A Comparative Analysis of Fish Tank Virtual Reality to Stereoscopic 3D Imagery

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Abstract

Stereoscopy is commonly used in film and interactive media to provide depth perception, but is not the only method available to meet this need. This paper examines fish tank virtual reality as an alternative to stereoscopy. A study was conducted using three methods of depth perception projection: a stereoscopic image, a fish tank virtual reality (VR) image, and a combination of stereoscopic and the fish tank VR images. Results indicate that the combination of Fish Tank VR and stereoscopy was most preferred by participants, followed by the fish tank VR system for providing depth perception., The traditional anaglyph stereoscopy method was least preferred by the participants.

Introduction

Stereoscopy is the primary method in which to convey depth perception in film and interactive media, but can present a plethora of problems to individual viewers. A proposal of an alternative solution to depth perception is Fish Tank Virtual Reality, which is less expensive, easier to implement, and may span a larger audience. Fish Tank Virtual Reality is a perspective projection coupled to the head position of the observer.

Fish Tank Virtual Reality, Head-coupled Perspective, or Eye-coupled Perspective is the characterization of "systems where a stereo image of a three-dimensional scene is viewed on a monitor using a perspective projection coupled to the head position of the observer" (Mulder & Van Liere, 2000). In such a system, the illusion of depth is created through the use of tracking an individual's location in three-dimensional space and subsequently displaying the images with the correct perspective. Colin Ware, most notable for his endeavors into data visualization, coined the term "Fish Tank VR" in 1993 to overcome the seclusion created by other methods available at the time (Ware, Arthur, & Booth, 1993). Although Fish Tank Virtual Reality (known as Fish Tank VR from here on out) has been around for several decades, it has not received the same recognition as another form of viewing three-dimensional content— stereoscopy. Stereoscopy is defined as "exploiting human binocular vision to give the illusion of depth to objects in an image or video" (Autodesk, 2008). However, there are a number of issues surrounding stereoscopy; most notably are eye strain, headaches, fatigue, and binocular anomalies (Lambooij, Fortuin, IJsselsteijn, & Heynderickx, 2009).

Fish Tank VR touts several distinct advantages that are worth noting. These systems utilize higher resolutions, more brightness, increased crispness of images, and are more comfortable to wear (Demiralp,

Jackson, Karelitz, Zhang, & Laidlaw, 2006). Further, Fish Tank VR systems can be simpler, easier to implement, more versatile, and cheaper than other alternatives (Rekimoto, 1995). However, these systems are not perfect. In fact, they suffer from a limited viewing angle and a fixed location (Mulder & Van Liere, 2000). This limits the effectiveness and number of applications in which Fish Tank VR can be used.

The purpose of this research was to attempt to find a non-stereoscopic based viewing method for generating depth in two-dimensional imagery. Previous research has approached the subject with intent to analyze the effectiveness of virtual reality systems, stereoscopy, and a combination of the two. The most ideal situation for viewing content was found to be a combination of three-dimensional stereoscopic images and eye-coupled perspective (Arsenault & Ware, 2004).

Method

In order to accurately implement variations among viewing methods, a custom virtual environment was created. This would allow for modifications to the amount of depth, pivot point, and tolerance of the images to create an effective viewing method for individuals. In an effort to limit the amount of manipulated variables, modifications were not considerable between each viewing method. Each of the virtual environments utilized the same pivot point and distance between layers; the only major difference being the type of image (stereoscopic and non-stereoscopic).

Prior to testing, a pilot study was conducted to evaluate the necessary number of participants for the actual test. Taking a small sample of five individuals across the spectrum of college-aged participants, the necessary number was calculated to be around forty. This pilot study helped to solidify the testing procedures and ensure minimal revisions. The open-ended questions provided valuable feedback to strengthen the overall product before primary testing commenced.

Subjects

Before testing commenced, subjects were to be recruited from the 18-64-age bracket. However, due to a population of convenience, the average population was 21.7 years old. This population was chosen based on availability and willingness to participate, which meant that a majority of individuals were Purdue University undergraduate students. No individual assessment of knowledge based on the software was taken into account. In an attempt to test whether corrective lenses had an effect on preference or perception of depth, participants were asked to indicate whether or not they used corrective lenses. Participants were then divided into one of two groups: individuals that wore corrective lenses (thirty-four individuals) and those that did not (twenty-six individuals). Once the groups were established, participants were presented with the three viewing methods.

Hardware and Software

For testing purposes, three components were utilized to gather results: a Bluetooth driver, C# code, and a Nintendo Wii. Blue Soleil, the Bluetooth driver manufacturer, was chosen based on a recommendation from Johnny Lee. This allowed the Nintendo Wii remote to be synched to the laptop, thus giving it the ability to receive the data from the sensor bar and move the images on the screen (Figure 1). The C#

code was downloaded from Johnny Lee's blog and manipulated to fit the project's needs. Finally, the Nintendo Wii was used to power the sensor bar, which was attached to a hat for the participant to wear (Figure 2). The remote acted as a receiver, rather than a transmitter, which allowed for a fuller range of motion.

Procedure

This study consisted of an evaluation of participant's perception of depth and preference while viewing different visual methods (Figure 3). Participants took an initial survey prior to viewing the images (Appendix A). After each method was viewed, participants recorded answers via a second survey (Appendix B). All participants received the same survey and viewed the same three methods, albeit not in the same order.

Figure 1. Test Hardware

Figure 2. Participant Using System
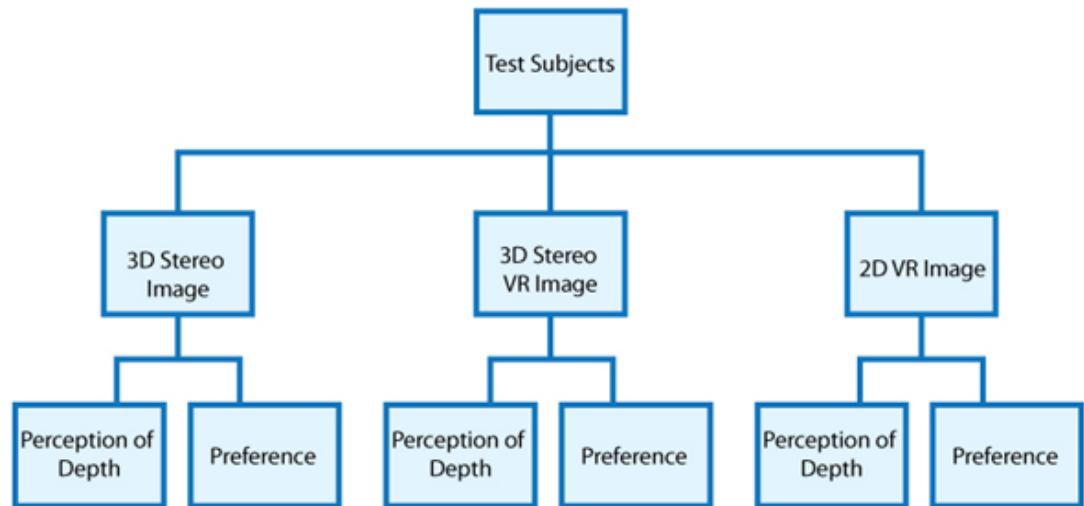
Figure 3. Study Methodology

The initial survey covered basic demographic information about each participant. This included gender, age, major, year in school, whether or not they had used virtual reality, whether they wear corrective lenses, and if they had eye problems. Participants were also asked their feelings about stereoscopy and were asked to rate it using the scale "I like it," "I do not like it," or "No opinion."

Upon completion of the initial survey, participants were asked to view three different viewing methods: a stereoscopic image, a Fish Tank VR system, and a combination of stereoscopic images and the Fish Tank VR system (Figure 3). The order in which participants viewed each method was predetermined and random. Participants were asked to record their preference and perception of depth—on a scale of 1 to 10—after viewing each method. To ensure participants did not suffer from a side effect—such as headaches, fatigue, or eye strain—while viewing the three methods, a break of one minute was provided after each method for rest. After viewing all three methods, participants were asked to provide input via open-ended questions.

Results

An Analysis of Variance (ANOVA) with three factors was chosen to analyze the data. The analysis showed that the combination of Fish Tank VR and anaglyph stereoscopy provided participants with the greatest sense of depth. The Fish Tank VR system alone was the second preferred viewing method when comparing depth, and the traditional anaglyph stereoscopy method was least preferred by the participants. The average number of users' perception of depth with the combination method was 7.5, the average for the Fish Tank VR method was 7.1, and the average for anaglyph method was 5.8. Upon closer evaluation, there was no significant difference between the combination method (7.5) and the Fish Tank VR method (7.1); however, they were statistically greater than the traditional anaglyph method (5.8). This suggests that the combination of Fish Tank VR and anaglyph stereoscopy and the Fish Tank VR methods can provide individuals with a greater sense of depth when compared to the traditional anaglyph method.

Using the same analysis test (ANOVA), preference for each method was calculated from the data. The analysis showed that the preferred method was the Fish Tank VR system, followed by the combination of Fish Tank VR and anaglyph stereoscopy, and traditional anaglyph stereoscopy coming in last. The average number of users' preference with the Fish Tank VR system was 7.7, the average for the combination was 6.8, and the average for anaglyph stereoscopy was 5.4. Further examination yields that each method was significantly different from the other.

After analyzing the data, it was shown that wearing corrective lenses was an insignificant factor in this study. The results did not show a significant difference between individuals that wore corrective lenses and those that did not.

Qualitative feedback was also requested as part of the survey when viewing the three methods. Due to the open-ended nature of the questions, participants had the opportunity to provide multiple thoughts to each of the three questions. As such, key words and phrases were extracted from the responses to find trends. The first question asked: what are some practical applications for this (Fish Tank VR) technology?

As shown in Figure 1, some answers were video games with twenty-seven (27) occurrences, film with thirteen (13) occurrences, simulations with seven (7) occurrences, and medical with seven (7) occurrences.

The second question asked: was there any physical discomfort experienced during this procedure? The answers would presumably be more clear-cut than that the previous question. The three most prevalent answers were eye strain with twenty-six (26) occurrences, none with twenty-two (22) occurrences, and wearing both the hat and glasses with seven (7) occurrences. Although this question did not ask participants to elaborate, most of the eye strain came from wearing the anaglyph glasses. More responses are shown in Figure 2.
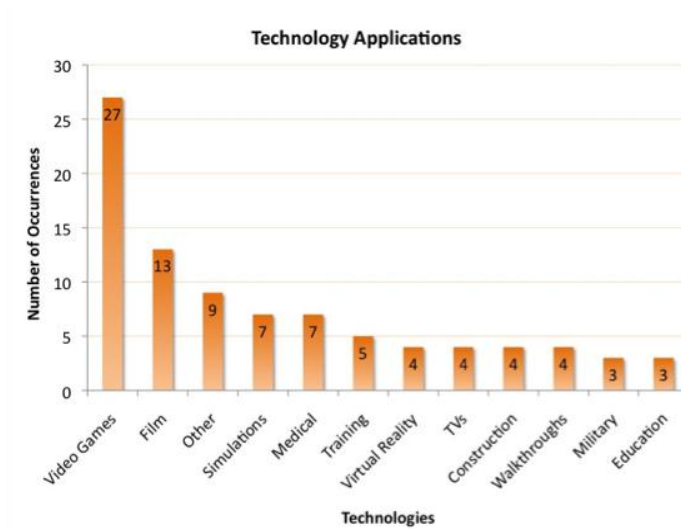
Figure 1. Potential applications for Fish Tank VR by participants
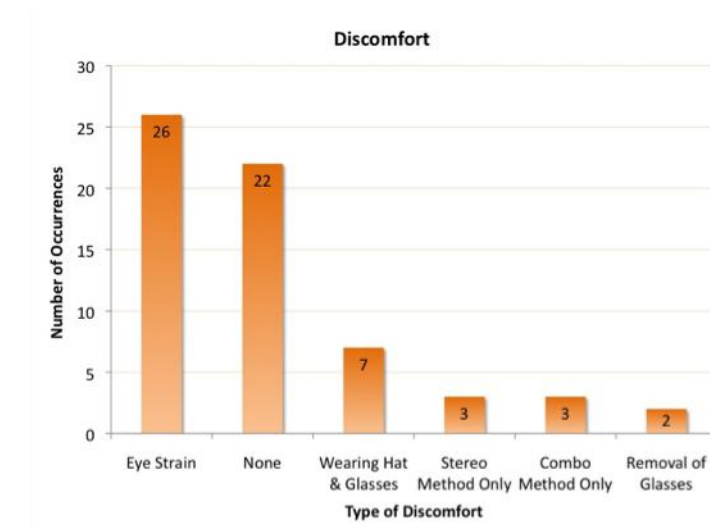
Figure 2. Discomfort while viewing the methods

Discussion

Perhaps due to the inexpensive nature or the lack of glasses, Fish Tank VR was shown to be a viable alternative to stereoscopy when focusing on a single image. Although "more and more studios are releasing animated and live-action feature films in stereoscopic 3D format" (Autodesk, 2008), Fish Tank VR could become the next pivotal method for creating and displaying depth in a virtual environment.

The aim was to find a viable alternative to anaglyph stereoscopy because of the continuing problems associated with the medium. Headaches, eye strain, fatigue, and binocular anomalies were all noted problems associated with viewing stereoscopic content (Lambooij et al, 2009; Cai 2010). By utilizing a Nintendo Wii, C# environment code, and a Bluetooth driver, research was applied for measuring the perception of depth and preference among individuals.

Based on the analysis, anaglyph stereoscopy was shown to provide participants with the least amount of depth and was preferred the least. Fish Tank VR had the second highest rating for perception of depth and was preferred the most among all of the methods tested. Although this only applies to a single image, recommendations were made to further enhance Fish Tank VR as a viable, and potentially effective, method for viewing three-dimensional content.

This research has potential for future development. With this research study, depth perception and preference were analyzed. Other variables could be tested, such as tolerance or distance of the participant relevant to the display device. In keeping with depth perception and preference, a further study could analyze other factors that might have an effect on these two variables.

The virtual environment code utilized in this study was prewritten and was modified to suit the project's needs. Interested individuals could test the same variables, but using a game engine or real time rendering engine. This would allow for research participants to see a three-dimensional model in real time and would also allow for viewing around objects in space. In this research project, the images appeared to have a cardboard cutout effect. By utilizing a game engine, scenes could look more three-dimensional.

Only one participant had the opportunity to view the Fish Tank VR system at a time. To optimize its use in a real world setting, the system must allow for multiple user input. This would either require a different camera and infrared light setup or multiple display devices. By having more than one individual view the system at time, more practical applications become available.

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Appendix A: Pre-Survey

EARLY BIRD STUDIOS

Demographics

Please mark where applicable:

1) Gender: _____ Male _____ Female

2) Age: _____

3) What is your major? : _____

4)   Freshman   Sophomore   Junior   Senior

5) What are your feelings about stereoscopic 3D?   I like it   I don't like it   No opinion

6) Have you used Virtual Reality before?   Yes   No   Unsure

7) Do you typically use corrective eyewear? _____ Glasses _____ Contacts _____ None

8) Do you have any existing eye problems or impairments, such as color blindness, glaucoma, etc?

_____ Yes _____ No

9) If yes, please describe briefly below:

Appendix B: Post Survey

EARLY BIRD STUDIOS

#_____

Question 1 - Preference
Please rank viewing method NUMBER 1, based on preference, on a scale from 1 to 10 (1 being the worst, 10 being the best)

1   2   3   4   5   6   7   8   9   10

Please rank viewing method NUMBER 2, based on preference, on a scale from 1 to 10 (1 being the worst, 10 being the best)

1   2   3   4   5   6   7   8   9   10

Please rank viewing method NUMBER 3, based on preference, on a scale from 1 to 10 (1 being the worst, 10 being the best)

1   2   3   4   5   6   7   8   9   10

Question 2 – Perception of Depth
Please rank viewing method NUMBER 1, based on perception of depth, on a scale from 1 to 10 (1 being the worst, 10 being the best)

1   2   3   4   5   6   7   8   9   10

Please rank viewing method NUMBER 2, based on perception of depth, on a scale from 1 to 10 (1 being the worst, 10 being the best)

1   2   3   4   5   6   7   8   9   10

Please rank viewing method NUMBER 3, based on perception of depth, on a scale from 1 to 10 (1 being the worst, 10 being the best)

1   2   3   4   5   6   7   8   9   10

Free Response
What are some practical applications for this technology?

Was any physical discomfort experienced during this procedure?

Are there any additional comments related to any portion of this procedure?