Avatars at the Flying Palace
Stereographic panoramas of Angkor Cambodia

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Biography

Sarah Kenderdine is by training a maritime archaeologist and museum curator. She has researched and excavated sites throughout Australia and the Indian Ocean region, and published a number of books on shipwrecks. Since 1994, Miss Kenderdine has developed portals and designed digital environments for cultural organisations. Miss Kenderdine is a Director for the Virtual Heritage Network and currently project manager for The Virtual Room based at Museum Victoria. Her current research focus involves the use of real-world stereographic panoramas for heritage-based interpretation and aspects of presence in Virtual Heritage. Miss Kenderdine is currently publishing a book with MIT Press on the theoretical aspects of digital cultural heritage.

Abstract (EN)

The paper documents the creation in 2004 of real-world stereographic panoramas at the UNESCO world heritage listed site Angkor, in Cambodia. The project builds upon the history of the panorama as a medium of virtual travel that has existed from the eighteenth century. The significance of the current project is the way in which real-world (as opposed to computer generated) stereographic panoramic scenes may be used in conjunction with augmented narratives and interactive device to enhance attributes of presence in virtual heritage applications. The Virtual Room at the Melbourne Museum provides a unique delivery platform for the material, and can distribute the Angkor panoramas at a real-world scale in stereographic and immersive setting. The paper gives an introduction to the potential to expand upon these images and embed additional contextual information and sound scapes to this environment—with powerful effect.

Keywords: Stereographic; panoramas; Angkor; virtual heritage; digital photography; video avatars; image-derived models; blue screen.

Introduction

> We live in a poor and enclosed world. We no more feel the world in which we live than we feel the clothes we wear. We fly through the world like Jules Verne characters, through "outer space in a capsule". But in our capsule there are no windows. [...] We live as if coated with rubber. We must recover the world (Shklovsky, 1923).

The paper documents the creation in 2004 of real-world stereographic panoramas at the UNESCO world heritage listed site Angkor, in Cambodia (Figure 1). This archaeological park is the largest low density pre-industrial city in the world, containing the single largest temple, Angkor Wat.

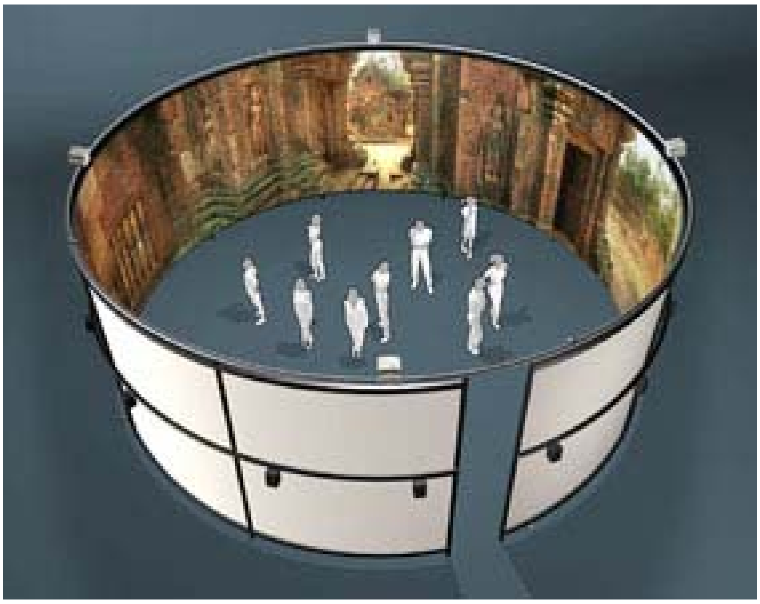

Fig 1: Panorama visualisation, Banteay Srei, 'Citadel of the Women', Angkor, Cambodia. 2004.

The work builds upon the history of the panorama as a medium of virtual travel that has existed from the eighteenth century. The significance of the current project is the way in which real-world (as opposed to computer generated) stereographic panoramic scenes may be used in conjunction with augmented narratives and interactive device to enhance attributes of presence. The Virtual Room at the Melbourne Museum provides a unique delivery platform for the panoramas, and can distribute the content at a real-world scale, in an immersive environment. This paper explores the potential to expand the images and embed additional contextual information and soundscapes—with powerful effect. Augmentation is possible using atmospheric effects, animations and additional textures. The Angkor project also includes embedded real-time stereographic real-world characters into the geometry of the panoramic scene.

It is the argument of the author that real-world stereographic photography and spatialised soundscapes of appropriate fidelity, combined with narrative device and user interaction can potentially provide a rich sense of ‘presence’ and provides a counter argument to computer-generated models and reconstructions for digital heritage applications. The research presented here is specifically related to 'interpretation' of heritage for non-specialist audiences. However, the technologies identified also have application in scientific research in the area of archaeology and art history. This publication marks the first in a series of papers by the author intended to cover different aspects of the project in more detail.

I. Section 1

1. Panoramas in an historic context

> I am swaying between reality and unreality, (...), between truth and pretense. My thoughts, my whole being are given a movement which has the same effect as spinning or the rocking of a boat. Thus I explain the dizziness and sickness which overcomes the concentrated onlooker in the Panorama (Eberhard, 1805)

Public screen entertainment most notably panoramas, dioramas and magic lanterns made their debut in the late 1700s, and were initially conceived of in purpose-built designs. For example, Robert Barker’s patent for a panorama relied on the creation of a purpose-built rotunda for its visual impact. The circular building ensured that the viewer was encapsulated by the scene. The specific venues relied on both visual spectacle and optical scale for their appeal. Due to the enormous resources that these projects demanded and the limited turn over of images shown (one per year)—most were short lived. Multi-activity complexes (panoramas and roller skating for instance!) allowed some large format pictures to continue to be produced but they remained something of a novelty. Panoramas found a viable market in the latter part of the nineteenth century and the 360-degree screen became standard, for example, at the Universal Exposition in Paris 1989 (which housed a total of 7 different panoramas), and the Universal Exposition of 1900 which housed the Pleorama, Stereorama, Cineorama and the Lumiere Brothers photodrama. The panorama functioned as a cinema of attractions, and laid the basis for future large screen formats such as the Cinenascope, Cine 180, IMAX and OMNIMAX

What can be observed in most of the late nineteenth and early twentieth century attractions is a reliance of overwhelming sensory experience rather than narrative structure and—on realism and spectacle. Dominant themes included exotic landscapes, vast cityscapes, natural disasters and large news events. The appeal of these shows signified the 'opening the optical unconscious' (Benjamin, 1970, p. 12). With the proliferation of optical inventions the supernatural illusion of natural magic was superseded by a new technical visuality. Optical technology opened up a realism whose modernity gave it a general scopic fascination.

Merleu Pont has argued that seeing is a kind of possession, and one of the recurring features of the nineteenth-century relationship with the screen is the desire for interactivity. Optical devices such as the stereoscope subverted the conventional rules of perspective, and in doing so they disturbed the viewers' comfortable relationship with the world.

> The thrill of many optical toys derives from the unstable subjectivities they produced: where the spectator, nevertheless remained in control of the image….large scale screen formats intensified the spectating process provided by small optical toys. Like the kaleidoscope, panoramas offered a disorientating optical experience. In contrast to the singular spectating position assumed by conventional painting, the panorama offered an unending simultaneity of viewpoints (Plunkett, 2004).

There are many critical histories written of the panorama which maybe consulted to foreground the use of the virtual reality (VR) panorama seen today (e.g. Oetermann, (1997) *Panorama: History of a Mass Medium*; Hyde, (1984) *Panoramania;* Comment (2000), *The Painted Panorama*).

Relevant in the context of this paper it is useful to refer to a number of authors currently exploring through critical analysis the history optical devices —to chart development and implications for “new media” products. The reader is referred to pre-eminent authors such as Crary (2001), Grau (2002), and Manovich (2001) among many others, for an extensive discussion of trajectories for optical device into digital media arts and immersive environments. For an introduction to optical historiography in relation to The Virtual Room at the Melbourne Museum refer to Kenderdine & Hart (2003).

2. The VR panorama

In the late 1980s panoramic and spherical maps were popularised by Apple with their QuickTime VR software. Since that time, there has been a profusion of panoramas (and softwares) generated for internet applications. Murphy (2002) makes the distinction between naturalistic “virtual reality” surround imaging technologies of the VR panorama (basically latter day variants of the painted panorama concept) and, multimedia information spaces – which can also be considered surround systems. The information space type he mentions (multimedia extravaganza; the city in all its information feeds) are immersive environments in the way they duplicate the constant sensory input of our lived worlds but they do not, in his mind, generate the same kind of sense of “telepresence” as do more naturalistic surrounding displays.

A recent New York Times article has highlighted the powerful effect for web-based panoramic content. As noted by Fred Ritchin, Associate Professor of Photography and Communications at New York University, the full potential of [online] panoramas has yet to be realized. Mr. Ritchin said that viewers—and photographers—are still accustomed to the conventional photograph's single viewpoint. He said he would like to see the panoramic image present multiple viewpoints to better effect. Because panoramic images can contain links to other panoramic images, Mr. Ritchin also imagines their use in elaborate non-linear narratives.

Interesting developments for the navigation and interpretation of panoramas include the enclosure of avatars (real-world video footage or virtual characters) into the scenes (e.g. www.fieldofview.nl/spv.php. These experiments are welcomed by Erik Goetze, a Web designer in Palo Alto, Calif., who maintains a blog about panorama technology <www.vrlog.com>. "One of the things about panoramas is they're fairly static," he said.

"They typically just show a place; they don't tell a story." However, augmented panoramas can bring these static scenes to life.

Artists such as Jeffrey Shaw and Michael Naimark have been working within the oeuvre of extended narratives and augmented device for panoramic images since the mid 1980s. Shaw ‘evokes the navigation methods of panorama, cinema, video and VR. He “layers” them side by side (Manovich, 2001, p.282). Such works can be considered seminal as a basis for large-scale exhibition implementation of panoramic content.

II. Section 2

3. Panoramic Imaging: cylindrical, spherical and stereoscopic

There are three frequently used techniques for rapidly displaying either photographic or computer generated surround environments, they are: cylindrical, spherical, or cubic mappings (cubic mapping will not be discussed further here). In all three cases images are mapped onto some geometry (cylinder, sphere, cube) with a virtual camera located in the center, and depending on the performance of the host hardware and software the user can interactively look in any direction. This can lead to a strong sense of immersion especially if the environment is projected onto a wide display that fills up a significant part of the viewers’ field of view. It is generally considered that an even greater sense of immersion can be achieved by stereographic projection (Bourke, 2004).

The typical cylindrical (rectilinear) panorama image shows 360-degrees of horizontal detail and about 120-degrees of the vertical. Rectilinear images preserve the straightness of all scene straight lines. This image format has many advantages for scene encoding —they are easy for human reading, i.e. they are pictorially fairly naturalistic except when the vertical angle exceeds about 100 degrees (Murphy, 2002).

Equirectangular (or spherical) panoramas differ from cylindrical because proportionally equal lateral or vertical intervals of the image correspond to equivalent visual angles of the scene. Hence all full view 360 by 180-degree equirectangular images have proportions of 2:1. The geometry of such images corresponds closely (but not identically) with Mercator projections of a sphere. Like Mercator projections equirectangular images tend to look naturalistic in equatorial areas but increasingly compressed towards the poles.

A panorama for visual stereo consists of a pair of panoramic images, where one panorama is for the left eye, and another panorama is for the right eye. A stereo panorama cannot be photographed by two omnidirectional cameras from two viewpoints. It is normally constructed by mosaicing together images from a rotating stereo pair, or from a single moving camera.

The ultimate immersive visual environment should provide three elements: (i) stereo vision, where each eye gets a different image appropriate to its location in space; (ii) complete 360-degree view, allowing the viewer to look in any desired direction; (iii) allow free movement. Stereo panoramas use a new scene to image projection that enables simultaneously both (i) stereo and (ii) a complete panoramic view. No depth information or correspondences are necessary (Pelag & Ben-Ezra, 2000).

4. Stereo insertions

An obvious extension for the panoramas is to add computer generated aspects to the environment such as avatars. To do this correctly the added geometry needs to be in the correct perspective, as the avatar may need to be occluded behind geometry in the panorama, and it needs to be illuminated in a consistent way with the lighting of the panoramic. The first step to achieving this is to determine the sun position, and ground plane(s) positions so any additional geometry can lie at the correct vertical position and move into the foreground/distance correctly. If the outlines of objects in the scene are known such as the gravestone then any added geometry that moves behind that gravestone will be occluded by it (<to see illustrations refer to <http://astronomy.swin.edu.au/~pbourke/stereographics/stereopanoramic/>).

5. Real-world real-time for presence

Research into issues of presence in virtual environments has multiplied in the last 5 years. This research aims to provide a design methodology and tools based on the theoretical and empirical study of presence in computationally virtual environments. Two such projects that explore the use of real-world photo-imaging are introduced here. Both examples seek to investigate the effectiveness of real-world places and objects into the experience of “being there” using a range of projection technologies from Head Mounted Displays to CAVE type environments.

In the first instance the BENOGO project <http://www.benogo.dk/> uses a new technology of Image Based Rendering that does not require a reconstructed geometrical model of the scene to be ‘presented’ (Arnspang et al, 2002). The research analyses the level of psychological, physiological and neurological aspects of presence using the themes of acquisition and real-time rendering of real places, augmentation using video avatars (with special emphasis on seamlessly blending introduced computer generated objects), and audio augmentation (using ambient spatialized soundscapes; and understanding directional information based on the users motion; and the production of a moving sound with little notion as to the geometry of the scene which will have a noticeable contribution to the spatial understanding of the scene). The reader is referred to numerous articles and the various aspects of this project contained on the BENOGO website <http://www.benogo.dk/publications/>.

Another noteworthy project in the context of research into representation of virtual heritage using photorealism is the CREATE project <http://www.cs.ucl.ac.uk/research/vr/Projects/Create/>. These researchers acknowledge that there has been a number of virtual heritage projects using sophisticated and technologies but that most “of these environments suffer from either a lack of realism of a low degree of interactivity…” (Roussou & Drettakis, 2003. p.2). The project creates photorealist models using the modelling-from-image techniques, corrective modelling and addition of dynamic behaviours. As noted by the researchers the “realness” factor demands appropriate blending between adjacent photo images; and additional algorithms for occlusion culling and optimised rendering. Consistent lighting between the photo-real, and inserted computer generated elements is also important for high quality immersion.

Heritage is “as much about the living and evolving place, people, and environment, as it is about any single static monument” (Addison 2000 cited in Roussou & Drettakis, 2003). One of the ways this is achieved is by the inclusion of dynamic elements such as atmospheric and dynamic effects and real-time videos inserted into the scene.

Significantly, these researchers make the distinction in virtual heritage applications about the need for —“realness”. Through aligned research in the project ARCHEOS which uses non-photo realistic (NPR) representation they concluded:

> …photorealism may be less important with the NPR techniques that resemble traditional methods of depiction used by specialists may suffice, or even be preferable. In the case of the general public, VR representation is developed to provide a window into the past which incorporates the interpretations made by specialists into engaging presentations. In this case, we believe that photorealism is a necessary aspect for educational and recreational value of representation (Roussou & Drettakis, 2003, p.8).

III. Imaging Angkor

6. Angkor: a world heritage site

Angkor, the capital of the medieval Khmer empire in Cambodia from the ninth century AD to some time in the sixteenth or seventeenth century, is world famous for its immense and beautiful temples. These monuments have been meticulously studied, yet the most basic information about the vast urban complex within which they were situated remains a matter of dispute.

The Angkor Archeological Park contains the splendid remains of the successive capitals of the Khmers. These include many temples, including the famous temple of Angkor Wat and the royal city of Angkor Thom and a considerable hydraulic infrastructure (the Occidental Baray, the Oriental Baray, the Baray of Preah Khan, dikes and irrigation canals, etc.). The vast and impressive remains of the Angkor monuments are of national and world significance. The Supreme National Council of Cambodia, upon ratifying the World Heritage Convention in November 1991 nominated the Angkor Archaeological Park for inscription on the World Heritage List under criteria C (i), (ii) and (iii) in 1992.

Angkor is the fastest growing tourist destination for a World Heritage site and expects over 1 million visitors in 2004. Recent satellite imagery has shown that the site is now 1000^2 km while previous estimates put the site at 400^2 km. Significant sections of the north portion of the site are still out-of-bounds due to large scale deployments of land mines. Current urban development takes place through the site, as does, intensive agriculture. It is a cultural and environmental landscape under considerable stress.

The site is managed by APSARA-Authority under the auspices of UNESCO. And although there are a number of foreign organisations working there exists no coordinated tools for the visualization of complex of data that they have to deal with. Interpretation and visualisation of the enormous and complex site for visitors is undeveloped.

7. Angkor: prior panoramas and stereographic material

Angkor has long been the subject of the ‘tourist gaze’ (Urry, 2001). While it is not intended to discuss the extensive historical archives or archaeological visualisations that have taken place at and about Angkor three works are worthy of note in the context of the Angkor panorama project.

Professor Poncar as part of the German Conservation Foundation at Angkor produced single photographs of all the gallery reliefs of Angkor Wat <http://www.gacp-angkor.de/>. The photographs produced have earned two entries in the Guinness Book of Records for the largest negative (the size of the negatives of the Historical Parade and the Battle of Asuras and Devatas is 70 x 2450 mm) and the largest printed photograph (1.25 x 62 m)

Michael Naimark’s *Be Now Here* is an installation about landscape and public places. Visitors gain a strong sense of place by wearing 3-D glasses and stepping into an immersive virtual environment. The imagery is of public plazas on the UNESCO World Heritage Centre's list of endangered places - Jerusalem, Dubrovnik, Timbuktu, and Angkor, Cambodia. For production, a unique recording system was built consisting of two 35mm motion-picture cameras (for 3D, one for each eye) mounted on a rotating tripod. The installation consists of an input pedestal for interactively choosing place and time, a stereoscopic projection screen, four-channel audio, and a 16-foot rotating floor on which the viewers stand.

As described on the project website *Be Now Here* is an extension of several media trajectories. One is of enhanced cinematic representation, such as the Imax-sized projections of the Lumiere brothers in 1900 and the 3-screen triptychs of Abel Gance's Napoleon in 1927. Another is of non-narrative cultural activism. It is both a regard and a provocation <http://www.naimark.net/projects/benowhere.html>.

Tito Dupret has initiated World Heritage Tours <http://www.world-heritage-tour.org/>. The WHTour is a private non-profit organization dedicated to creating a documentary image bank of panoramic pictures and virtual reality movies for all sites registered as World Heritage by UNESCO. Mr. Dupret embarked on an international mission to photograph the 754 sites, from the Statue of Liberty to the Taj Mahal, using panoramic images for the Internet. He has completed 13 panoramas of the site of Angkor <http://www.world-heritagetour.org/asia/kh/angkor/>.

IV. Avatars at the Flying Palace

8. Omni-camera stereo capture

Fieldwork for the Angkor project was undertaken over a five day period in January 2004 in accordance with the contract specified by the APSARA-Authority. Eight temple sites were identified and panoramas were shot at desirable locations within these complexes. These sites are: Bapuon; Bayon; Angkor Wat; Ta Prohm; Preah Khan; Phnom Bakeng; and the West Mebon. In addition, linear sequences of relief sculptures at Angkor Wat and Bayon were also captured to help with interpretation of narrative function of the temples (following Roveda's (2003) concept of 'temples as texts').

Panoramic stereoscopic image pairs were captured using a medium quality digital SLR with an ultra-wide-angle lens (185 degree fisheye). The camera was mounted on a (360 degree) notched rotating platform on a tripod. Up to 360 image slices make up each of the stereo pairs. These are stitched together using off the shelf stitching softwares.

There a very few other cited reports using omni-camera capture for stereo, however, the reader is referred to Pelag *et al* (2000), Pelag & Ben-Ezra (1999), and Gluckman *et al* (1998).

The images were shot at times of the day mostly free of tourists, and in 'flat light' to allow for later addition of atmospheric effects during post processing and computer generated augmentation. Each panorama must be shot in the shortest time frame possible to prevent fluctuations in the light levels. Multiple exposure records were made to encompass high scene lighting contrasts in some locations. The capture process currently requires a relatively static scene so some crowd marshalling was necessary on site.

The finished stereo panoramas comprise high resolution image pairs which provide 360-degree horizontal by 160-degrees vertical scene coverage. For each stereographic panorama two images are produced, one for each eye. They are offset from each to the degree that creates comfortable stereo (usually 60 mm or the distance between left and right human eyes). Each resulting image is 8192 pixels wide, in other words of very high quality (Figure 2).

Fig 2: Panoramic image (equirectangular), Angkor Wat at dawn, Angkor, Cambodia, 2004. Photography Peter Murphy.

9. Projection options

Swinburne Astrophysics Laboratory in Melbourne had written a panoramic viewer based upon OpenGL which simply required a cylinder or sphere with the panoramic mapped as a texture. Writing a stereoscopic viewer was not much more difficult (Bourke, 2003).

The main complication for high resolution panoramas is the texture memory available and the largest texture supported. For example a 4096 by 2048 texture is usually going to require 32 MB. Many OpenGL drivers place modest limits on the largest texture size, the way around any such restriction is to tile the panoramic in N by N pieces on the cylinder (Bourke, 2003)

By October 2003 extensions were made to the viewer originally written for cylindrical stereoscopic panoramic images to:

- Support spherical panoramas
- Support panning over large planar stereoscopic images
- Remove restrictions found in most other viewers (eg: QuickTime VR), in particular it is possible to barrel roll, in other words, the virtual camera need not be upright. While this is useful in mono mode it has limited application when viewing stereoscopic panoramic pairs
- Run under Linux (with hardware OpenGL support) and Mac OS-X
- Support multiple synced and optionally genlocked machines has been implemented. A server and n clients are supported through TCP-IP communications, any user actions on the server is replicated on the clients (as per The Virtual Room environment discussed below)

10. Additional datasets

In September 2000 NASA/JPL, as part of PACRIM 2, carried out a comprehensive, detailed aerial radar survey of the environment and cultural landscape of the World Heritage site of Angkor in Cambodia (Figure 3). The survey was for a joint research project of the University of Sydney with APSARA (Royal Cambodian Government agency responsible for Angkor) and the École Française d’Extrême Orient in association with World Monuments Fund and the Mekong River Commission.

Fig 3: Section of the radar image of greater Angkor. Note the moat around Angkor Wat (lower left hand corner), and large baray or reservoir (mid section).

The radar survey of Angkor was completed in order to obtain more detail on the former extent of the complex and to acquire modern environmental data. The radar provides a multi-frequency and multi-polarity record of the landscape and the data will include a topographic record that allows the preparation of a 1 m contour interval map of the entire region. Current estimates indicate that the Angkor complex covered more than 1000 km square and was associated with extensive forest clearance for rice agriculture. The implications for an understanding of the failure of Angkor are considerable. The evidence today of severe flooding and reduced fish supplies, as the same process begins again, is of some significance. The importance and comprehensive view that this data provides is useful to the interpreting the scale and complexity of Angkor. For this reason the macro-visualisation was incorporated into 'Avatars at the Flying Palace' installation as a fly through of the 3D terrain.

Angkor was described in historical accounts that date back to the thirteenth century to have been covered in gold and ochres, blacks and whites which are slightly visible in some places of the existing archaeological remains. More exacting archaeological research in the form of polychromatic studies at Angkor Wat (Keisewetter *et al*,) has enabled inclusion in the panoramic scenes of discrete overlays of colour textures in sections of the architectural or sculptural surface (in particular in this instance in sections of relief sculpture).

11. Projection options

The resultant stereographic panoramas can be realised in a number of projection systems including Head Mounted Display, CAVES, stereo dome projections and other panoramic projection systems. The creation of an effective stereographic surround cylindrical projection is still in development (e.g. Figure 1), but this would be a highly desirable environment in which to display the images. The project under discussion here however is destined for The Virtual Room (for October 2004), which inverts the panoramas so they appear on the outside of the cylinder of stereographic screens. While this introduces a set of optical distortions between images of adjacent screens these are not insurmountable to the effective projection of the work.

12. The Virtual Room

Fig. 4: A visualisation of The Virtual Room.

The Virtual Room <http://www.vroom.org.au> was subject of greater discussion at ICHIM 2003 (refer to Kenderdine & Hart, 2003). In brief, The Virtual Room consists of an eight screen 360 degree rear projected stereoscopic display system (Figure 4). The system can be configured to be interactive with the use of wands and motion tracking devices, movement and immersive qualities will also be enhanced through the use of spatial soundscapes. The environment can be reconfigured to position the viewer into the interior or panoramic immersion (an octant enclosure), or perambulatory (or circumlocutory) exterior viewing (of a contained world). It is currently configured in the latter formation. The Room opened in January 2004 and has had 120,000 visitors in a 6 month period.

13. Programming environment & runtime creation

To effectively display the panoramas a virtual camera is placed in the centre of each scene—for the left and right eyes shown here in 3D Studio Max™ (Figure 5). The virtual reality software (Virtools ™) has been configured to take advantage of the PC cluster arrangement used in The Virtual Room. The Angkor scene components are distributed and synchronised across each of the PC's in the cluster. These distributed components allow the scene to be rendered across all eight screens in stereo where each host PC renders a different field of view to form a single 360 degree image (Figure 6). Figure 7 shows a panorama in the programming environment with the various layers and behaviours attached.

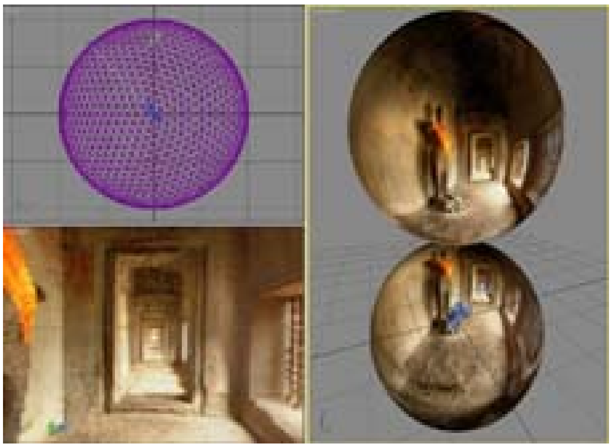

Fig 5: Set up in 3D Studio Max™ showing camera inside the sphere and an equirectangular image mapped on. Sight lines for the camera position are also visible.

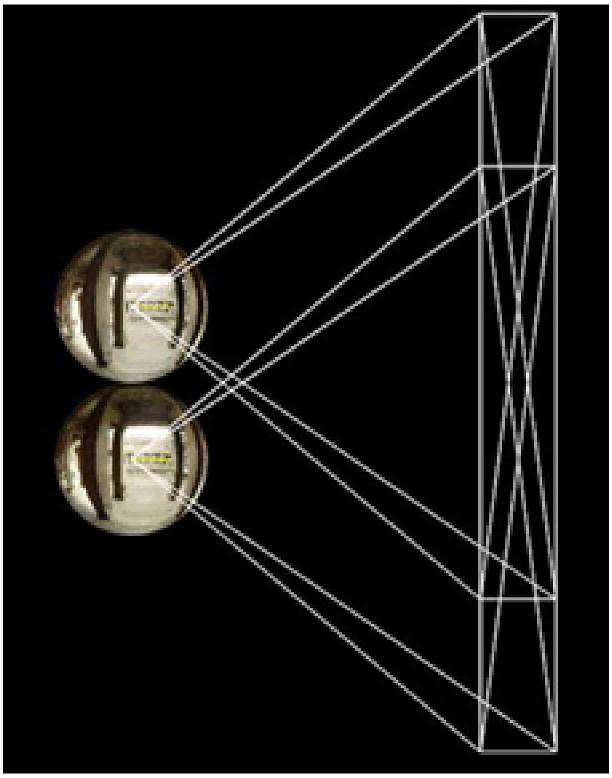

Fig 6: Position of cameras inside the panoramas and the projected views to a single screen. Note The Virtual Room has 8 screens and a different slice of the image appears on each screen to make up the whole panorama around all 8 screens.

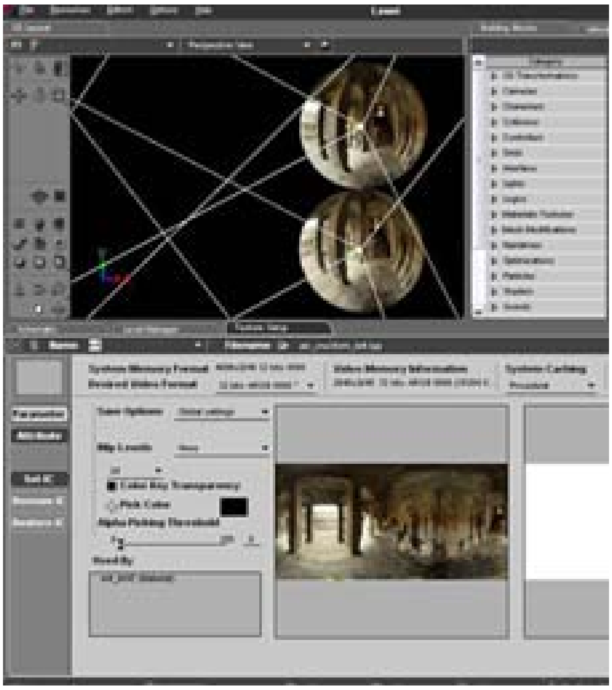

Fig 7: Panoramas set up in Virtools ™, which camera sight lines and behaviour layers visible.

14. Soundscapes and spatialisation

The sound in technology based presentations can play various roles in creating or enhancing a sense of presence, from augmentation of (visual) senses to—playing a major role by providing a sense of continuity for an experience. Various aspects of sound are more important than others in creating a sense of presence and this can change based on the application and the objectives and content of that application. Presence can be most powerfully achieved by recognising the requirements for sonic identification in such multi-disciplinary works. Particularly with photo-realistic visual imagery, similarly realistic sonic elements are required to most fully engage the observer and not create cognitive dissonance with sonic elements that mis-match the fidelity of the image.

The crux of this issue is what Pierre Schaeffer termed the source-cause, where the listener identifies the source or cause of the sound. Of particular interest with virtual reality presentations is that the sonic source-identification, setting-identification and space-identification are appropriate to the image displayed. While this may all be easily managed with less than realistic images, as real-time photo-realistic images become the norm in virtual reality presentations then the degree to which the sound must match is similarly more demanding (Doorbusch, 2004).

It was found that source recordings made during the Angkor fieldwork, despite their limited flexibility, were the most useful sound sources because of the strong source-identification aspect. However, much more than simple recording playback is required, as the recordings need to be modified substantially to achieve the presence required. The sound of such fidelity provides a strong stabilising element for the photographic panoramas. The developers are aware that the use of human voice narrative to explain the images caused a significant discontinuity in the sense of presence. Ways in which this (required) didactic narrative could be folded into the surrounding ambient environmental soundscape calls into question the use of this information in an otherwise immersive environment. The proposed solution has been to place headphones throughout the installation space (using a BlueTooth®) implementation). Visitors can engage with the didactic narrative on demand.

15. Conclusion and future statements

The Angkor stereographic panorama project is a prototype application that forms the basis of low cost immersive environment for heritage interpretation. This paper introduces a number of themes related to the capture and presentation of stereographic panoramas for this virtual heritage application. These themes extend from the historical trajectory for panoramic images and their extension into new forms of narrative device and immersive space —to technical requirements and methods for stereographic capture and projection and, the creation of presence. Each theme warrants further explanation and will be the subject of upcoming papers.

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