Measuring Game-play Performance and Perceived Immersion in a Domed Planetarium Projection Environment

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Abstract. Game playing in immersive projection environments such as caves and domes is assumed to offer an enhanced experience but there is little quantitative research that measures this. This paper reports on a study of user performance statistics while playing a computer game projected onto a planetarium dome and compares these with similar measurements taken in a conventional projected flat screen environment. A survey of users' subjective impressions of immersion was also taken and used to compare these display modes. Analysis of users in each mode revealed differences in user experience and some aspects of performance. It was confirmed that dome projection enhanced the player's sense of immersion when compared with flat projection. Navigation speed was found to decline in the dome while other performance metrics showed no significant difference between the environments.

Keywords: Dome-projection, computer games, user interfaces, immersion, game-play performance

1 Introduction

Planetariums have long been used to entertain, educate and excite their audiences. Digital projection systems have opened the full potential of a multi-media experience to planetarium audiences. The environment is dynamic and can now be interactive. Dome projection is perceived to offer significant advantages when used as a virtual reality display as its hemispherical nature engages the viewer's peripheral vision and more closely matches the natural world [1]. The migration of gaming into this environment is to be expected as players seek to enhance the game playing experience.

The cost of sophisticated dome projection equipment has been a barrier but a low cost dome projection system called "MirrorDome" [2] overcomes this to allow wider use of dome projection. MirrorDome uses a spherical mirror to reflect video from a single data projector onto a hemispherical surface. Content to be projected is first distorted in software so that the resulting projected image, after reflection from the mirror, appears undistorted on the dome surface. The Cube[1] game engine was selected for this study, firstly, because it provides a fisheye viewing option which is required as the first distortion in MirrorDome. Secondly, the Cube source code is

[1] http://www.cubeengine.com/cube.php4

available. This allows us to interpose another layer of distortion before the image is displayed. The low cost of this system makes dome projection viable for gaming arcades, home theatres, as well providing a cheaper option for virtual reality labs and workplace visualisation suites. The attractions of dome projection in terms of its usability and the level of immersion and enjoyment are generally assumed, without being widely researched. If possible, these should be measured to quantify the effectiveness of this mode of presentation for games.

Although these experiments were conducted using the first person shooter Cube game engine running on a Mirrordome projection system, we believe the results are applicable to any dome projection system running interactive content.

2 Background

2.1 Games in Cave/Dome Environments

Games are now joining simulations, visualizations and instructional presentations as content for immersive display environments. Immersive simulations/games such as low-end flight simulators, and sports games such as Golf[2], Grid-Iron Football[3] and Boxing games like 'Cyclone Uppercut' [3] fit somewhere in a continuum between serious training and pure entertainment. More commercial games such as Quake III (Cave Quake III) [4]and Unreal Tournament (CaveUT) [4] have also been produced in Cave and Dome display formats. There have been quantitative studies into user performance in Cave and virtual environments in general [5], but studies specifically relating to the user experience of immersive gaming tends to be qualitative [6] whether in cave or dome environments [7]. Caves and domes have been used in museums to project instructional content but we speculate that the engagement with the user will less than is typically found in games where there is a competitive personal stake. As games are much more engaging it can be expected that user experience will be heightened when playing in the larger dome of a planetarium.

2.2 Usability

Studies of immersive environments have revealed psycho-physical impacts such as simulator sickness and balance problems related to wide fields of view, [8].
Immersive imaging affects on cognition have also been studied [9] revealing limits on cognitive benefits of environments. The advantage of spherical projection seems to be limited to providing an immersive and engaging user experience rather than optimally transferring information. It is reasonable to expect these physiological responses and cognitive factors to result in differences in user performance when games are played in different visual environments.

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[2] http://www.sports-coach.com
[3] http://www-vrl.umich.edu/project/football/index.html
[4] http://www.visbox.com/cq3a/

2.3 Immersion.

Immersion is a subjective sensation that is more difficult to define and therefore less amenable to quantitative measurement. Immersion is said to be "the degree of involvement in a game" [7]. Studies into the use of game engines for visualisation of virtual environments report positively on user engagement when using wider fields of view [10]. It is reasonable to expect a similar response when playing games.

3. Experimental

3.1 Experimental method.

Twenty participants were recruited to measure performance and perceived immersion when playing the game in the dome and then with a flat screen. Males and females from age 18-34 (average age 22), with a broad range of skill levels at playing first person shooter (FPS) console games, took part. Each participant undertook two trials, each of two rounds. They first navigated a 3D maze built in the Cube virtual space. In the second trial they played Cube as a FPS game in a controlled virtual space. The first round of each trial used dome projection; the second used flat screen projection. Quantitative data was gathered by automatic logging of times and events when the maze was traversed and the game was being played. This data was extended by qualitative responses collected from the participants in a post experimental survey. The participants were divided into two groups of ten to perform the trials in each environment. The first group began the trial in the conventional display environment while the other group used the dome projection first. This was done because it was expected that they would become better at performing the task at the second attempt no matter what the environment.

Four metrics werecaptured by instrumentation of the program and logging of user scores. These four are abstracted under the heading 'game-play performance'

The performance metrics were;

1. **Navigation (**n), measured by the time taken to navigate the maze.
2. **Accuracy** (a), measured by the ratio of opponents hit (h) to the number of shots (s) fired by the player, expressed as a percentage.
3. **Dodging ability** (d), measured by the ratio of the number of hits (h) suffered by the player, divided by the shots (s) fired at the player by opponents, then subtracted from one. This is expressed as a percentage.

   $$d = 100(1 - h/s)$$

4. **Number of opponents destroyed** (Frags) Opponents destroyed by the player.

3.2 Projection Environments

Two display environments were used in this study. The first used the MirrorDome projection system with an 8m diameter dome in a small planetarium. The second environment was in the same location but with a rectangular image projected onto the side of the dome instead of covering the entire surface. This method of rectangular projection was chosen because it made the image closer in size and orientation to that of dome projection. All other environment variables were kept constant (e.g. sound system, ambient lighting, seating position, and computer and projection hardware). This was done to limit the degrees of freedom in the experiment to one, the display mode.

The Cube game was instrumented to collect game-play statistics while the participants played, and data was also gathered from a questionnaire completed by the participants after the tests.

Each participant was told that their accuracy was being logged and was instructed to be as accurate as possible to discourage them from firing continuously or randomly when not under threat, as this would have distorted this measurement.

The dodging factor measures a player's ability to avoid being hit by opponents. This factor is less meaningful than the accuracy as the participant had no control over the accuracy of the opponents. It also depended on their movement through the task.

3.3 Measurement of usability

Navigation. In the first trial users traversed a maze to test navigation speed. The maze was identical for all users and in both modes. Arrow images were placed on the walls to act as visual cues. The instrumented game engine logged the time taken to reach the end of the maze.

The Death Match. The remaining three metrics (Accuracy, Dodging and Frags) were measured in the second trial where the Cube game was played in a controlled virtual world containing wide corridors where the participant had to shoot, and avoid being shot by, opponents while moving to the end point.

A custom map was created within the game specifically for this trial, so that all users met the same opponents in about the same locations. The map consisted of three long, wide corridors with opponents spaced at even intervals on random sides of the corridor. The participant encountered the obstacles in sequence but, because of the width of the corridors, was still required to aim the gun at different areas of the map. This made the accuracy measurement more meaningful.

4 Results

4.1 Quantitative measurements.

The pairs of data sets for each of the measured quantities were analysed using the non-parametric Wilcoxon signed ranks test with 'Analyse-it' software. This was applied to identify any statistically significant differences in performance between modes in each of the four categories. The performance results of two participants were outside two standard deviations of the mean and were discarded as outliers. The results are shown in Table 1 below. Differences are calculated by subtracting the Flat screen measurement from the Dome measurement.

Table – 1. Analysis of logged performance data

	Difference of means	W+ W-	1 Tailed p	Better performance
Navigation time	4.2sec	102.5 33.5	0.034	Flat p<=0.05
Accuracy	4.2%	52 119	0.08	Not sig p>=0.05
Dodging	3.27%	69 102	0.25	Not sig p>=0.05
Frags	0.167	41 37	0.45	Not sig p>=0.05

The analysis reveals that navigation speed is significantly better in the flat screen mode. The other metrics showed no significant difference in performance between display modes.

4.2 Qualitative Survey results

The participants were invited to provide a subjective evaluation of Navigation and Orientation, Sense of control and Sense of immersion in each environment. Each question was presented as a Likert scale. They also had the opportunity to make free text comments. A short summary of these

Navigation and orientation. Participants rated the ease of navigation and orientation to be higher in the flat screen environment. Some participants commented that they felt disoriented in the dome display.

Sense of Control. The overall feeling of navigation control confirmed that participants felt more in control on the flat display than on the dome display.

Sense of Immersion.The sense of immersion was reported to be higher in the dome display than in the flat display.

5 Discussion and conclusion

This study confirms that dome environments do not hinder player performance in three of the four performance metrics. The exception of poorer navigation performance in the dome environment may be plausibly explained as the full surrounding visual space is more difficult to monitor during game play and navigation may suffer as a result. This conjecture is supported by some players who commented that a in a surround display, parts of the game action are necessarily out of view. It also suggests that games need to be designed specifically for immersive environments rather than simply modifying existing games that have been designed for a flat screen environment. Other comments concerned the placement of HUD information and the lower brightness and contrast levels in the Dome environment.

Participants reported the sense of immersion, to be much stronger in the dome than with the flat screen and that this contributed to the overall enjoyment of the experience. One participant commented that they felt closer to the dome display. The physical distance between displays was kept constant for all experiments but this comment was most likely a way of expressing the feeling of immersion experienced when viewing the dome display. The dome gives the illusion of drawing the user closer to the projection surface. This could be a result of either the wide field of view, the size of the display, the fact that the display surrounded the user or a combination of all these factors.

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