Towards an academic praxis for domed virtual environments

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Abstract

This paper sets out the current state of activities for the domed virtual environment located within the University of Plymouth, UK. Some of these activities have arisen through reactions to demands on the dome. Some, particularly those concerning students education, have arisen by design. The paper describes the theoretical frameworks, curricula, methodologies and tools that have emerged, and suggests that these are first steps towards what might be termed a praxis of domed virtual environments.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality H.5.1 [INFORMATION INTERFACES AND PRESENTATION (e.g., HCI)]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1. Context

Domed Virtual Environments exist at the intersection of many media types. They are part Cinema, part simulator and part visualisation. The most familiar use, is as a Planetarium. Traditionally these were, and in many cases still are, based on opto-mechanical projection devices - where each feature in the night sky is generated by a dedicated light source. Connected to what amounts to a precision made orrery. For the University they represent a technological and media culde-sac. They are geocentric - in that they are limited to a simulation of the night sky as seen from Earth. The advent of analogue, digital and latterly laser projection technologies has given rise to a much wider potential for content creation. These technologies, are often referred to as 'fulldome' reflecting their ability to illuminate the whole of the domed screen as an array/matrix of infinitely variable pixels. 'fulldome' is a nebulous term, hybrid domes which couple opto-mechanical and video projectors blur the line. For the purposes of this paper, 'fulldome' serves to demarcate any system capable of projecting real-time or pre-rendered video. Here there is a convergence with cinema and other Virtual Environments. As fulldome borrows technologies and approaches from Cinema, Gaming Consoles etc, the motivations, content and techniques also arrive - largely with their cultural contexts and critical theories intact. In the absence of a language of fulldome, in the sense that there is a language of Cinema, it tends to borrow from the fields that donate their technologies - Be that gaming environments, simulations ported from CAVEs or 3D animation. The University has existing expertise in these areas in i-DAT (Institute of Digital Art and Technology). i-DAT is a 'Centre of Expertise', and acts as a hub for creative research and innovation across the fields of Art, Science and Technology.

2. Theoretical Framework

Domed virtual environments have unique characteristics that set them aside form other immersive environments, and as such have been historically neglected by the academic community. Despite a lack of literature, much can be reappropriated from other research into experiences which are technologically mediated. First though, domed virtual environments must be correctly located both taxonomically and socially. Milgram [MK94] has suggested was he calls the "Virtuality Continuum" as a taxonomical device. Domed virtual environments would fit neatly into this continuum somewhere near a CAVE. Whilst they may seem to provide a lesser sense of immersion due to lack of binocular cues, the lack of glasses impinging on the viewer's perception, and shared nature of domed virtual environments would suggest that the sense of immersion might be equal or even increased for certain applications. Indeed it is interesting to look at original CAVE proposal by Cruz-Neira et al, from Siggraph in 1993:

> "One rarely noted fact in computer graphics is that the projection plane can be anywhere; it does not

> have to be perpendicular to the viewer (as typical on workstations, the HMD, and the BOOM). An example of an unusual projection plane is the hemisphere (like in Omnimax theatres or some flight simulators). However, projection on a sphere is outside the real-time capability of the ordinary high-end workstation. And, real-time capability is a necessity in VR." [16693]

These technological considerations have ceased to exist for lower resolution, smaller screened domed virtual environments - such as Plymouth's IVT. Would a hemisphere be the natural choice if CAVEs were emerging today? perhaps the richest vein of research into virtual environments is the presence community.

A central principal, which unifies the scope of this interdisciplinary approach, is that cognition is recognised as a cultural, socially distributed and embodied phenomenon. This perspective rejects a separation of mind and body, in favour of a view of consciousness as a parallel development of cognition, perception and action. Distributed and embodied theories hold that thought and knowledge do not occur separately, but take place within the context of our semantic knowledge of, and interaction with, our environment, objects and other people. [Hut96] [VTR93]

Presence as a body of work is a study of perceptual processes in mediated environments. Presence is conceived in multiple, overlapping terms, but is singularly defined as 'being there' and is the application of social and cognitive psychology to technologically mediated experiences. The degree of presence in a given environment inversely correlates with degree of awareness of the mediation.

> 'Perceptual immersion, "the degree to which a virtual environment submerges the perceptual system of the user" (Biocca & Delaney, 1995 cited in [LD97]), can be objectively measured by counting the number of the users' senses that are provided with input and the degree to which inputs from the physical environment are "shut out" (Kim, 1996 cited in [LD97]). Not only immersive virtual reality systems but also simulation rides, IMAX theatres, and even standard movie theatres can be said to immerse the senses of media users [LD97].
> The question of "presence" arises for virtual environments (VEs) because VEs override sense impressions from the real world with those generated by computer display systems in (ideally) several sensory modalities.' [Sla04]

Presence provides methodologies for inquiry with more exacting definitions and measurements to evaluate the impact of the mediated experience, and consequently to determine the extent users feel perceptually present in the virtual / augmented environment. It is widely applied to all technologies across the 'virtuality continuum' [MK94], from CAVE environments to social networking groups, though anecdotally they seem to be unaware of domed environments [Sch07].

> "The eye is not a camera that forms and delivers an image, nor is the retina simply a keyboard that can be struck by fingers of light." [Gib79]

His experimentation and discussion on the need to 'obey' vestibular and angular 'laws' of typical human perception echoes Gregory's concept of 'Strongest Hypothesis'

"Perception is not something that happens to us, it is something we do" [No4]. It is an activity where we bring to bear the extent of our world knowledge - without knowledge, perception has no meaning. Richard Gregory's work in experimental psychology, largely with those with corrected visual impairments, makes evident how meaning is interpreted based on the strongest hypothesis derived from prior experience. We do not perceive what is actually there, but instead filter stimuli depending on our expectations and contextual information. Perception, according to Gregory, is 90% memory. He provides the example of viewing a physical model of a concave face, this is a form humans are unfamiliar with as our reinforced experience dictates that faces are convex, and therefore that is what we see regardless of what we are presented.

3. Activities

The William Day Planetarium at the University of Plymouth dates back to 1967. It was built before the University was established, for the purpose of teaching stellar navigation to Merchant and Royal Navy navigational officers. Use of the Planetarium slowly fell, due to lack of integration within the University curriculum, coupled with the difficulty in training staff to use the vintage equipment. Eventually it was mothballed by the University. In 2004, the University was awarded four HEFCE funded 'Centre of Excellence in Teaching and Learning' (CETL) awards, one of which was the Experiential Learning CETL - Tasked with furthering the University's research and excellence in environmental field work - by re-fitting the Planetarium for use as a means of providing virtual field trips. The Immersive Vision Theatre (IVT) as it became known, was conceived with a reasonably narrow remit, namely investigation into the use of virtual field trips to supplement and enhance actual field trips for undergraduates. Through a process of workshops, consultation and ad-hoc opportunities that continues to this day, it has since embraced a much wider remit. Activities generally fall into four areas: Research, Outreach, Postgraduate and Undergraduate. The University has also purchased two inflatable domes. A 6m, and a 3m 'rigid' half-dome. The 'half-dome' is setup semi permenantly in a classroom for undergradute content creation. The 6m, is used by postgraduates and staff for activities off-campus.

Outreach

Lyme Bay: Modifying an existing 3D animation created for Devon marine wildlife trust, into a dome animation/real-time production. School of Earth, Ocean & Environmental Sciences

NMA: Production with Plymouth National Marine Aquarium for their outreach activities with our 6m inflatable dome.

Livecoding Event: Slub and Wrongheaded performed a livecoding performance. Collaboration prior to provide dome-correction to livecoding environment 'fluxus'.

Postgraduate

Postgraduates are supported in a purely ad-hoc manner, and are seen as a method of stimulating novel production pipelines and uses. Postgraduates are often the most autonomous users we serve. They are very transdiscipinary, stradlling the Arts, Science and Engineering. For the most part, arts students have been the more prolific. This can be put down the the relative technical ease of producing digital art, rather than the more data orientated visualisations of science and engineering. As we produce tools and art-paths to manipulate this data, this situation is changing.

i-DAT was awarded a Canada Council for the Arts 'Grants to New Media and Audio Artists: New Media Residencies' for the Quebecois sound and installation artist Marc Fournel. This included a performance in the dome, and collaboration to produce dome-correction routines for the visual programming environment PureData.

Supporting various projects with Faculty of Art 'Media and Art' and 'Fine Art' postgraduates. Installations including 'billboarding' of conventional rectilinear content for viewings, and bespoke software to view LadyBug2 equirectangular footage.

Undergraduate

Coastal Engineering: The development of 3D dome visualisation from research and undergraduate work. This has included face to face tutorial support to develop undergraduate student 3D modelling and visualisation skills, and to facilitate the development of a real-time 3d environment. School of Computing, Communications & Electronics/ School of Engineering.

BA/BSc Digital Art & Technology Lecturing. Lecturing in 3d modelling, animation and real-time productions.

Many users of the dome arrive with finished content, or content that needs re-purposing for the dome having embarked on a dialogue with the IVT staff. For others, the small IVT team work to a brief supplied by the subject expert. Taking on the entire production. These two models of production represent very different levels of engagement with the medium and the space from the commisioner. Perhaps the most extreme example would be requests for dome-corrected versions of PowerPoint slides which take very little advantage of the medium.

These are very different activities to teaching 'fulldome' as a subject. Until recently, the teaching programs consisted of practical tuition in the mechanics of production software, reflecting the technologically deterministic nature of the industry surrounding domed virtual environments. [14809] [Wal07] [GPCZ06] However in 2009 a new module was introduced, 'Reflexive Design'. This is a one year module for 2nd year undergraduates on BA/BSc (Hons) Digital Art & Technology and BA/BSc (Hons) Design for Visualisation. The module uses the creation of content for domes and the critiquing of existing content as a vehicle for the teaching of media for virtual environments. The technological view of virtual environments is usurped by one that is user-centric, and informed by cognitive science. Students try to understand the immersive qualities of the dome through mastering the mechanics of the space - working through perceptual processes by measuring effect of creative work. The aim being to produce students able to deconstruct the perceptual and cultural contexts of any medium or media. Key to this module is the psychology underpinning the model presented.

Research

Pore-Cor: Video Production for activities in Applied Chemistry. Incorporates a mix of 3D modelling and animation and dome corrected video footage. School of Earth, Ocean & Environmental Science

Portland Square (PSQ) Building Campus Carbon Footprint: A development of the Arch-OS project in collaboration with the Centre for Sustainable Futures CETL. This project attempts to create a real-time 3d visualisation of the carbon footprint of the Portland Square building through data feeds generated by the Arch-OS system. This has generated a flexible 3D model of the campus and PSQ building, as well as a number of visualisations used to support another projects (Development of a joint Centre for Creative Design and Technology).

Spatial Memory: The incorporation of the PSQ 3D model to support behavioural experiments derived from experimental psychology, involving tightly controlled manipulations of the immersive experience, random assignment to experimental conditions and appropriate statistical analyses. The 3D model of Portland Square has been incorporated in a number of spatial memory and immersive environments experiments. School of Psychology.

Insect Anatomy: The support of a cross disciplinary project modelling high resolution scanning electron microscopy images for use in the IVT. Projected in full panorama within the IVT, the image sets allow detailed investigation of fine structure in specimens of selected invertebrate groups. Plymouth University Electron Microscope Centre, School of Biological Sciences.

4. Software and Techniques

As stated earlier, many of the production and display technologies employed by domed virtual environments are borrowed from Cinema. Save for astronomical simulation software, pre-rendered movies are far more common than real-time applications. This is in marked contrast to CAVES, where 'films' are very rare. This may be due to the multi-user capability of domed virtual environments, or the difficulty in imposing real-time stereo correction onto pre-rendered content. From our preliminary research and observation, one of the most successful modes of content has been expert-led real-time applications - much like the approach of traditional Planetaria. To this end the University has pursued a variety of real-time technologies with a view to enabling expert presentations based on novel data. As identified by Cruz-Niera et al [16693] the main technological hurdle, is the 3D projection distortion required. The vast majority of data visualisation or simulation applications, and their underlying libraries (such as OpenGL or DirectX) do not have the required projection distortion. Therefore various multi-camera amalgamation techniques are employed to derive the equi-angular fisheye that is required. Therefore in terms of the University's aims for real-time data visualisation the options are a) adapt an existing dome-corrected application to accept the required datasets, or b) modify an existing real-time data visualisation application to produce a dome-corrected output.

In the pursuit of option a, proprietary Planetarium-specific platforms were investigated for their suitability. Since a core requirement of any real-time application for use in the dome would be the visualisation of data, and most real-time astronomy visualisation applications are already doing just that - namely astronomical databases. It was thought that these applications would be the most suitable starting point for investigation. For one application in particular, supplied by the system vendor, a license was acquired which included access to the source code. Also, inquiries were made with the vendors of the various data-visualisation applications already in use around the University, such as ArcGIS, Fledermaus etc. To ascertain the feasibility of adding dome-correction capabilities within these applications, but ultimately this proved fruitless.

The later option is difficult for closed source applications, and those vendors who were willing to provide access to the source, also imposed restrictions on the applications developed as result. A survey was also made of open source software. This yealded many technologies at the scenegraph or game engine level, as well as several 3D, video and audio authoring applications.

OpenSceneGraph
: Complete and powerful scenegraph, programmed in C++, useful support for volumetrics including DICOM http://www.openscenegraph.org/projects/osg

Partiview
: Useful in the visualisation of particulate data types, such as the Digital Sky atlas. http://virdir.ncsa.illinois.edu/partiview/

PureData
: Alternative to Max/MSP, visual programming environment very popular with artists http://virdir.ncsa.illinois.edu/partiview/

Blender
: 3D authoring application, very powerful Python scripting enabling exchange with Panda3D, VTK. Yaf(a)ray is a pure raytracing renderer supported by Blender and has equi-angular fisheyes. Blender also has the Blender Game Engine, which as of recent development has support for equi-angular fisheyes http://www.yafaray.org/ http://blender.org

Panda3d
: Powerful game engine developed by Carnegie Mellon and Disney. Very clean approachable Python API, with excellent support for video textures and support for equi-angular fisheyes http://panda3d.org

Fluxus
: Scheme based 'livecoding' application, with fisheye support http://www.pawfal.org/fluxus/

VTK
: Very powerful data visulisation library and tools. Used for conversion of data, rather than final display. http://www.vtk.org/

GDAL
: Powerful support for GIS and other Geographical data sources. Used for conversion of data, rather than final display. http://www.gdal.org/

Hugin
: Mature GUI for various panoramic photography libraries. Useful in the creation of equirectangular projections from multiple equi-angular fisheyes. http://hugin.sourceforge.net/

Much of this research was conducted in response to requests from Researchers, Lecturers and Artists who had already incorporated these tools into their disciplines. Since the source code was available, it was possible to directly investigate incorporating dome-correction techniques. The communities behind these software projects were often a valuable source of information regarding the capabilities of the applications and feasability of integration into domed virtual environments. In some instances (OpenSceneGraph, Blender) the community embarked on the development themselves, or were happy to incorporate development undertaken within the University.

Of these significant use has been made of OpenSceneGraph, Panda3D and Blender. Blender and the Blender Game Engine has also become the primary vehicle for undergraduate tuition. Offering a single environment for pre-rendered and real-time content creation, and the significant advantage of not encouraging student software piracy which is often a feature of Adobe or Autodesk centred study.

Audio

A word should be said about audio - often the poor relation in virtual environments. A recognition of the role of perception and cognition in virtual environments is accompanied by an increased priority for audio. Aspects of perception such as perceptually guided action, [SFR] show that audio can provide strong cues, increasing the level of presence in a virtual environment.

The software and hardware landscape for Audio is equally as rich as that for Video and 3D. It has been found useful to categorise audio technologies for immersive audio into those that use panning or amplitude to position audio, and those that use psycho-acoustic approaches. This reflects Amplitude based techniques include standard stereo, surround sound, 5.1 etc. Psycho-acoustic approaches would include Ambisonics, HRFT, VBAP. Here too it was found that Open Source applications proved more malleable and easier to integrate into the University's facility. Real-time audio platforms are less common. Amplitude (+doppler) based libraries exist in the form of OpenAL, and many higher level game engines make OpenAL available.

The Plymouth IVT was originally specified with a 10.1 system driven by a proprietary psycho-acoustic simulation system. This allows for effective playback of Stereo, 5.1, 7.1 through the creation of virtual speakers within the simulation. For real-time applications it has proven to be difficult system to integrate. Of more use is the Ambisonic approach, allowing for the recording, storage, synthesis and playback of both pre-rendered and real-time immersive soundscapes. Recently the combination of Ardour, CLAM and Blender has proven to be a very comfortable and useful environment for all modes of of sound design and integration, both pre-rendered and real-time.

Ardour
: Multichannel audio application - capable of ambisonic and other surround mixing http://ardour.org/

CLAM
: Realtime acoustic simulation software. http://clam-project.org/

5. Conclusion

By having a wide remit from the outset, The University of Plymouth's IVT, has subjected itself to a barrage of demands. By fostering a psychologically informed approach to meeting these demands, we seek to at the very least locate domed virtual environments within the academic literature, and provide a context for meaningful discourse. Further we seek to accumulate evidence, methodologies and tools, to enable a meta understanding of human perception in domes - and crucially for their use in a University, their pedagogical value. The bulk of this task remains, but with a solid technical and psychological foundation, the process can begin with confidence.

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