Immersive Scientific Visualization in Education, Storytelling and Art

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Scientific visualization is regarded as a tool for scientists to represent, investigate and understand complex data. Much of the knowable universe can now only be experienced and understood through scientific visualization, making this an essential modality for sharing our expanding view of the physical universe with non-scientists. Through education, storytelling and deeply engaging art, nonscientists assist in the assimilation of scientific knowledge into deeper personal and cultural meanings - fueling an expanded cosmology or "world view" - in ways that scientists cannot. Group immersive visualization environments, particularly "fulldome" or digital dome theaters, are powerful venues for the dissemination and assimilation of new scientific understandings into personal and cultural cosmologies. Recent trends in digital planetarium programming are discussed along with the need for scientific visualization in digital domes.

1. Introduction

In 1987 McCormick defined scientific visualization as "the use of computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results [1]." The implication is that scientific visualization is an aid for *scientists* in understanding simulations of physical phenomena. Indeed, computer visualization techniques have been extremely successful in advancing numerous fields of science, ranging from physics to chemistry, biology, materials science, earth science, cosmology and astrophysics. Practical applications of data and information visualization include engineering, medicine, nanotechnology, gas and oil exploration and pharmaceuticals.

It might be argued that much of the universe can only be known through the tools of scientific visualization. From the large-scale structure of the universe, to galaxy collisions, fluid flow, down to atomic models and quantum phenomena, scientific visualization provides scientists with windows into phenomena that are either too large, too small, too fast or too slow to directly observe. While scientists are rightfully tasked with opening these windows into the knowable universe, such windows should not be reserved for scientists alone. It might even be argued that the highest role of science is revealing the mysteries of the universe and rendering them understandable and accessible to all humanity.

Recent advancements in digital planetariums (often referred to as “fulldome” theaters or “digital domes”) now allow the rapid and affordable dissemination of scientific visualizations in a powerful immersive format [2]. Artfully combined with narrative, music and surround audio, the format provides a compelling medium for the public assimilation of scientific knowledge and visuals into deeper personal and cultural meanings and realizations. The medium fosters an expanded cosmology or “world view” for individuals based on scientifically inspired simulations of phenomena that lie beyond our everyday experience.

2. Digital Domes

Digital planetariums are essentially group immersive visualization environments capable of navigating audiences through real-time and pre-rendered scientific and information visualizations in addition to other programming. The planetariums of the world are rapidly converting into digital domes. There are currently 519 fulldome theaters listed in Loch Ness Production’s *Fulldome Theater Compendium ONLINE!* [3]. In 2008 alone over 170 additional digital domes opened, ranging from large public facilities in major metropolitan areas, to small school planetariums, to even smaller portable domes. Many were optomechanical planetariums that added digital projection capabilities or completely converted to digital. There are over 3,300 planetariums worldwide serving 110 million visitors annually – approximately 16% of these domes are now digital. The trend towards digital is expected to continue and possibly accelerate in the coming years.

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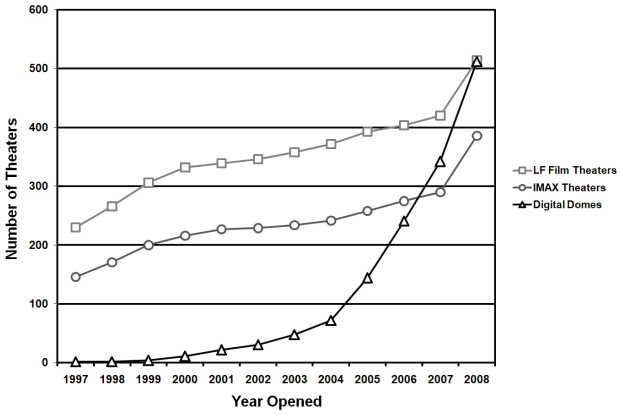

Table 1. Worldwide growth of digital domes. (courtesy Visual Bandwidth, Inc.)

Most digital planetariums systems sold today are capable of navigating, in real-time, extensive 3D models and simulations of the known universe including simulated spaceborne views of the Earth using data from MODIS sensors on NASA's TERRA and AQUA satellites, satellite and space debris tracking, simulations of planets and their moons, nearby stars from the Hipparcos and Tycho-2 3D star catalogs, the Tully and 2μm All-Sky Survey galaxy datasets, multi-wavelength skies, deep-space quasars and the microwave background radiation all-sky image captured by the Wilkinson Microwave Anisotropy Probe (WMAP). These datasets and simulations can be navigated in real-time with the help of a live presenter, or rendered into a show. The most popular collection of datasets for digital domes is the Digital Universe Atlas from the American Museum of Natural History's Hayden Planetarium. This curated package of "data products" is distributed by major fulldome vendors who offer the capability to navigate the datasets in real-time on their server clusters with their own value-added features.

Digital planetariums have naturally placed emphasis on astronomy because planetariums historically emerged as domed simulations of the celestial sphere. However, naked-eye astronomy is only a narrow branch of astronomy and astrophysics, which is only one branch of physics, which itself is only one of the sciences. In these difficult economic times, many digital planetariums find success by expanding their programming into other sciences and even into arts and humanities. Interestingly, scientific visualization has much to offer in all these areas. Digital domes provide a compelling opportunity for the scientific visualization profession to grow while fulfilling important cultural needs.

3. Education

Efforts have been underway over the past decade to increase the role of scientific visualization in the classroom [4]. Scientific visualization tools used by scientists are often inappropriate for students because of their reliance on specialized knowledge of expert users, and the need for high-end technology infrastructure and specialized training of instructors in schools. Digital planetariums allow concentration of classroom-based scientific visualization efforts into a single, powerful group visualization theater.

Besides applications in scientific discovery, engineering and technology, the most widespread application of scientific visualization is informal science education, including science documentaries, television programs, IMAX films and digital planetarium programs. One of the leading scientific visualization teams in the U.S. is the National Center for Supercomputing Application's Electronic Visualization Lab led by Donna Cox. Located on the campus of the University of Illinois at Urbana-Champaign, Cox's team has provided visualizations for IMAX films, digital planetariums, HD documentaries and more [5]. Topics include atmospheric imaging, cosmology, oceanography and astrophysics. These programs weave visualizations into journeys or storytelling themes.

4. Storytelling

The presentation of scientific visualizations in a theater setting presents some unique challenges, especially when simulating a journey where storytelling is the focus rather than the data themselves. Scientific visualizations become scientifically accurate props, settings, or special effects. Absolute accuracy may take second place to "look" and "feel."

In some cases, "best guess" spatial or temporal extrapolations of datasets are required. Examples include creation of a complete navigable model of

our own galaxy (which cannot be fully imaged from our position in the spiral arm), or recreation of nebulae with large error bars on star positions (forcing assumptions about star positions).

In other applications astrophysical simulations are possible, as with solar system formation, black hole visualization, galactic collisions or early evolution of the universe. In cases where insufficient data exists and simulations are unavailable, artistic license must be employed based on the best data available in the tradition of astronomical art [6]. Examples include a simulated sub-surface expedition to Europa or journey to an extrasolar planet.

5. Art and Culture

Because planetariums are science-focused institutions, it is natural that a blend of art and science would emerge as a popular means of cultural entertainment under the dome. So-called "ArtScience" or "SciArt" productions are steadily gaining in popularity in the U.S.

Art and music are powerful modalities for stimulating unique neural states associated with affective educational and cultural entertainment goals. Music is especially well known to be a powerful mood-altering agent [7]. Beautiful nature scenes have been shown to lower blood pressure and reduce stress [8]. Immersive SciArt presentations are especially powerful, drawing upon the awe-inspiring natural beauty of the universe as depicted in scientific visualizations. It is difficult to ignore the parallels of immersive ScArt to opera's formation in the Reniassance by the Florentine humanists who gathered as the "Camerata de' Bardi" and sought to uplift humanity through beautiful, enriching art.

One example of a SciArt production is *Bella Gaia*, a touring planetarium performance and collaboration between Carter Emmart, director of astrovisualization, and creator Kenji Williams [9]. The production seeks to trigger the "overview effect" in planetarium visitors, an experience reported by some astronauts who experience lasting affective shifts from seeing the earth from orbit [10]. It is hoped that the exposure to this experience will expand nonscientist's view of the earth as an interconnected biosphere and invoke "conservation consciousness" without a lecture on the importance of recycling or environmental responsibility.

Fig. 1. Kenji Williams performs *Bella Gaia* (photo courtesy Remedy Arts)

In the Bella Gaia performance, classically trained violinist Kenji Williams performs live over looping electronic beats while audiences gaze at the earth from space produced by SCISS' Uniview using JPL's OnEarth and NEO datasets. Occasional excursions to the earth provide a multicultural dimension to the piece. NASA Astronaut Piers Sellers, upon seeing the production, said "BELLA GAIA is Just Beautiful. It really felt like I was back in space." Bing Quock, Assistant Director of the Morrison Planetarium at the California Academy of Sciences, said "I believe Bella Gaia can be a truly transformative experience that inspires people to think of our world as not a collection of countries and regions but as ONE place, and to be more aware of the alarming fragility of our planet."

Another SciArt collaboration is First Friday Fractals, presented by Jonathan Singer of the Fractal Foundation at the New Mexico Museum of Natural History and Science in Albuquerque, NM. This extremely popular program combines a presentation on fractal science, and a visual journey through infinitely complex fractals set to music [11].

6. Personal cosmology

Cosmology is the study of the universe in its totality, including humankind's place in the universe. Cosmology originated in ancient civilizations including the Egyptian (c. 3150-31 BC), Babylonian (c. 2300-500 BC), Mayan (c. 2000 BC to 250 AD), and Greek (c. 2000-146 BC) civilizations. Religions

have historically been the keepers of cosmology, using art, literature, and storytelling to communicate their world view. Architecture has also played a prominent role, with awe-inspiring cathedrals, temples and mosques immersing their subjects in rich religious symbology and metaphor. These various modalities (art and music, literature, architecture and storytelling) facilitated the assimilation of religious "knowledge" into deeper personal and cultural meanings, forging a religious cosmology that remains deeply infused in our world cultures even today.

Science has now taken its place as the institution responsible for defining at least the physical origins and evolution of the universe – a physical cosmology. Yet, despite the best wishes of many science educators, the personal cosmologies of non-scientists continue to be steeped in metaphysics, a multitude of world religions, and esotericism which often compete with the views commonly held by mainstream scientists. For a given individual, these world views intertwine into a "personal cosmology" or overall world view.

As science expands the known universe, new cosmologies are born, sometimes revising metaphysical, religious or esoteric notions – at least for the scientists who are exposed to these discoveries. Some have called for a new cosmology that weaves the many revelations of science into an integrated whole [12-14]. In this sense, digital planetariums are not unlike the cathedrals and temples of the past, using art, music, storytelling and powerful visualizations to immerse visitors in a scientific world view. Assisting the assimilation of scientific knowledge into deeper personal and cultural cosmologies is a task that lies beyond the purview of scientists and, at times, even beyond educators. At the extreme, it lies in the realm of poets, artists, and storytellers who can bring new realizations to life, providing them with context, emotional meaning and deeper personal value.

7. Conclusion

If we are to realize the full value of scientific visualizations, we must not limit their access to scientists, engineers and educators alone. Storytellers and artists play a vital role in the dissemination and assimilation of new scientific understandings into personal and cultural cosmologies. Digital planetariums combine these modalities in a powerful group immersive setting, and represent a growing demand for scientific datasets, simulations and visualizations.

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