Experience in the Design and Development of a Game Based on Head-Tracking Input

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ABSTRACT

Tracking technologies, such as eye and head-tracking, provide novel techniques for interacting with video games. For instance, players can shoot with their eyes in a first person shooter using gaze-based input. Head-tracking systems allow players to look around a virtual cockpit by simply moving their head.

However, tracking systems are typically based on expensive specialized equipment. The prohibitive costs of such systems have motivated the creation of low-cost head-tracking solutions using simple web cameras and infrared light detection. In this paper, we describe our experience developing a simple shooting game which incorporates such low-cost head-tracking technology.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – evaluation/methodology, input devices and strategies, user-centered design.

General Terms

Design, Human Factors.

Keywords

Head tracking input, game design

1. INTRODUCTION

There have in recent years been significant advances in novel techniques for interacting with video games. One interesting direction involves the creation of more immersive ways of providing input to games, where players' natural movements translate into in-game actions. Perhaps the most well-known of these are gesture-based interactions using a Wii Remote [6], and movement-based interaction using a dance pad or Wii Balance Board [5].

A very different style of approach has been the use of passive input devices that capture player's focus of attention, and use this as a direct source of input to games. An example is eye-gaze control of video games, where for example, a player of a first person shooter can aim his gun simply by looking at the desired target. In this approach, players do not control the game through a physical input device; they simply look. Gaze-based input requires expensive equipment (e.g., a $28,000 Tobii eye tracker), and therefore cheaper approaches have been developed, such as head-tracking.

Unlike eye trackers, head tracking systems cannot directly determine eye-gaze. Instead, player attention is approximated by capturing head position and orientation. In this manner, players can freely look around their cockpit in a flight simulator game. Head trackers, however, are not just low-fidelity substitutes for eye trackers. For instance, the act of dodging projectiles in a shooting game is naturally captured by lateral head movements.

Recently, Lee [3] has developed a low-cost head-tracking technology demo based on the Wii Remote, and has made this software publically available. In this paper, we present the results of using Lee's code to develop a 3D game using head-tracking as a core interaction technique. We found the software to be robust and easy to adapt to our intended game purpose. We found its performance to be sufficient for real-time gaming, and its accuracy to be sufficient for coarse-grained pointing actions. Informal feedback indicated that the game was fun and engaging, and that players found the head-tracking interface to be intuitive.

2. BACKGROUND

Video game players can become so immersed in games that they unconsciously move their body in response to game events. For instance, players in a racing game may lean in to turns. Players may also tilt their head to look around corners in shooting games. Although players perform these actions, these motions have no effect on the game. Passive input devices have the ability to transform these body movements into useful input.

Several technologies have been developed for passive input devices, such as optical, magnetic, and inertial motion tracking [9]. Due to the different characteristics of each technology, some applications may be more suited to one tracking system over the others. For example, optical tracking has low latency, but suffers from line of sight (LOS) issues. Users must always remain in view of a camera. Optical tracking is therefore suitable for head/eye tracking of stationary users. LOS problems do not affect magnetic tracking; however, it is slow, making it suitable for tracking human motion for non real-time applications. Finally, inertial tracking is fast and does not suffer LOS problems, but is inaccurate when capturing slow position changes.

FuturePlay 2008, November 3-5, 2008, Toronto, Ontario, Canada.

Commercial products have been developed for motion tracking in virtual environment applications such as flight simulators or 3D games, but they are typically expensive. For instance, Flock of Birds [1] uses magnetic tracking for head/hand/body tracking in flight simulators, and virtual environment games. However, it costs at least $2,500 with one receiver. VFX-1 [9] uses inertial tracking for head-tracking in 3D games such as first person shooters and flight simulators. This systems costs $995. A less expensive optical tracking technique involves capturing infrared (IR) light. We discuss some examples in the next section

2.1 Infrared Head and Eye-tracking Systems

IR tracking is a form of optical tracking where IR light is captured using an IR filtered camera. Due to the filter, only IR light emitting objects are seen by the camera. For instance, head-tracking can be achieved by using a camera to observe IR light-emitting objects placed on a user's head.

TrackIR [4] is a commercial head-tracking game peripheral based on this technique. IR light captured by the camera comes from reflecting tape placed on the user's head, rather than IR light emitting diodes (LEDs). TrackIR can track six degrees of freedom in 3D space. TrackIR costs approximately $200.

Using TrackIR, head motions can be used to simulate eye-gaze in video games. In a flight simulator game, players in a cockpit may want to "look down" at their controls. This is performed by physically tilting their head down while looking at the screen. However, such motions are awkward as TrackIR games may require players to move their head in one direction while looking in another direction.

In addition to head-tracking, eye-tracking can also be achieved using IR light tracking with Tobii eye trackers [8]. Instead of reflecting IR light off reflective tape, the light is reflected off of the user's eyes. This provides the position of the user's eyes relative to the camera. A nine point calibration system can also be used to determine user's eye-gaze, or where they are looking on screen. Eye-gaze accuracy is rated at 0.5 degrees, meaning error in the detected gaze location may be up to 0.5 cm for users sitting normal distance from their monitor. A Tobii eye tracker costs $28,000.

A feature of eye trackers such as the Tobii is that they operate completely passively. Players simply look at a screen and their eyes and gaze are passively captured by the camera. Unlike TrackIR, users do not need to wear any equipment.

An issue with the above tracking systems is their prohibitive cost. At $28,000 the Tobii eye tracker is beyond the price range of most consumers. TrackIR costs significantly less; however, the $200 price is still high for a gaming peripheral.

2.2 WiiDesktopVR

WiiDesktopVR is a low-cost (less than $100) head-tracking technology demo created by Johnny Chung Lee [3]. The demo uses a Wii Remote, Bluetooth receiver and IR LEDs. The Wii Remote is a motion sensitive controller equipped with an IR filtered camera. Using it as a camera, it is possible to track IR LEDs placed on a user's head. The Wii Remote transmits information via Bluetooth, which is interpreted using the Bluetooth receiver.

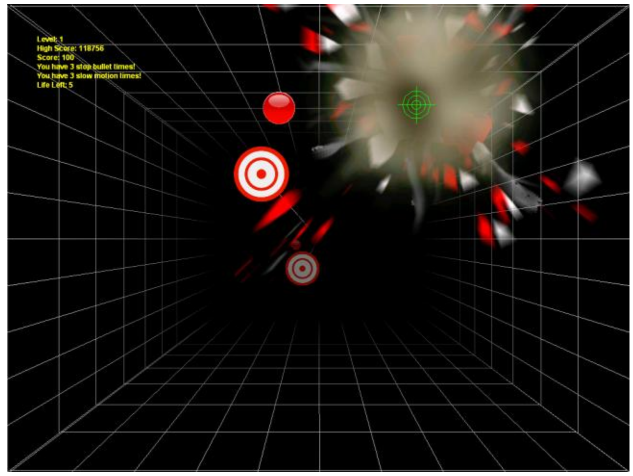

Figure 1. Shooting target in Dodge It!

The tech demo allows users to view targets floating in a virtual 3D space. The purpose of the demo is to illustrate the differences between viewing a 3D world with and without head-tracking enabled. Without head-tracking, the world remains stationary regardless of users' head position. With head-tracking enabled, the view dynamically reacts to users' head positions.

In our experiences with the tech demo, we found the code understandable and well written. Using WiiDesktopVR as a foundation we built a simple shooting game. We discuss our experience developing the game in the following section.

3. DODGE IT!

Dodge It! is a simple shooting game played from the first person perspective (see Figure 1). It is based on the WiiDesktopVR head-tracking tech demo. In Dodge It!, players must shoot down targets while dodging red projectiles fired by the targets. Levels are completed by shooting down all available targets. As the levels progress, more targets and faster projectiles appear. Players have a limited number of lives, which decrease when hit by projectiles. In addition to firing at the targets, players have the ability to slow down time and freeze projectiles in midair.

To play, players aim a green reticule using a Wii Remote. Players shoot targets by pulling a trigger located underneath the remote and press a button to slow time. Players may also thrust the remote forward to freeze bullets in midair. Finally, head-tracking is used to allow players to dodge bullets by physically moving their body or head.

3.1 Game Design

In traditional first person shooters, players move a mouse to aim a reticule centered on the screen. Players line up their shot by centering the screen over a target before firing. The mouse is effectively used to simulate player gaze. Ideally, players would simply look at a target and shoot. The problem is that using the eyes to control aiming and player orientation in a virtual world is difficult.

With eye-based control, players move in the direction they look at [7]. While this is a very natural input technique removing the intermediate step of moving the mouse, it can become difficult for

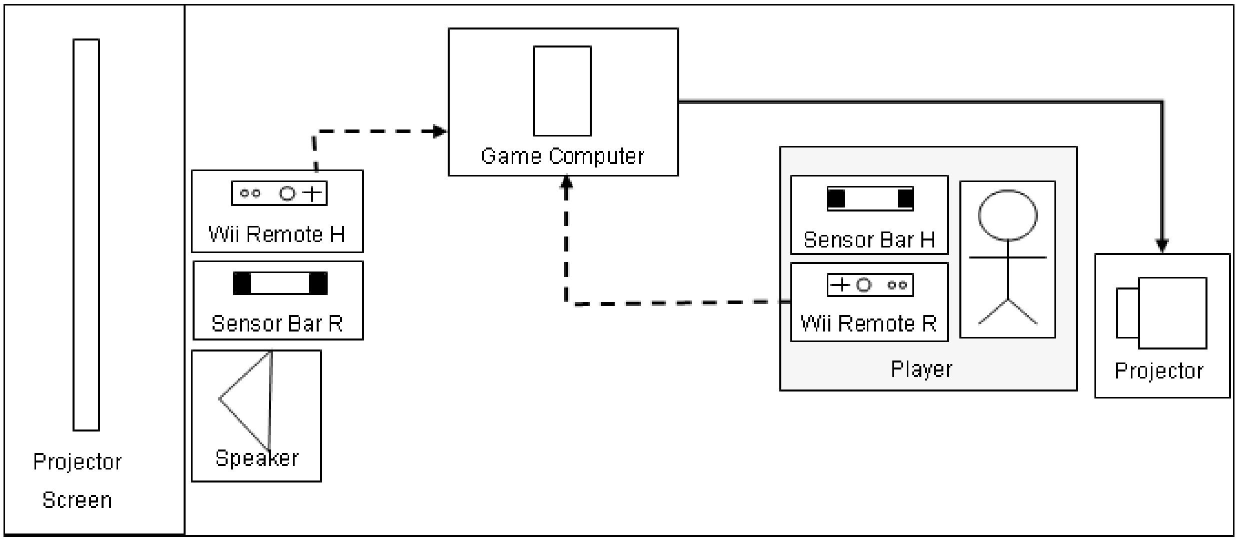

Figure 2. Schematic diagram of game apparatus.

players to walk in one direction while looking at another. If players' attention is temporarily distracted by an interesting event, they may inadvertently change orientation towards the event.

Isokoski and Martin [2] also examined the issue of gaze-based controls in first person shooters. In their game, player position and orientation was controlled by the keyboard and mouse. Eye-tracking controlled the aiming reticule on screen. Players simply look at a target and press the right mouse button to shoot. Initial results showed that using an eye tracker did not improve performance compared to a keyboard and mouse configuration for a traditional first person shooter.

It is possible that players were overloaded with too many control tasks (position, orientation, aiming) in the above research. On-rails shooters simplify controls by removing player control of movement and orientation. Movement and orientation are controlled by the game along a pre-determined path, similar to a roller coaster. Removing movement and orientation controls allows players to focus on aiming at targets on screen, like in a shooting gallery.

Dodge It! takes inspiration from on-rails shooters by reducing player control to movement and aiming. As players move their head/body, the in-game camera moves in the same direction. By removing rotation around the three axes, players are only concerned about objects in front of them.

Unlike traditional first person shooters, where the reticule is locked in the center of the screen, players are free to aim anywhere in Dodge It! The reticule simulates player gaze. By separating player position from aiming, players can freely move in one direction while aiming in another.

An obvious approach in on-rails games where players do not control their movement is to control aiming via head-tracking. We believe that due to the dual problems of accuracy of the head-tracking hardware and the difficulties of moving the head in one direction while wanting to look in another makes this impractical, just as Bérard's experiments have shown head-tracking to be a poor pointing technology for document editing tasks [ref].

3.2 Game Apparatus

Dodge It! is played with a large projection screen and 5.1 surround sound system. Figure 2 shows a schematic diagram of the game apparatus. Solid/dashed arrows indicate wired/wireless connections. IR light tracking techniques are based on WiiDesktopVR. Head and cursor tracking is achieved using a pair of sensor bars and Wii Remotes.

Head-tracking is implemented by placing a sensor bar on the player's head (see Figure 3; Wii Remote H captures Sensor Bar H). A Wii Remote placed near the screen is then used to keep track of the position of the sensor bar/head.

Reticule tracking is similar to head-tracking except in reverse (Wii Remote R captures Sensor Bar R). Players hold a Wii Remote in their hand while a second sensor bar is placed near the screen (see Figure 4).

4. DISCUSSION

Figure 3. Head-tracking using sensor bar.

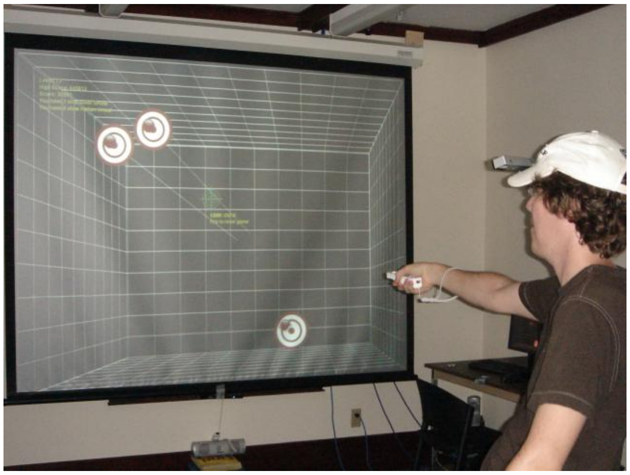

Figure 4. Playing Dodge It!

We held an informal play session for three participants to try out Dodge It! Participants enjoyed the game and were surprised at how well the motion tracking worked.

One player stated: "I liked that I had to jump around. It was really fun." They enjoyed how body movements such as dodging had an effect on the game, unlike traditional shooter games. Another player said "Motion tracking worked really well. I was impressed by how easy it worked. It was fun too; I would definitely play it again." They did not perceive any latency between head movements and actions on screen and found the game, "Surprisingly fun, surprisingly responsive. There was very little lag."

There were also some criticisms of the game. Players commented that the game was a little too easy; projectiles should travel at a higher velocity and use predictive aiming. Finally one player found the head-tracking sensor bar to be unsteady, and worried that it might fall off other players' heads.

Ideally, players would use eye-gaze to simply look and fire at targets. However, games created with the limitations of the coarse grained accuracy of head-tracking can still be enjoyed by players. Formal experimentation will be needed to quantify this system's responsiveness, accuracy, and intuitiveness. However, the players' positive feedback about these attributes indicates that incorporating head-tracking into shooting games can provide an enjoyable and immersive gaming experience.

WiiDesktopVR is a technology demo. It was not intended to be a flexible system or library for use in other applications. As a result, we required some time to understand the code and recast it for our purposes. The code was, however, well-written and we did not need to modify the head/IR tracking code. To convert the tech demo into a shooting game, we added hit detection, projectiles, and particle systems code.

5. CONCLUSION

Recent technologies such as the Wii Remote and Wii Balance Board have popularized gesture and movement-based interactions with interactive systems. These systems require direct manipulation of a device.

Passive input devices such as eye and head-tracking systems are capable of capturing players' attention as input for applications. While novel, these systems are typically expensive.

Lee demonstrated how to create a low-cost head-tracking system with his WiiDesktopVR tech demo. This system was robust and its responsiveness was sufficient for typical video game applications. Using Lee's demo as a foundation we created Dodge It!, a simple shooting game that incorporates head-tracking technology. This game illustrates how certain pitfalls of eye-gaze based games can be avoided by separating player position/orientation from aiming.

Informal tests with Dodge It! reveal an enjoyable and intuitive gaming experience. Players with minimal training easily adapted to the ability to dodge projectiles by simply moving their body. They found the head-tracking to be responsive and perceived little to no latency.

Ideally, eye-gaze would replace aiming with a controller; however, with Dodge It! we have shown how to develop an enjoyable and immersive game within the limitations of a head-tracking system. Future work would involve experimentally quantifying this system's responsiveness, accuracy and intuitiveness.

6. ACKNOWLEDGMENTS

We would like to thank Rob Fletcher, Tad Stach, and Chris Wolfe for helping us with the game.

7. REFERENCES

[1] Ascension Technology Corporation. Flock of Birds. www.ascension-tech.com. 2007.

[2] Isokoski, P., and Martin, B. Eye tracker input in first person shooter games. In Proc. COGAIN 2006. Turin. September 2006.

[3] Lee, J.C. Head-tracking for Desktop VR Displays using the Wii Remote. www.cs.cmu.edu/~johnny/projects/wii/. 2008.

[4] NaturalPoint, Inc. TrackIR. www.naturalpoint.com. 2008.

[5] Nintendo Company Ltd. Wii Balance Board. www.nintendo.com. 2008.

[6] Parker, J.R. Games for Physical Activity: A Preliminary Examination of the Nintendo Wii, In Proc. IACSS 2007. Calgary. June 3-6, 2007.

[7] Smith, J.D. and Graham, T.C.N. Use of eye movements for video game control. In Proc. ACE 2006. June 14-16, 2006.

[8] Tobii Technology. Tobii Eye Tracker. www.tobii.com. 2008.

[9] Youngblut, C., Johnson, R.E., Nash, S.H., Wienclaw, R.A, and Will, C.A. Review of Virtual Environment Interface Technology, 1996 Institute for Defense Analyses, http://www.hitl.washington.edu/scivw/IDA/.