

Towards an Affordable Alternative Educational Video Game Input Device

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Abstract: We present the prototype design results of an alternative physical educational video gaming input device. The device elicits increased physical activity from the players as compared to the compact gaming controller. Complicated and expensive alternative input devices are available, but remain unaffordable for developing countries. We propose a design that is more suitable for local manufacture in developing countries. In addition, we are concerned about the social isolation experienced by gamers. To address this, we project the gaming area onto the floor in front of players and the spectators. This is to encourage co-located collaboration and increased social interaction between players and the spectators. Four players take positions around the projected rectangular image. Angle sensors attached to each player's elbows serve as game inputs. As an educational component, the game incorporates the graphical display of dynamic vectors. We present an overview of the educational gaming software developed, the mechanical design implemented, the advantages and limitations of our input device, together with recommendations for future development.

Keywords: Floor projection, education, video game, vector algebra, human computer interaction, social interaction, multiple players, co-located, elbow angle measurement, body-driven input device.

1. Introduction

In our research we want to know whether a) an affordable interface can be built that requires increased physical activity by the player, b) young children can be exposed to vector algebra in such a way that is not intimidating and also fun for them, a concept that has been called technology enhanced natural learning [3], and c) a gaming environment could be developed that will increase social interaction among the players and also with spectators.

Computer games with their small user interfaces have been criticized for the lack of physical activity on the part of the player, and for the player's social isolation during play [10]. In an attempt to encourage whole-body interaction, a number of game system designers [e.g. 15] have incorporated accelerometers or web cameras [4] to track game player's movements. These remain mostly unaffordable for children in developing countries. Most video game manufacturers are not progressive in their game interfacing mechanisms, having retained the small hand-held controller with multiple tiny buttons ("twitch-controllers"[6,p99]) [16]. We are of the opinion that these, at best, provide exercise for the fingers. Prevalent generic physical user interfaces are limited and typically consist of the mouse, keyboard and computer screen. These interfaces restrict the wide range of kinaesthesia that the human body is capable of, being reduced to slight wrist movements, clicking and typing [6]. Laakso [8, p1] confirms that the use of bodily and special interfaces provide for increased immersive and compelling interfaces.

According to Laakso, all existing camera-based body-driven game systems are intended for single players only. Real body-driven multiplayer games have received little or no attention [8]. Increasing physical activity such as body movement improves the important actions of real-world perception, experience, and interaction.

Still, social bonding amongst computer game players are far from the level experienced in a sports game, and the physical exercise remains limited [9].

We attempted to use the children's built-in abilities, as opposed to their trained computer skills as required by so many educational software programmes [7, p1708]. Most commonly, a child uses a palm-sized controller to interact with a game. The child also views the game on a screen, which limits eye movement to a few arc-degrees. The game is mostly played in solitude, sometimes with another player. Seldom do more than two players physically interact during play. Physical activity is mostly limited to the fingers, and the player is usually in a seated position.

Using the setup we describe in this paper, the number of co-located players is increased to four, spectators have increased visual access to the gaming display, and physical activity by both spectators and players is increased. Our input device can be constructed using equipment available at a FabLab [11]. FabLabs allow users to build just about anything from inexpensive and readily available materials. There are currently four established in South Africa, with at least ten being envisaged.

Children in developing countries are the primary intended beneficiaries of this research. Children in developed countries where obesity seems to prevail may also benefit from this research.

Our work is based on the basic computer game of Pong [14]. Just as 'Hello World' is typically the first programme a programmer trying out a new programming language would write, so is Pong the first game a programmer would typically write. Because we are investigating various ways the whole player's body can be used in playing the game, the name 'BodyPingPong' was decided on.

2. Objectives

Our aerobic goal was motivated by the obesity seen amongst today's youth. We experimented with whole-body interaction, although the current system uses only input from the player's arms. Our interest was the design of alternative and affordable gaming controllers for educational use, rather than the use of commercial controllers. Secondly, we wanted to explore an alternative visualisation technique that would provide for spectator participation. Thirdly, we wanted to introduce the educational component of vector graphics in a game-like environment. Our fourth goal was to explore the possibility of a social game.

Our ultimate goal was to increase the player's involvement in the game by physically engaging the user through full-body interaction.

3. Technology Description

The prototype system consists of four custom designed- and manufactured controllers, commercial joystick interfaces, a data projector with mounting frame, a Personal Computer, and custom-written educational gaming software. We attached custom-made sensors to the players' arms, very much like partial exoskeletons. The sensors were in turn attached to modified commercial joysticks, which served as the computer interfaces. The data projector was mounted some two meters off the ground at the apex of a collapsible frame. This frame was salvaged from a commercial gazebo and can easily be erected and collapsed. This made it possible to quickly erect the game in an area that served multiple purposes. The relatively low intensity of the projected image was partially overcome by using a white

sheet on the ground to serve as the projection surface. The controllers can be classified as integral devices [6, p7] because movement control is simultaneously possible in both of the two dimensions.

We considered a number of options for the gestures. One was the horizontal motion of the arms, and the other the vertical motion.

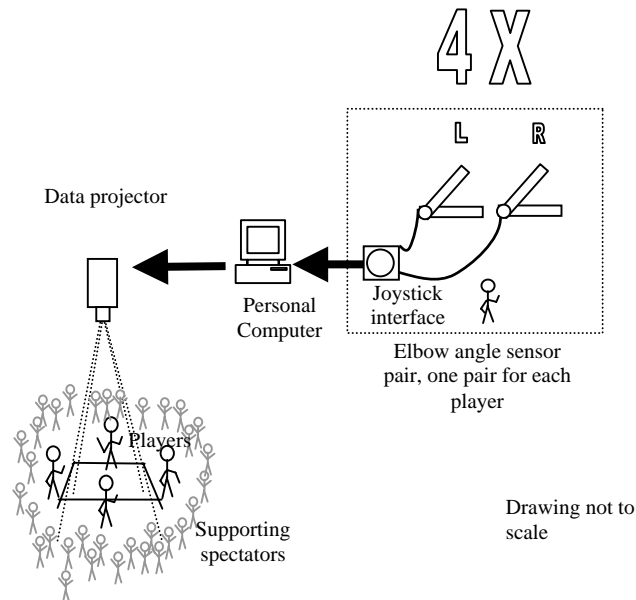


Figure 1. System components

We found that the horizontal motions mapped well with the East/West (Figure 4) motion of the paddles and decided to implement that option. Placing vectors on the displayed paddles did not add much to the understanding of the game. Instead we decided to add the vectors to the ball (Figure 6).

3.1 Original Design concept

In the first version of the game we mapped the angular elbow movements to paddle angles. The paddle magnitudes were kept constant. A resultant vector was calculated by the gaming software. The paddle angles were directly related to the elbow angles. The position of the paddles remained fixed.

Figure 2 illustrates how the elbow angles affected the paddle angles. Also shown is the magnitude and direction of the resulting vector. The left and right ‘ghost’ paddles were displayed on the play-field along with the resulting vector which served as the active paddle. We deemed this mapping of the elbow angles to active paddle orientation cognitively too complex and abandoned the idea.

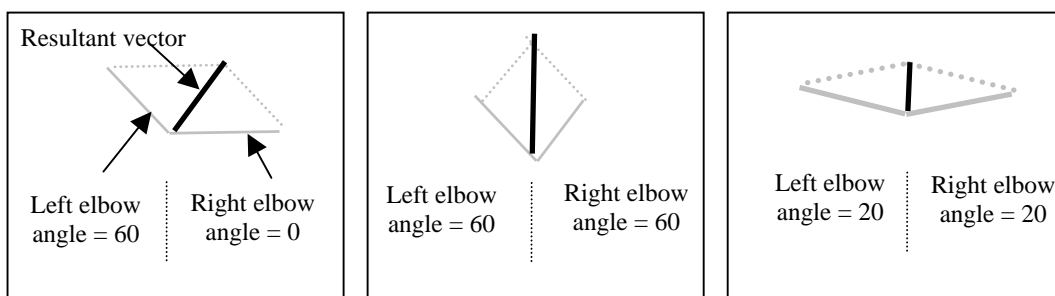


Figure 2. Three scenarios of extended arms are shown. Extended arms represent vectors. The vector summation of the two is a third vector. All three vectors are visible in the game.

3.2 Modified design concept

In an effort to reduce the cognitive load on the players, we implemented a simplified version of the design. In this design the elbow angles were used to control the East-West (Figure 4) movement of the player's two paddles. The left arm controlled the position of the left paddle, and the right arm controlled the position of the right paddle. The displayed vectors were no longer associated with the paddles and arm angles, but rather indicated ball movement.

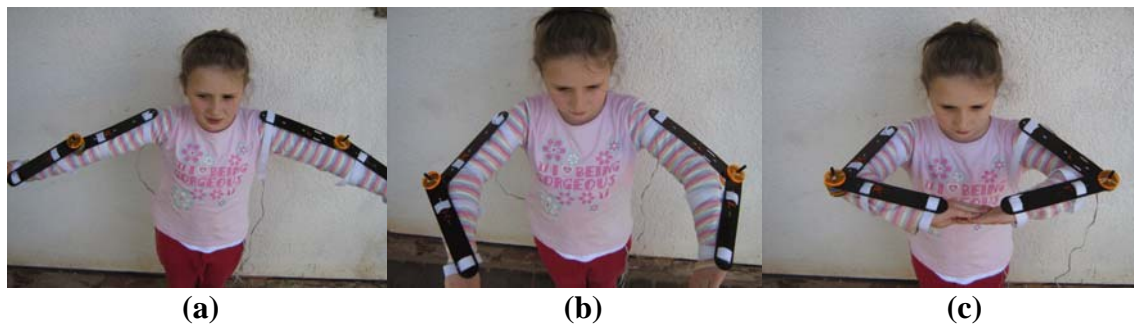


Figure 3. Elbow-angle sensors attached to a player. Elbows angles at (a) $\sim 180^\circ$, (b) $\sim 120^\circ$, (c) $\sim 60^\circ$.

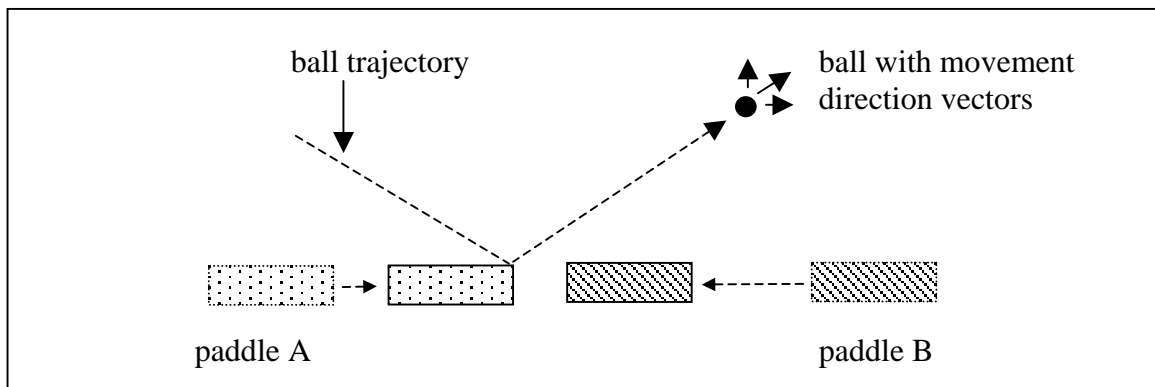


Figure 4. East-West movement of paddle A successfully intercepts the ball. Paddle B misses the ball.

4. Game Overview

BodyPingPong is based on the familiar Pong [14] video arcade game developed before the advent of the Personal Computer. Pong is a simplified version of tennis. In the Pong game, the ball bounces off the wall unless it is intercepted by a player's paddle. BodyPingPong is a simple game with simple objectives, with its main aim to investigate the integration of vector algebra principles into a gaming environment, using player interaction that requires more than simple wrist and finger movement.

The projected image gives the players an aerial view of the playing field. The game consists of four paddles that can be moved to the left (West) and right (East) relative to the player's point of view (Figure 4). The four paddles are distributed along the four sides of the rectangular play-area projection (Figure 5). A rotating target is positioned in the centre of the play-field. A ball moves across the play-field and interacts with the paddles and target when touched. The ball's movement vector is changed when the ball and any of the paddles intersect. The same holds when the ball and the target intersect.

The BodyPingPong game objective is for each player to hit the target in the centre of the screen. The gaming software keeps track of which paddle last hit the ball, attributing a successful “hit” to that player. Should the ball not hit a paddle as it approaches one of the playing field’s edges, the ball will stay in play by “bouncing” off the edge of the field. Should the ball approach a paddle from the South (Figure 5) after having bounced of the edge of the play-field, no interaction between the ball and paddle would be registered. In this case the “owner” of the ball remains unchanged.

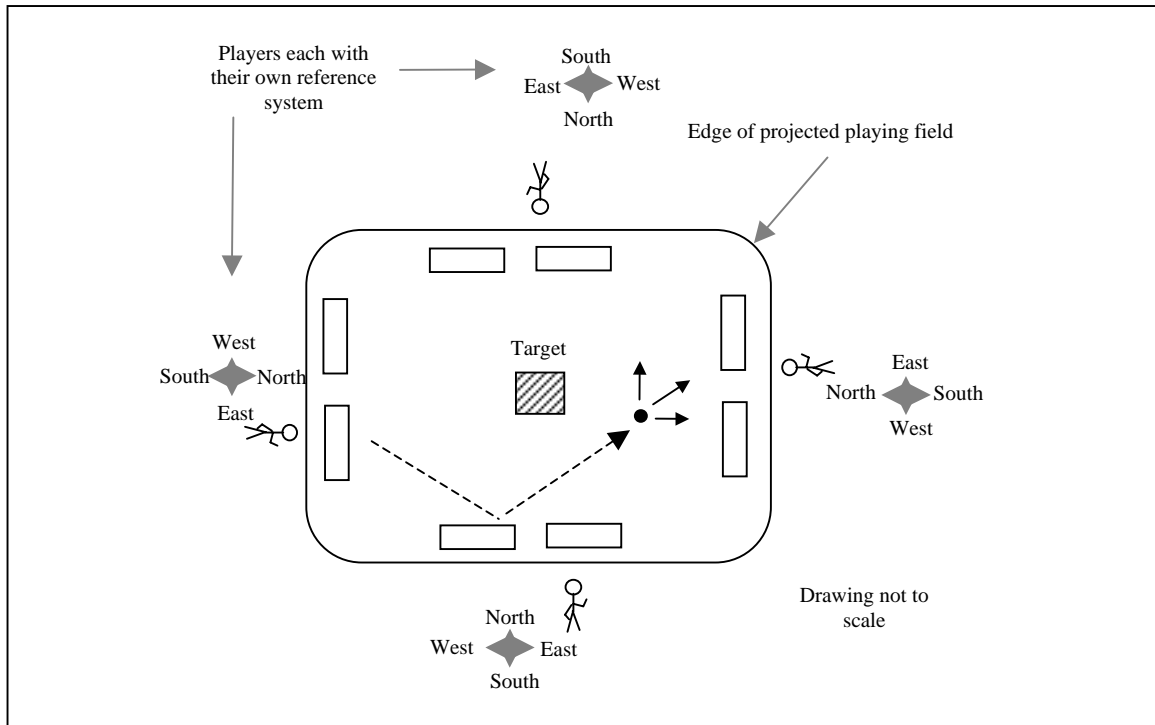


Figure 5. Key aspects of the game

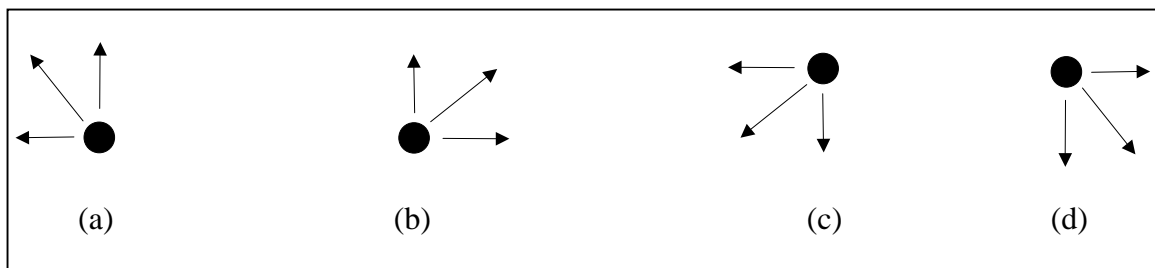


Figure 6. Ball with vectors indicating the ball’s velocity. Direction: (a) North-West, (b) North-East, (c) South-West, (d) South-East

We did not incorporate any time restriction on the game, and the players can play indefinitely. Figure 5 illustrates a number of the key aspects of the game. The dashed lines represent the trajectory of the ball. The two orthogonal arrows, pointing away from the ball, indicate the vector components of the ball’s velocity. The third arrow pointing away from the ball represents the vector-sum of the other two. It is hoped that the children will notice the change in vector direction as the ball changes its own direction, and deduce the relationship between the ball direction and the vectors as displayed on the playing field [Figure 6]. These three vectors move along with the ball over the playing field. We used three different colours for the vectors, one colour each for the North/South-, East/West-components, and summed vector respectively.

5. Implementation

5.1 Hardware implementation

Custom-built hardware connects to the computer through modified commercial joysticks. The cost of the additional custom-built hardware is minimal, being made from acrylic material and laser-cut in a local FabLab. The technology we used for constructing the input devices are increasingly accessible to developing countries through local FabLabs. A variable resistor and wire are required for each sensor attached to each player's arms. The interfaces do not add any additional latency, which already exists in the joystick console, and the update rate remains unaffected by the added sensors. These are passive sensors, containing no active components. The sensors are immune to player orientation changes, magnetic fields, radio interference, infra-red and visible light illumination, and have no line-of-sight requirements. In contrast, more sophisticated interfaces often suffer from these interferences and requirements. Finally, we made use of hook-and-loop strips to secure the elbow angle sensors to the arms.

5.2 Gaming Software

The software was originally written in the Python language and later rewritten in Java. The change in programming language was purely due to the preference of the various software developers who contributed to the research.

6. Related Work

Optical imaging systems are used in many tracking systems, with the obvious advantage of removing wire tethers. As an example, Body-Driven Pong is a game using optical images to determine arm postures of the player [8], with the images projected onto a vertical screen. Optical systems are passive tracking systems. Used in isolation, they lack tactile and force feedback [12, p127]. A number of research papers have aerobic goals, which encourage physical activity on the part of the player [8].

7. Method

We evaluated the system during a number of workshops where children were involved. These were mostly at science shows where no a-priori participant screening was possible. Groups of approximately 20 children would interact with the game during each workshop session. Four children would have an opportunity of approximately three minutes to familiarise themselves with the game, and another five minutes to play the game. After this time had elapsed, another subset of four children was given the opportunity to experience the game. We captured the children's interactions with the technology, as well as with each other, by using video- and still-cameras. A professional usability testing company was contracted to report on the usability and educational value of the system during one of the workshops [1].

8. Results

The energetic support provided by the spectators at science shows confirms that the design of the large projected playing area is successful in eliciting wider involvement, other than by the players themselves.

Feedback from the users indicated the wish for keeping score. This confirms results reported by Paush [13].

9. Conclusions and Future Directions

We implemented a game where the paddles are moved East-West depending on the angle at which the players held their elbows. We would like to revisit the alternative option of rather controlling the paddle angles with the inputs received from the elbow sensors, as opposed to controlling the lateral positions of the paddles.

We developed the game and interfaces as open-content. The source code is freely available for download and modification [2].

Because our research investigated a number of aspects, not only tracking mechanisms, we opted for a wired interface. Some optical tracking systems, that do not use markers, are susceptible to line-of-sight obscuration. In contrast, a tethered interface has the advantage that spectators do not have to stay out of a camera's field-of-view. A tethered interface also reduces the computational load of the software significantly, allowing more complex games to be played with the same computer processing power.

Future games should preferably include player collaboration to accomplish a pre-determined task. This could enhance social interaction, a dimension missing from the majority of current computer-based games. Our system does not fully utilise the 3-dimensional movement the human body is capable of. Adding additional sensors to the body could exploit these movements.

Wireless data transmission (either infrared or radio) could alleviate some of the problems experienced due to the tethered interface.

The sensor mounting mechanism may be improved by incorporation of the sensors into a jacket, to be worn over the player's own clothes.

The East-West velocity vector magnitude could be made to vary, depending whether the direction, before intersection, of the ball and paddles were coincident. If the directions were coincident, the ball velocity vector magnitude would increase by a fixed amount. If they were in opposite directions, the velocity vector magnitude would be decreased by the same fixed amount, but never to less than a certain minimum amount.

We hope that the system described in this paper would be the beginnings of future affordable body-driven gaming systems that encourage social communication and player coordination skills development.

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