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EDITOR'S CORNER

The major mission for the Advanced Distributed Learning (ADL) initiative is to make it possible to deliver learning materials anytime, anywhere, and to anyone seeking them. Naturally, therefore, ADL is interested in any technological innovation to facilitate that. At the last meeting of the American Educational Research Association I attended a session devoted to showing how instruction can be delivered in an innovative environment: digital domes. The developers erected a dome, an inflatable tent, accommodating up to 20 or so people in one of the meeting rooms (See Figure 1). They showed how people might learn about ancient civilizations by displaying actual ruins of the civilization right in the dome, giving attendees a sense of actually being there. I asked Jeffrey Jacobson, Director of Public Virtual Reality to prepare a manuscript on the domes, which appears to the right.

As always, please send me any comments, questions, or suggestions and they will be considered for

Dome Theaters for Education

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Introduction

Enabled by advances in graphics technology, interactive media is expanding into new venues and formats. One exciting area of innovation is the new generation of Digital Dome theater, panoramic displays that surround the audience with an inside view of some virtual world or object. It reveals structures that are not otherwise easy to see, and it also produces a compelling experience of presence, the feeling of being there in the projected scene. Most are *Full Dome* theaters, featuring a tilted hemispherical screen over the audience's heads (Lantz, 2007), but they can also be a section of a cylinder, a section of a sphere, or even a very large flat screen with the seats up close. We would like to call them *visually immersive displays*, which provide visual immersion for the audience. In the literature, they are also called "Giant Screen" displays (Fraser et al., 2010), but the term could apply to small portable domes capable of traveling to K-12 venues (Sumners & Reiff, 2005). See Figure 1 for an example of a portable dome made of cloth. It is an inverted cup (no bottom) kept inflated by an outboard fan.

Figure 1 - Discovery Dome by E-Planetarium (E-Planetarium, 2011)

The projection system for the dome shown above may be seen in Figure 2.

inclusion in future issues of the Newsletter

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Figure 2 - Discovery Dome projection system.

We recommend Lantz's overview of the current state of dome theater technology and usage (Lantz, 2007, 2011). In this article we will introduce the basic concepts from an educational perspective. We will also characterize the relevant educational theory and practice.

Background

First on the scene, were planetaria with optomechanical projection systems, which project a night sky star field while other devices (e.g. slide projectors) depict stellar phenomena. They became popular with Karl Ziess' system, invented in 1923, but the historical precursors are much older (McConville, 2007). The show is usually under the control of a live presenter who interacts with the audience controlling the projections during the presentation. Very few new theaters are built with this technology, but many are still in use (Bruno, 2008; Lantz, 2011).

In the early 1980's, a new generation of dome movie theaters was developed (e.g. IMAX) which used multiple projectors to fill the dome with a panoramic image. Their era began with the Digistar system in 1983. The movie is a single linear experience, like a traditional movie (Bruno, 2008), mostly made from live action footage (Lantz, 2011). Although these domes usually present documentaries, many Hollywood movies are produced in both regular and dome compatible format.

Dome-based video presentations inherit all of the educational advantages one gets from a projection screen or computer monitor. They can show distant or long disappeared places; visualize scientific concepts; show things that are too small, too big, or too dangerous to see in real life. They include audio information, which supports the visuals, and depicts familiar things in a new way. Ultimately, the success of the presentation depends on the quality of its narrative and how it fits the educational goals of its environment. We recommend Fraser's overview of the educational research around linear presentations in dome format films (Fraser et al., 2010).

Interestingly, the very wide view visual format does require different treatment by the cinematographer for best results. For example, the audience can see more of the virtual landscape or world depicted in the film with a single view, a broad panorama. This allows the filmmaker to use less "pan and scan" techniques and fewer changes in view point. Also, the dome audience will be able to tolerate less camera movement because of motion sickness induced by visual flow in their peripheral vision.

The New Digital Domes

While there are still thousands of optomechanical and IMAX-like dome theaters, a new generation of all-digital domes is rapidly outpacing them in installations and usage. These new domes are controlled by computers, which support linear movies, but also real-time generated computer graphics and interactive content (Lantz, 2007, 2011). There are also small portable domes suitable for visits to K-12 schools, often as part of a museum-based outreach program (Sumners & Reiff, 2005). Skillfully handled, the interactivity can be part of an immersive narrative (Apostolellis, 2010; Lantz, 2011), which in turn can be part of a larger curriculum.

For example, a digital dome can produce a star field under the control of a live presenter just like the old planetaria. The presenter can answer questions from the audience, s/he can move the display in real time to focus on objects of particular interest, relate the experience to things outside of the planetarium, and so on. For astronomy, digital domes have the added advantage of being able to visualize alien landscapes or stellar phenomena on a large scale (Wyatt, 2005). Another application would be to visualize physical landmarks that Native Americans would have used to measure movements of the stars.

In another example, Handron & Jacobson (2010) describes a virtual Egyptian temple that is thematically tied to the physical Egypt collection at the Carnegie Museum of Natural History in Pittsburgh. A presenter gives regular tours of the virtual Temple in their partial dome display, the Earth Theater. S/he can also lead discussions, recruit audience members to act out Egyptian themes, work with props, and so on. This is considered part of the regular Egypt collection and tied in with their K-12 related daytime programming.

Theoretically, a digital dome is a large-format computer monitor, so it could sustain any kind of interactivity ordinarily seen in a computer game or virtual reality application. In practice, the interaction is group oriented, because everyone shares the same virtual environment. Also, interaction design for a dome often has to be somewhat different.

For example, a standard method of navigation in a first-person-shooter game is for the cursor to be in the center of the screen at all times. When the user wants to look in the direction, s/he rotates the view. When the user wants to *move* in a direction s/he must rotate the view to point there, then trigger a forward movement command, usually by holding down a key on the keyboard. To select an object, the user centers the cursor (and the view) on the object of interest and presses a different key. This works well in hundreds of computer games, but in our personal experience, it works rather poorly in a dome. Having to constantly rotate the view simply to select objects is disorienting. In our experience, the user does much better if s/he employs separate navigation and selection mechanisms.

There are many possible applications (Apostolellis, 2010; Lantz, 2011; Yu, 2005). Audiences can "vote" on questions posed by a presenter by holding up colored paddles, which are read by a camera and processed by computer. Uniview (scalingtheuniverse.com), is a tool developed by the Elumenati (Eluminati, 2011), which allows a remote presenter to control a dome show via an internet link. The *Gates of Horus* game by PublicVR allows a single user or presenter to click on features of a virtual Temple using a cursor drawn on the dome screen. Selecting an object prompts an animation of an Egyptian priest to explain what it is (Jacobson, Handron, & Holden, 2009). Finally, a remote presenter or even a local puppeteer can control one or more avatars, which can then interact with the audience. This is an example of *telepresence*, more commonly associated with applications under the name *virtual-reality*.

Virtual Reality

The development of digital domes has occurred in parallel with the development of visually immersive VR applications. They too employ displays that fill the user's field of view, usually a Head Mounted Display (HMD) or a CAVE™ (Cruz-Neira, 1993) (like a digital dome except cube shaped), a flight simulator, or even a digital dome. The difference is that VR applications are almost always intended for a single user, providing a high degree of interaction with an imaginary virtual world through control devices. For example a "data glove" and the correct software support allows the user to touch, feel, and manipulate virtual objects. However, it is possible to use a digital dome as a display for a single person, creating an application much more like traditional VR than like a typical dome presentation.

By the year 2000, the term "Virtual Reality" (VR) had stretched to include online virtual worlds such as *Second Life* or *World of Warcraft*. The user interacts with a persistent online, shared virtual world through his/her desktop computer. A better and more specific term is MUVE (Multi-User Virtual Environment) (Dede, et al., 2000). A great deal of educational research is currently being conducted with this type of VR, and much of it describes the user experience as "immersive". However, they are really referring to ***narrative immersion*** where the user is drawn in by the story/action/curriculum. Conversely, when (Fraser, et al., 2010) use the word "immersion", they are actually referring to *visual immersion*.

Another important trend is the growth of *augmented reality* applications, where the user interacts with some mixture of virtual and physical objects. This work is interesting and important, but beyond the scope of this article.

Beginning with flight simulators in the 1950s, visually immersive displays have been heavily developed and researched for training. We define training to mean learning how to perform some specific task, like flying a plane, engaging in combat, doing surgery. The VR training literature in these topics is vast (e.g. Seymour, 2008). There have also been hundreds of applications for education in the kinds of topics one associates with museums and schools, but research has been scant (Jacobson, 2011).

Presence

Performance: A Workshop Report (Sep. 2009).

Training Evaluation Information on the ADL Website (Feb. 2008).

Video Games to Assess Learning (Mar. 2011).

Web 2.0 and ADL (June 2008).

Newsletter archives, as well as the current issue, are available in the archive.

Those who are active in the world of digital domes believe that (1) sensory immersion raises observers' sense of presence, the feeling of being *there* in the virtual world of the movie or virtual environment, (2) the increased sense of presences enhances engagement, and (3) the increased engagement enhances learning (Fraser, et al., 2010; Yu, et al. 2009). The research community around visually immersive VR believed essentially the same thing during the 1990's, when most of their papers on its use for education referred to presence, including nearly all of the 14 empirical experiments we are aware of (Jacobson, 2011). They argued that presence focuses the student's mind on the learning task and structures the interaction in a natural way.

However, research by the VR community did not find a causal connection between presence and learning outcomes. Byrne (1996), Moreno (2002), and Rose (1996) all based their learning experiments with sensory presence as the independent variable and found no effects. The problem may have been that *presence* was too poorly defined, leaving no good way to test for it (Bailenson et al., 2008; Slater, 2004). Other possibilities are (1) that learner engagement causes presence, not the other way around (2) both have a common root in the immersive visuals (3) the causal relationships between presence, engagement, and immersive visuals are complex, requiring a more detailed understanding to support research.

Slater (Slater, 2009) provides a good overview of the topic and his own efforts to achieve a more stable definition of presence. He makes a distinction between the type of presence achieved through sensory immersion and the engagement one develops toward a character by role-playing it in the context of some narrative. Others retain a broader definition of presence, but posit a more stable theoretical foundation (Chertoff & Schatz, 2008). We believe that *presence* is a real phenomenon and that its relationship to learning is still to be established by further research.

The Inside View

The broad field of view produced by dome displays creates unique educational opportunities. To quote Fraser (Fraser, et al., 2010; Jacobson, 2011):

> *After more than thirty years of research, it has become clear that immersive environments enhance science-learning outcomes. The literature suggests that the sensory provocation, in combination with sensation of being within an experience rather than observing that experience from outside a frame has both cognitive and affective impacts.*

For example, a panoramic interior (egocentric) view can help the audience better see the internal structure of the human heart, a geological formation, the constellations of the night sky, or the spatially highly organized iconography of a Catholic Cathedral. Different things become apparent or more readily accessible with a full "egocentric" view of some phenomenon (Jacobson, 2011), especially when combined with external views (Salzman, et al., 1999).

One can take this argument further to say that visual immersion is beneficial when the visualization shown on the screen is best seen in a single piece, or at least larger pieces. The classic example is a depiction or projection of the night sky on the interior of the dome. Understanding the spatial relationships of the stars to each other is much easier if one can see the whole thing at one time. Similarly, skillful use of the digital dome has been shown to help students learn the difficult concepts around the Earth-Moon-Sun system (Yu & Sahami, 2008).

In another example, primitive peoples used mountains and other landmarks on the horizon line to measure the rising and setting of the sun moon and stars at different times of the year. More civilized peoples built observatories like Stonehenge, which were very precisely arranged to support measurements of celestial movements. With a digital dome, we can visually place the observer inside a 3-D simulation of one of these ancient observatories complete with the night sky. The modern observer can then use the simulation in the same way ancient people used the real ones by lining up stars with the features of the observatory.

Conclusion: Comparative Studies Are Needed

It is one thing to show that a media format supports learning, and quite another to show how or when it is desirable over other formats. Students will learn *something* from almost any exposure to educational materials, and digital domes are much more expensive than a standard projection screen. Unfortunately, there has been far too little comparative research looking for evidence to justify the use of digital domes (Fraser, et al., 2010; Jacobson, 2011). Research for educational topics in visually immersive VR is similarly lacking.

More research is needed, because some educational topics will be sensitive to visual immersion, and others will not be. As yet, there is no established guiding theory, but we can make some educated suggestions on what a visual-immersion sensitive topic would look like

1. There must be three-dimensional imagery, which is relevant to the topic, if not central.
2. There must be something about the informational structure of that imagery that gives the viewer an advantage when s/he can see it in a panoramic view. Otherwise, one could just as well view it on a computer monitor.
3. The user must be able to interact with that imagery in some meaningful way.

Success or failure depends on the pedagogical design. The visual immersion must support some part of the learning tasks the student must perform. Even where visual immersion is helpful or useful, the educator must decide whether employing it the curriculum is cost-effective. We continue our research to help educators and educational researchers with these questions.

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