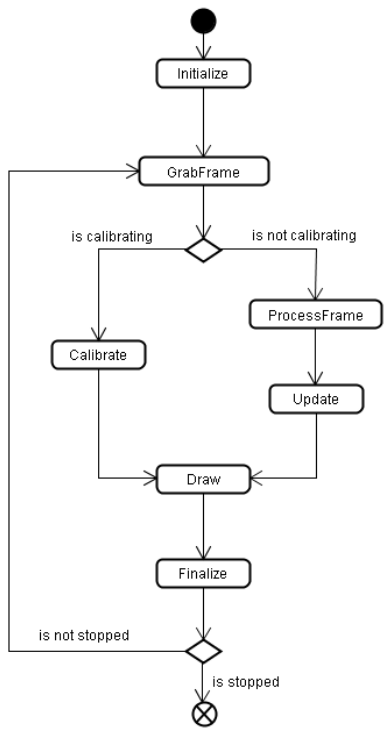

Figure 4: Game loop.

4. Planning the Physical Environment

The basic structure of the proposed way of gaming is a projector, a surface to receive the projection and a camera, which is used to "see" what happens in the projection. Different positions of the camera related to the projector offer different possibilities of visual interpretation. For the proposed work, the camera is positioned close and above the projector. 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 offset any important "blind spot" for the games.

Depending of the game, the size and shape of the surface may influence the gameplay. The first four games presented in section 6 have the gameplay influenced by the characteristics of the surface.

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 interaction, provided that the shape of the shadow does not change much. But in some cases, the very 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 surface of the projection 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.

The projector position in relation to the surface that receives the projection and to the player is also important. If the distance of the projector from the floor is the same as of the waist of the player, when the player approaches the projector, the player can completely block the projection, however, if the projector is hung on the ceiling or above the player, the player can not hide the entire projection, just parts of it.

Another important element in relation to the position of the projector is the size of the shadow created by the player. The size of the shadow projected is directly proportional to the proximity with the projector. When the player is close to the projector, the produced shadow is greater than when he is far from it. This feature allows the creation of games that make the player move closer to or further from the projection, by simply capturing the size of the shadow and inducing the player to increase or decrease the actual size of the shadow to cover an area that expands or shrink.

5. Shadow Identification and Gameplay

One of the first questions that arise in relation to the interface concept 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 generated, which is in the field of play, and move it accordingly. If the camera is used to film the player on another place and draw their image in the projection, it would be necessary a much larger space to play. Other problems and limitations are:

- Brightness of the environment: The light affects the perception of color. Low light make the identification of color and shape harder. With the use of shadows, the game can be played in environments too light or too dark, since the light of the projector generates the shadow.

- Player size: For some games, throwing a child against an adult would let the child in a disadvantageous position. If the interface of the game is the projected shadow, the child could be near the projector, making his shadow bigger. If the captured image is used instead, focus problems could arise if both players are not aligned. Using shadow, the problem disappears.
- Size of the projection: According to the surface that receives de projection, the projection may be much larger than the player or much smaller (like the case of a 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 as a pencil or pen. This flexibility is not easily achieved using other methods of detection. It's necessary to consider that a game can became too easy or to hard depending on the size of de projection.

For game design, the use of shadows as interface can give the following information for gameplay:

- X and Y coordinates of the projected shadow: it is possible to determine the center of the projected shadow creating a bounding box around the shadow and determining its center.
- Z Coordinate: the proportional increase or decrease of the shadow without a radical change in it's form may indicate a movement in the Z axis perpendicular to the surface.
- Volume of the shadow: volume can be estimated by defining the minimal bounding box around the shadow.
- Shape of the shadow: with the detection of the shadow basic shape, some simple shapes can be used as a way to send commands for the game. Shapes like to point or the openning and closure of the hands can be used to point the mouse to a location and perform a click in the region.
- Speed of the movement of the shadow: besides of the measurement of the speed in the X and Y coordinates, parallel to the surface, the proportional increase or decrease in the size of the shadow can also allow the speed estimation in the Z axis.

6. Some Game Designs

The following five game design proposals use the detection of shadows as interface and are also influenced in some degree by the way the game is projected in the surface and the size of the projection.

6.1 Shadow Volley

In the Shadow Volley each player stands on one side of the projection, outside the field of projection but close enough so your hand and forearm 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 a normal volleyball game should start. A virtual ball is created and moves towards another player considering the strength and position of the player's initial movement. The other player hit the ball with his shadow. The players need only to move their arms, and may also jump or crouch to catch the ball. There is no movement toward the projector. The players are positioned near the surface of projection, which is horizontal.

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 5 shows a gameplay of the game.

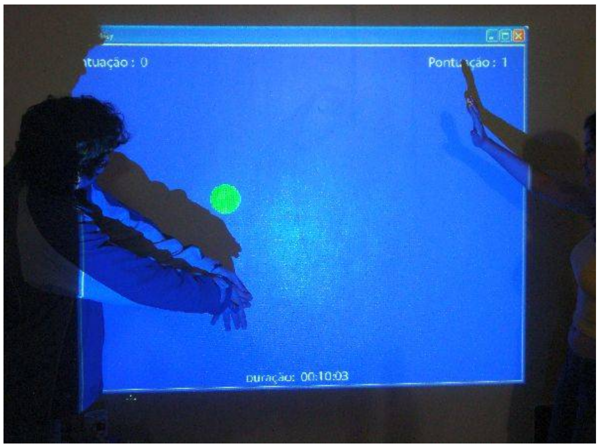

Figure 5: Shadow Volley gameplay.

6.2 Shadow Stretch and Squach

In this game, the player needs to cover with his shadow specific areas as quickly as possible. The regions are defined by colored rectangles on the screen. The player has a maximum time to cover the colored region with his shadow. The score increases accordingly to the speed in which the shadow completely cover the region. If the shadow created by the player is greater than the region when the counter exceeds the time limit, the player's score is reduced. As the colored regions may appear as small rectangles far from the player, the player needs to move into and out of the field of projection, and close or away from the projector to create shadows with different sizes and within different regions of the play field. More than one rectangle appearing at the same time can force the player to use his arms and legs.

The proposed game, due to its characteristics, requires that the player stay in constant motion. Figure 6 shows the gameplay of the game.

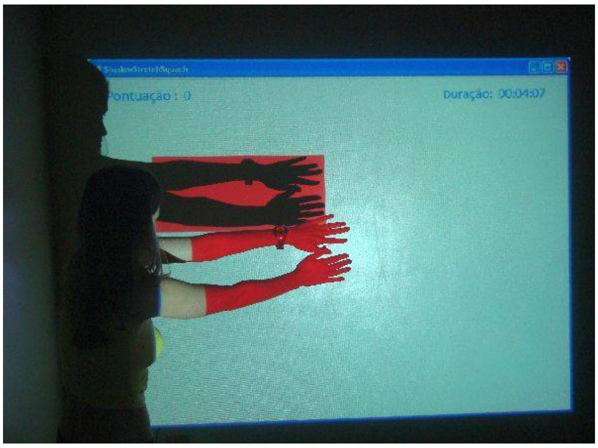

Figure 6: Shadow Stretch and Squach.

6.3 Catch the Target

This game can be played with a large projection on a wall or with a smaller projection, on a surface like a table. Targets appears randomly in the projection and the player needs to cover the target with his shadow as fast as possible. The player scores every time he covers a specific target. Some targets cannot be covered by a shadow. These "prohibited" targets force the player to plan his creation of shadows, to avoid covering the prohibited targets.

A variation of this game can be played with a projection on a table. In this case, the player uses a pencil or pen, to project a shadow over the targets.

Both mechanisms described above can have a multiplayer version where the screen is divided into two regions and the color of the targets corresponds to specific players. Figure 7 shows the gameplay of the game.

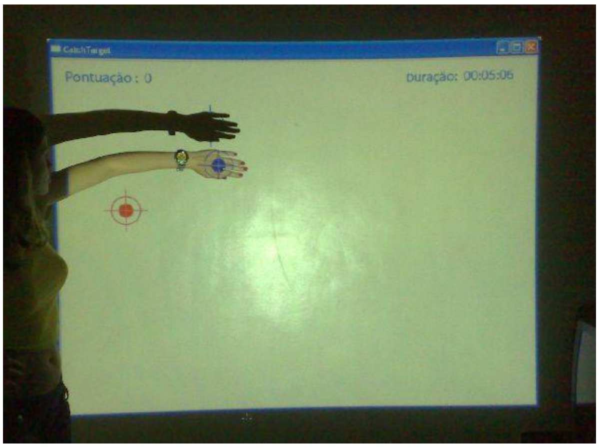

Figure 7: Catch the Target.

6.4 Virtual Pong

Similar to Shadow Volley, Virtual Pong works with each player using one of his hands as a control for the batter. Unlike Shadow Volley, the shadow is only used to move the batter, which has fixed size. As in the Shadow Volley, two players can play this game. Figure 8 shows the gameplay of the game.

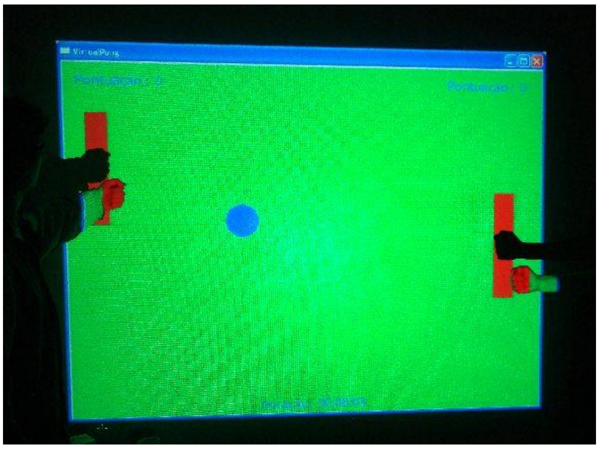

Figure 8: Virtual Pong.

6.5 Shadow Box

In Shadow Box, the player is positioned in one side, next to the projection. This is a game for one player. During a match, fireballs are thrown in the direction of the player in varying trajectories. The player must intercept the fireballs as quickly as possible using his arms and hands. The game punishes the player if its shadow occupies a region too large of the screen. Figure 9 shows the gameplay of the game.

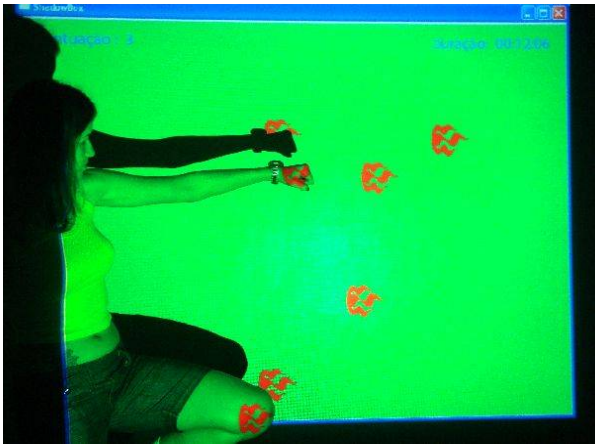

Figura 9: Shadow Box.

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 them 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 has good chances to become popular very soon.

Another definitely important issue is the game experience that can be provided by the proposed solution. 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's controller, which, after some time playing it is possible to notice that the movements do not need to be so drastic, which reduces the amount of calories expected to be burned, the interaction with a projection, especially in large spaces, force the player to stay in constant motion, really burning many calories.

As further work, more kinds of games can be devised as a way to experiment with different structures of gameplay. The identification of the form of shadows could allow the creation of board games, where the projection of the shadow of the physical pieces on the surface allows 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 blured regions, the detection of gestures can be more easily implemented, offering a additional mechanism of gameplay for games.

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