Mediterranean Archaeology and Archaeometry, Vol. 16, No 5,(2016), pp. 63-72

DOI: 10.5281/zenodo.204967

A 3D PEDAGOGICAL HERITAGE TOOL USING GAME TECHNOLOGY

Erik Malcolm Champion

Curtin Institute for Computation (CIC), Australia-Asia-Pacific Institute (AAPI), MCCA, Faculty of Humanities, Curtin University

Received: 12/12/2015
Accepted: 12/06/2016
Corresponding author: erik.champion@curtin.com.au

ABSTRACT

This paper will propose and address issues that contribute to a serious challenge for virtual heritage: that there are few successful, accessible and durable examples of computer game technology and genres applied to heritage. Secondly, it will argue that the true potential of computers for heritage has not been fully leveraged and it will provide a case study of a game engine technology not used explicitly as a game but as a serious pedagogical tool for 3D digital heritage environments.

KEYWORDS: Game-based learning, digital archaeology, Kinect-projection, pedagogy.

1. INTRODUCTION

Computer games offer potential for virtual heritage purposes as low-cost open-ended learning experiences, but they don't scale easily, they pose issues in terms of digital preservation and they are not cultural learning experiences in a strict definition of culture. How can game technology be used to creatively connect to archives and scholarly infrastructures in general in order to further virtual heritage as both a preservation and communication medium? How do we thematically include conjecture and interpretation? And how can these projects be made more accessible to the general public?

This paper will first outline why the fundamental problem is an issue of limited interaction design and a conflation of digital heritage (as a preservation medium) with virtual heritage (as a communication medium). It will then provide an example that blends computer games, low-cost camera tracking and virtual heritage environments in order to address the above questions both for virtual heritage projects and for heritage content that may be more engagingly integrated into cultural tourism applications.

2. DEFINITIONS

Despite their success as an entertainment medium, games have not been fully examined by archaeologists and heritage studies professionals for their pedagogical potential (Anderson et al., 2009, Anderson, 2008, Stone, 2005, Tredinnick and Richens, 2015). But if we carefully analyse the components of successful games and virtual heritage environments, we will see overlapping concepts. For example, Champion (Champion, 2008) provided the following five definitions that lay the groundwork for the argument that games are undervalued for their pedagogical potential.

i. Game: A challenge that offers up the possibility of temporary or permanent tactical resolution without harmful outcomes to the real world situation of the participant.
ii. Cultural presence: a feeling in a virtual environment that people with a different cultural perspective occupy or have occupied that virtual environment as a 'place'.
iii. Virtual heritage: the attempt to convey not just the appearance but also the meaning and significance of cultural artefacts and the associated social agency that designed and used them, through the use of interactive and immersive digital media.
iv. New Media: the act of reshaping the user experience through the innovative use of digital media.
v. New Heritage: re-examine the user experience that digital media can provide for the understanding and experiencing of tangible and intangible cultural heritage.

The definition of games is important as it focuses on games as challenges and as media that allow for different strategies to be pursued. Games are knowledge-seeking activities insofar as knowledge is reached because of activity and during activity.

Secondly, virtual heritage is not merely a combination of cultural heritage and virtual reality technology, for virtual heritage is increasingly based on a technical platform of real-time rendering engines (i.e. computer game engines) rather than on dedicated virtual environment technology.

In order to further the aims of UNESCO World heritage, virtual heritage must attempt to communicate the cultural significance – the importance and context of the cultural heritage being simulated. To convey how a site may have been inhabited we also need to provide the significance of the site to a culture that may no longer exist, or if even if it exists, contains a mindset greatly different to our own.

The best way to do so is to incorporate the distinctive non-book strengths of digital media: its ability as ergodic media to provide learning through process (procedural memory); the capacity to provide instant and personalised feedback to different audiences; the facility to provide different (and even conflicting) narrative paths; the potential to include new and changing data (unlike individual physical book copies); scalability; and the extra strategic advantage of cross-platform viability and portability.

Not only do virtual heritage designers need to convey the cultural significance of heritage content but they also need to continually improve its communication power. This definition is based on the fourth definition, the definition of New Media: the act of reshaping the user experience through the innovative use of digital media. New Media is not merely a platform or digital application, as the new are no longer new, but one continual theme of New Media is how it must be continually learnt, taught and relearnt. A real issue for virtual heritage is thus not the level and status of current technology but how new technology is understood and assimilated by society.

However, the above features require extensive user-testing, extensive understanding of different audiences and how they best engage with virtual heritage content; and expertise in designing technology to provide engaging experiences that are also educational.

The worrying lack of evaluation in virtual heritage projects (Pujol and Champion, 2011), the infrequent inclusion of impartial reflection on the success or failure of the project (Koller et al., 2009, Ioannides and Quak, 2014, Barsanti et al., 2014) and the lack of sufficient metadata (Kulasekaran et al., 2014, D'Andrea and Fernie, 2013, Wise and Miller, 1997) reveal serious user-related issues.

Although there have been promising recent developments (Potenziani et al., 2015, D'Andrea and Fernie, 2013), the field also suffers from a lack of robust but flexible frameworks that can incorporate and integrate media assets from secure archives (Ioannides and Quak, 2014, Wise and Miller, 1997, Koller et al., 2009, Kulasekaran et al., 2014), and there is no substantial base of knowledge from which researchers can determine how to improve the project itself in terms of usefulness and usability because 3D models are not easily integrated into scholarly output (Reinhard, 2013). Hence the need for definition 5: New Heritage: re-examine the user experience that digital media can provide for the understanding and experiencing of tangible and intangible cultural heritage.

Given these five definitions, we could argue that we have five major issues: creating a sense of cultural presence; engaging people with challenging tasks; affording a sense of cultural presence; leveraging new technology to create new and engaging experiences; and finally, providing for evaluation techniques and reflection-inducing interaction themes that help people encounter and resolve challenges in heritage.

In the short and medium term an important question is whether we can teach the mechanics, principles and issues of archaeology, history and heritage studies without requiring the design and creation of high resolution and complicated simulations. The central issue here is how to provide interaction that aids understanding and meaningful and useful transferrable knowledge. A second question is whether we can provide digital environments that allow and inspire debate about the issues of gamification, preservation, conjecture and interpretation. In the following case study we hope to examine an example that addresses if not fully resolves these questions.

3. GAME ENGINES AS INSTRUCTIONAL MODELS

Despite the large number of publications describing projects based on game engines, there are relatively few describing how game engines can be used as interactive frameworks for collaboration, teaching and videoconferencing.

While many education institutes use Skype, Google Chat or other commercial videoconferencing applications, these commercial applications are not suitable for presenting architectural or urban design or archaeological information, as they don't integrate the presenter with interactive 3D media. Nor do they allow spatial or component-based interaction controlled by the presenter in a natural and intuitive manner, without the need to sit or stoop over a mouse or keyboard.

To meet these demands we developed a prototype camera-tracking application using a Kinect camera sensor and multi-camera Unity windows for teleconferencing that required the presentation of interactive 3D content along with the speaker (or an avatar that mirrored the gestures of the speaker). Cheaply available commercial software and hardware and a large display screen in this case an 8 meter wide curved screen) allows participants to have their gestures, movements and group behavior fed into the virtual environment either directly or indirectly. Allowing speakers to present 3D virtual worlds remotely located audiences while appearing to be inside those virtual worlds has immediate practical uses and also particular game-related potential for teaching and demonstrations.

There are immediate practical uses for applications that allow participants to have their gestures, movements and group behaviour be fed into the virtual environment either directly or indirectly in order for presenters to present 3D virtual worlds to remotely located audiences while appearing to be inside those virtual worlds has (Alvarado and Maver, 1999). This project used widely accessible camera-tracking devices and other interface devices and cheaply available commercial software and hardware. Although it might sound highly technical, such a project could help game design classes and conferences to better integrate (thematically or fantastically), the speaker with the digital content (the virtual environment).

Secondly, tracking head movement and gaze direction (Sherstyuk and Treskunov, 2013a, Sherstyuk and Treskunov, 2013b, Gadanac et al., 2014a) and postural changes or biofeedback and 'thought control' (Powell et al., 2013) can allow conference participants, hosts and distantly located narrators the ability to create more immersive conference presentations inside and outside of digital 3D models. This is of great usefulness to the fields of architecture, urban design and archaeology (Cheng, 2003, Peng et al., 2002, Alvarado and Maver, 1999) and to learning in general (Andujar and Gilbert, 2013).

Museums have also explored the use of camera tracking via devices like the Leap controller and Microsoft Kinect to allow for hands-free interaction (Bostanci et al., 2015, Grammenos et al., 2013, Reunanen et al., 2015) as well as software that allows for a combination of the above (Fanini et al., 2015). Figure 1 also shows an example of Kinect for cultural heritage, which was later evaluated (Fanini and Pagano, 2015). There are a few examples of 3D tracking for videoconferencing (Gadanac et al., 2014b), but as far as we know, there is no comparable cultural heritage-focused application that caters for narrator-led split-screen educational experiences.

Figure 1: A demonstration at Digital Heritage 2013 by CINECA, featuring a model of Bologna and Kinect camera-tracked interaction.

Despite the above and other related work in cultural heritage (Figure 1), so far there does not appear to be an effective way to combine immersive 3D models and video conferencing, particularly for large scaled cylindrical displays such as the curved stereo display shown in (Figure 2).

For example, this specialized visualisation centre http://humanities.curtin.edu.au/research/centres/hive/visualisation-systems/ includes an 8-meter wide display that is a nearly perfectly semi-circular and due to its three-part projection system, it can accommodate several panes of teleconferencing windows, with the avatars on the outside windows able to see each other as well as the presently located person and aspects of the work that they are presenting. The primary software used in this example was Unity coupled with MiddleVR (for Unity) but other 3D real-time rendering engines can be employed.

Camera tracking can be provided economically via Kinect (Xbox 360) or Kinect One, or via proprietary software (Optitrack) and the centre also has developed the use of customized wand and helmet-based sensors that can also be added to other types of props or clothing, but the navigation requires some degree of expertise (experience and understanding of 3D space). So a more intuitive and immersive solution that allows the speaker to interact more directly with the audience would be very useful.

Figure 2: The cylindrical stereo screen of the HIVE, Curtin University, Perth, Australia.

There is an added issue in that in the current setup the sweet spot for viewing (and for stereo vision) is at the center of the display. This is where speakers typically stand to present. Either the speaker faces the audience with his or her back to the display (and hence cannot direct navigation in the virtual projected environment), or the speaker faces the display to navigate in the virtual scene and the audience can no longer see their face (and their voice is harder to hear).

Our hypothesis was that either:

i. The speaker would prefer to stand to the side of the display and navigate using an avatar in the scene that would control the navigation and display of objects in the environment based on the mirrored gestural motions of the speaker (Figure 3).
ii. Or, the speaker would prefer to be standing to the side of the screen looking between the screen and the audience (i.e. at an angle to both) and their body would be blue-screened into the virtual environment.

For both hypotheses we believe that they would appear both more immersive and more intuitive for non-expert users (from the point of view of both speakers and the audience and for a remote audience).

3.1. SIGNIFICANCE

A developed and thoroughly tested prototype allows conferences in archaeology, architecture, urban design and other fields with 3D media (models, sites and so on) to insert a streaming live narrator (or a pre-rendered movie of a narrator) into the environment and control aspects of the environment remotely via camera tracking using the Microsoft Kinect. Longer-term this could be extended to help participant movement and eye direction/eye gazing in head mounted displays.

Figure 3: *The avatar mirrors the tracked gestures of the speaker and triggers slides by pointing at the relevant object.*

3.2. AIMS

Being able to greenscreen a narrator into a 3D environment could allow an embedded real-time avatar provide both a sense of human scale and improve engagement and a sense of spatial immersion. We also wanted to control an avatar in the virtual environment using the speaker's gestures either via a mirrored in-scene avatar (Figure 3) or via a hand icon (Figure 4).

Our main aim was to trigger slides and movies inside a Unity environment via speaker finger-pointing. Ideally the speaker could also change the chronology of built scene with gestures (or voice), could alter components or aspects of buildings, move or replace parts or components of the environment.

The final aim was to better employ the 8 meter wide curved screen (that projects also in stereo) so that participants can communicate with each other (presenters and the virtual environment) without anyone getting in the way or risk having their attention distracted by conventional keyboard or mouse type peripherals.

3.3. Prototype For Pointing And Integrated Slides

The project involved exploring and developing possible methods of connecting motion control to interactive presentations on alternative displays. Displaying research data between scientists or to the general public is usually through linear presentations, either timed or stepped through by a presenter. Through the use of motion tracking and gestures, presenters could provide a more engaging experience to their audience, as they would not have to rely on prepared static media, timing, or mousing around.

Fields such as archaeology, architecture, or urban design could benefit from being able to take a non-linear course through what they are presenting, or being able to freely manipulate objects or environments within their presentations. However, game design could also employ this prototype to point out and change level design by using natural motions on a large display screen.

This project could allow a remote presenter to be displayed within their data or virtual environment, allowing them to interact with their data during a presentation, providing a more immersive viewing experience.

Possible display technology could be Tiled, Curved and Cylindrical displays used with the Kinect, Leap Motion or other hardware. There are possible applications in museums where a display can allow participants to engage in discovering more about an exhibit through motion control. The project aimed to investigate possibilities in hardware and software to identify how the different technologies interact and their application, as well as provide a base for future more specialized developments.

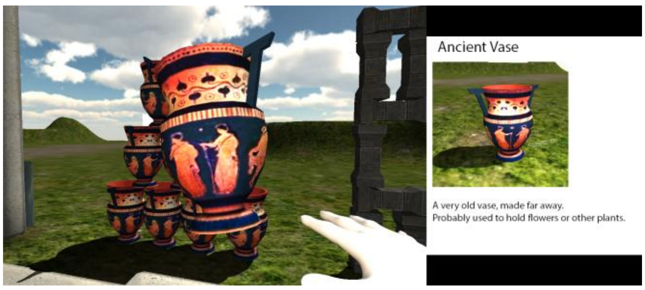

Figure 4: Another option is to simply have a hand which points to objects in the scene, the virtual hand moves and points according to the tracked hand of the speaker.

3.4. Prototype For Avatar Mirror-Controlled By Speaker

An alternative to the speaker controlling the movement and gestures directly is for their gestures to be tracked and mirrored by a Non Playing Character (NPC) as shown earlier (Figure 3). By transferring the speaker's gestures and movements to a NPC the audience can concentrate on the objects and events in-scene. Also the speaker can play different roles, constrained only by imagination and technology. We can also add some interesting effects. For example the appearance of the NPC could relate to the gestures or objects visited and triggered by the speaker or by the number of slides that the speaker and audience find and take the time to read.

3.5. *Technical Constraints*

The commercial company Zigfu allowed us access to the Zigfu Development Kit http://zigfu.com/ which allows developers to create cross-platform, motion-controlled apps with the Kinect and other 3D sensors in HTML5/JavaScript, Unity3D and Flash (Figure 5). The ZDK allowed us to easily connect the Kinect up to different types of environments and it also tracked the skeletons of multiple players simultaneously (three people could be tracked but the tracking was unreliable).

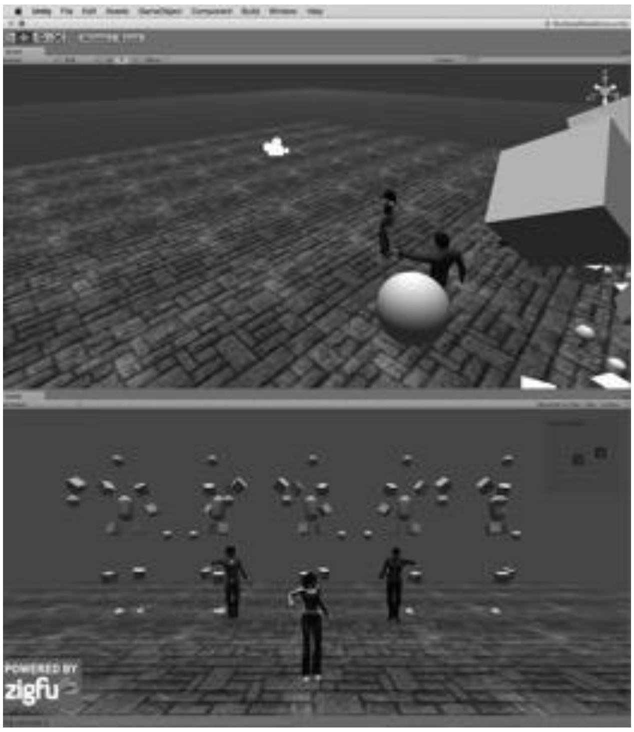

Figure 5: The commercial package Zigfu allows multiple players and interaction with physical objects but has some extra software requirements for development.

One possible limitation is that in order to develop with Zigfu one also needs to buy Unity Pro. For our prototype we could use Kinect 360 or Kinect One (although Kinect v2 requires Windows 8 and Direct X11, it is more accurate and powerful than the older Kinect 360). However, we did not use Zigfu code for the final code, for either Kinect v.1 or Kinect v.2.

Please also note that while this prototype was developed specifically for a 180 degree, 8-metre diameter cylindrical stereo screen, the prototype could also be used for HMDs, the web and other display devices.

4. SUGGESTED EVALUATION

The application of this tool to staged production and performances could benefit from study of mise en scène, the arrangement of staged elements for dramatic effect (and, in this case, for enhanced memorability). One notable virtual heritage project that incorporates a game environment as the 3D scene behind human actors (performing a classical play) along with in-scene artificial characters (controlled by a behind-the-scenes puppeteer) is the Egyptian Oracle project (Gillam and Jacobson, 2015). Unlike many virtual heritage projects, much of the 3D assets and related materials for this project are available online for free via http://www.publicvr.org/.

Although there is much to be learnt from screen interface design (Persson, 1999) and from dramaturgy and cinematography (Jacobs, 2015) in relation to game engines and the interactivity they can provide (Szabó, 2013), this tool bridges the area between immersive Virtual Reality, eLearning, and performance studies.

Presence research studies might seem to be the most appropriate field to consider in terms of adopting evaluation metrics, but the field still lacks a large amount of digital heritage examples and practical content (Tost and Champion, 2007, Turner and Turner, 2009). Presence research studies traditionally evaluated fully immersive stereo displays and CAVES (Schubert et al., 1999), and it has suffered critique and debate over its use of terms (Schuemie et al., 2001, Slater, 1999, Schettino, 2015) and its use of statistics (Gardner and Martin, 2007, Slater and Garau, 2007).

Given the above considerations, an evaluation framework will depend on the specific context, and whether responses are required from the instructor (narrator's) point of view, or from the audience point of view.

For the focus area presented in this paper (virtual heritage with an in-room instructor/speaker), evaluation could consider effectiveness and engagement from the speaker's point of view; and engagement, instructional clarity, memorability and impact from the audience's point of view.

Preferably at least 5-6 subject experts would be used to evaluate the usefulness and usability of the tool in terms of instructors/narrators. For the audience, at least 20 people but preferably 60 people (2 sets of 30 or 3 sets of 20) should be evaluated. Due to the smaller number of participants in typical heritage or archaeology classes, and in consideration of the smaller seating areas (say between 20-30 people) of most curved screen displays, a within-subjects evaluation may be more appropriate than a between-subjects evaluation.

The curved-screen environment (environment 1) could be compared to a large-display flat screen presentation (environment 2), and to avoid sequencing issues, there could be one groups who are evaluated in environment 1 then environment 2, while the second group would then be evaluated in environment 2 then 1.

Conversely, the test environments could be between a curved screen with the pointing software, and a curved screen of the same content with a typical mouse/keyboard setup. Another evaluation could compare curved screen environments with the narrator mirrored by a non-playing character inside the environment, with the same curved display environment but with the narrator not mirrored (but a virtual hand tracking their real hand).

If the focus is on entertainment rather than education, a novel test of the spatial effect of a curved screen display's advantages over flat screens could also be evaluated, and there have already been preliminary studies in this area in terms of spatial immersion and engagement (Champion et al., 2009, Mun et al., 2015). Previous research into similar projects also reveals that care needs to be taken in allowing a balance between user-freedom and guidance (Damiano et al., 2013) .

5. FUTURE WORK

The project team plan to review and develop a robust methodology and heuristics for presenting a narrator or conference presenters via a 2D real-time or pre-rendered movie inside a 360-degree panorama or 3D virtual environment, via an HTML webpage or directly inside a virtual environment on a curved or tiled display and on a head mounted display (HMD). An XBOX Kinect v2 camera is programmed to track gestures that can be fed into both 3D virtual environments and 360-degree panoramas into which movies have been inserted. These virtual environments can also be run on consumer head-mounted displays (HMDS), ranging from extremely low-cost devices such as Google Cardboard to Oculus Rift and Samsung Gear VR.

This pointing and tracking prototype may also help game design teachers to test simple game shell environments. Where games are provided with the original source assets, we could use this prototype to point out and trigger elements in the game to an audience via the 8-meter wide curved screen.

As potential future uses, instead of slides, the speaker could point to and thus trigger movies, cut-scenes, or other camera views. If displaying interactive game content, the resolution or shaders or camera shake of the side window camera view could also be affected by the speaker's gestural accuracy or their tiredness (or energy). This factor could in turn affect gameplay. Another option might be for the side view to replay past game events (or scripted future events) when the computer determines that the game play is slower.

If the objects in the game window are triggered by a Non-Playing Character (NPC) that mirrors the speaker's gestures, then the avatar's actions could also be affected by the speaker's gestural accuracy or their tiredness (or energy); these factors could also be recorded with biofeedback.

As an example of another type of media that could interact with this camera tracking, a collaborator created video panoramas that could be viewed on Google Cardboard VR or Samsung Gear VR. The case study and example shown was of Brazilian baroque churches and the community was trained to create these panoramas to both develop cultural skills and to increase their awareness of the dangers of vandalism. The original technology of the pre-rendered video and panorama ran on HTML using JavaScript and three.js.

Using the Kinect or other sensors, we can remove the background of a presenter in real-time and we would like to next work out how to stream panorama and live avatar together via the Internet, while allowing the presenter (or avatar) to trigger objects in the panorama by pointing at them.

For game design and built heritage applications that require presenter and audience to collaborate on designing and critiquing tectonic elements inside spatially immersive 3D digital environments, hybrid video streams and interactive panoramas could be shared via this alternative video conferencing system.

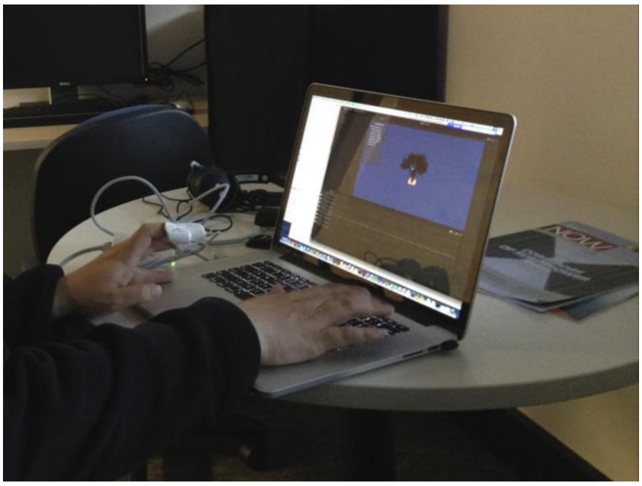

Figure 6: Middleware for biofeedback, here the equipment is Wild Divine finger sensors with a Unity environment. The code is available on Github [https://github.com/simultech/Biometrics_Service].

Finally, motion analysis from the HMDS, biofeedback from low-cost biofeedback devices (*emotiv, Neurosky, Wild Divine* et al.) and gaze analysis data (Torbii and other products) can be incorporated into generic feedback for both audience and presenter. These products can connect with entertainment technology (Set, 2013, Fassbender, 2012) or mainstream 3D real-time rendering engines such as Unity (used in this project). In 2014 we developed middleware for biofeedback sensors that could be connected to mainstream game engines (Figure 6) and we will also see if indirect biofeedback can be incorporated into the background of the presentation or provide feedback to the speaker.

Given the range of potential interaction, how can such technology as the Xbox Kinect version 1 or version 2 camera tracking improve the communication of heritage via digital media?

The following ideas for *thematically* using the avatars in the 3D world may help improve engagement, challenge and feedback:

1. Avatars appear to change to reflect people picking up things.
2. Avatars in the simulated world change their size, clothing or inventories – they scale relative to typical sizes and shapes of the typical inhabitants, or scale is dependent on the scene or avatar character chosen.
3. Avatars role-play – different avatars see different things in the digital world.
4. Narrator gestures affect the attention or behaviour of the avatar.

Secondly the Xbox Kinect camera tracking could change the simulated world or digital objects in that world:

1. Multiple players are needed to lift and examine objects.
2. Objects move depending on the biofeedback of the audience or the presenter.
3. Interfaces for Skype and Google hangout – remote audiences can select part of the screen and filter scenes or wire-frame the main model.
4. Levels of authenticity and time layers can be controlled or are passively / indirectly affected by narrator motion or audience motion / volume / infrared output.

We also developed similar software for MinecraftEdu (www.minecraftedu.com/). With three software engineering students we are currently continuing this work but building middleware so that the camera-tracking equipment can be easily connected to any mainstream real-time rendering engine (game engine) and a new and simplified interface is also being developed so that non-programmers can easily add or change gestures.

6. CONCLUSION

This paper discussed the development of a prototype that can be used to communicate both virtual environments and speakers (either separately or in-scene) to remote audiences or to large local audiences. An in-scene avatar can be provided, minimizing potential external distractions and allowing interesting 'slippages' between avatar and presenter as the avatar can also mirror the speaker's gestures.

In terms of the technical implementation, the current setup uses a large curved display that can also project in stereo, but this application can also be used on conventional desktops. There are at least four potential future uses: teaching game design (especially level design); creating split-screens (other camera views, cutscenes and backstory movies and alternative camera views); integrating with interactive panorama-video hybrid media and as biofeedback-augmented projects.

The prototype does not fully address the five major issues and definitions described at the start of this paper, but it goes some way to providing insightful suggestions for some of them. Creating a sense of cultural presence may be helped by the depiction of in-world avatars that gesture meaningfully. Providing triggers in the 3D world may help engage people with challenging tasks since they have to learn how ot meaningfully move and gesticulate or even talk, while comprehending the simulated content. The new and increasingly affordable camera sensor technology also promises a non-contact (and thus more hygienic) interface for museums libraries and galleries.

Finally, this prototype may eventually be developed with inbuilt passive evaluation techniques, but more work is needed to ensure that the interaction leads to critical reflection that help people encounter and resolve challenges in heritage.

ACKNOWLEDGEMENTS

This work was partially supported by an iVEC/Pawsey Supercomputing grant. In particular the authors would like to thank ZIGFU, Pix4d, for providing Chillon Castle to use as an example, Samuel Warnock for his work on version 1 code, the Curtin HIVE research facility, Andrew Dekker for his work as a visiting fellow on the biofeedback middleware and Demetrius Lacet for his visit and work on interactive movie panoramas for cultural heritage.

REFERENCES

Alvarado, R. G. and Maver, T. (1999) 'Virtual reality in architectural education: Defining possibilities', *ACADIA Quarterly*, 18(4), pp. 7-9.

Anderson, E. F., McLoughlin, L., Liarokapis, F., Peters, C., Petridis, P. and Freitas, S. (2009) 'Serious games in cultural heritage'.

Anderson, M. (2008) 'Putting the" reality" in virtual reality: new advances through game engine technology'.

Andujar, M. and Gilbert, J. E. 'Let's learn!: enhancing user's engagement levels through passive brain-computer interfaces'. *CHI'13 Extended Abstracts on Human Factors in Computing Systems*: ACM, 703-708.

Barsanti, S. G., Remondino, F., Fenández-Palacios, B. J. and Visintini, D. (2014) 'Critical factors and guidelines for 3D surveying and modelling in Cultural Heritage', *International Journal of Heritage in the Digital Era,* 3(1), pp. 141-158.

Bostanci, E., Kanwal, N. and Clark, A. F. (2015) 'Augmented reality applications for cultural heritage using Kinect', *Human-centric Computing and Information Sciences,* 5(1), pp. 1-18.

Champion, E. (2008) 'Explorative shadow realms of uncertain histories', in Kalay, Y., Kvan, T. & Affleck, J. (eds.) *New heritage: New media and cultural heritage*. Abingdon, Oxon, United Kingdom: Routledge, pp. 185-206.

Champion, E., Henden, C., Jacobson, J. and Muhlberger, R. (2009) 'A Surround Display Warp-Mesh Utility to Enhance Player Engagement', *IFIP Lecture Notes in Computer Science (LNCS): Vol. 5309*: Springer, pp. 46-56.

Cheng, N. Y.-w. (2003) 'Approaches to design collaboration research', *Automation in construction,* 12(6), pp. 715-723.

D'Andrea, A. and Fernie, K. (2013) 'CARARE 2.0: a metadata schema for 3D Cultural Objects'. *Digital Heritage International Congress (Digital Heritage 2013)*, Marseille, France, 28 Oct -1 Nov 2013. Marseille, France IEEE, 137-143.

Damiano, R., Gena, C., Lombardo, V. and Nunnari, F. 'Leveraging Web 3D Guidance in cultural heritage fruition'. *Proceedings of the Biannual Conference of the Italian Chapter of SIGCHI*: ACM, 1.

Fanini, B., d'Annibale, E., Demetrescu, E., Ferdani, D. and Pagano, A. 'Engaging and shared gesture-based interaction for museums the case study of K2R international expo in Rome'. *2015 Digital Heritage*, Granada, Spain, Sept. 28 2015-Oct. 2 2015, 263-270.

Fanini, B. and Pagano, A. 'Interface design for serious game visual strategies the case study of “Imago Bononiae”'. *2015 Digital Heritage*, Sept. 28 2015-Oct. 2 2015, 623-626.

Fassbender, E. 'Use of 'The Elder Scrolls Construction Set' to create a virtual history lesson'. *Game Mods*: ETC Press, 67-86.

Gadanac, D., Dujak, M., Tomic, D. and Jercic, D. 'Kinect-based presenter tracking prototype for videoconferencing'. *Information and Communication Technology, Electronics and Microelectronics (MIPRO), 2014 37th International Convention on*: IEEE, 485-490.

Gadanac, D., Dujak, M. o., Tomic, D. and Jercic, D. 'Kinect-based presenter tracking prototype for videoconferencing'. *37th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), 2014* Opatija, Croatia, 26-30 May 2014: IEEE, 485-490.

Gardner, H. J. and Martin, M. A. (2007) 'Analyzing ordinal scales in studies of virtual environments: Likert or lump it!', *Presence,* 16(4), pp. 439-446.

Gillam, R. and Jacobson, J. (eds.) (2015) *The Egyptian Oracle Project: Ancient Ceremony in Augmented Reality*. London: Bloomsbury Publishing.

Grammenos, D., Zabulis, X., Michel, D., Padeleris, P., Sarmis, T., Georgalis, G., Koutlemanis, P., Tzevanidis, K., Argyros, A. and Sifakis, M. (2013) 'A prototypical interactive exhibition for the archaeological museum of thessaloniki', *International Journal of Heritage in the Digital Era,* 2(1), pp. 75-99.

Ioannides, M. and Quak, E. (eds.) (2014) *3D Research Challenges in Cultural Heritage: A Roadmap in Digital Heritage Preservation*: Berlin, Heidelberg: Springer Berlin Heidelberg: Imprint: Springer.

Jacobs, J. (2015) 'Visualising the visceral: using film to research the ineffable', *Area*.

Koller, D., Frischer, B. and Humphreys, G. (2009) 'Research challenges for digital archives of 3D cultural heritage models', *ACM Journal on Computing and Cultural Heritage (JOCCH),* 2(3), pp. 7.

Kulasekaran, S., Trelogan, J., Esteva, M. and Johnson, M. 'Metadata integration for an archaeology collection architecture'. *Proceedings of the 2014 International Conference on Dublin Core and Metadata Applications*: Dublin Core Metadata Initiative, 53-63.

Mun, S., Park, M.-C. and Yano, S. (2015) 'Evaluation of viewing experiences induced by a curved three-dimensional display', *Optical Engineering,* 54(10), pp. 103104-103104.

Peng, C., Chang, D. C., Blundell Jones, P. and Lawson, B. (2002) 'Exploring urban history and space online: design of the virtual Sheffield application', *Design Studies,* 23(5), pp. 437-453.

Persson, P. (1999) 'Understanding representations of space: A comparison of visualisation techniques in mainstream cinema and computer interfaces', *Social Navigation of Information Space*: Springer, pp. 195-216.

Potenziani, M., Callieri, M., Dellepiane, M., Corsini, M., Ponchio, F. and Scopigno, R. (2015) '3DHOP: 3D Heritage Online Presenter', *Computers & Graphics,* 52, pp. 129-141.

Powell, C., Munetomo, M., Schlueter, M. and Mizukoshi, M. (2013) 'Towards Thought Control of Next-Generation Wearable Computing Devices', *Brain and Health Informatics*: Springer, pp. 427-438.

Pujol, L. and Champion, E. (2011) 'Evaluating presence in cultural heritage projects', *International Journal of Heritage Studies,* 18(1), pp. 83-102.

Reinhard, A. (2013) *Publishing Archaeological Linked Open Data: From Steampunk to Sustainability*. ISAW Papers. Available at: http://dlib.nyu.edu/awdl/isaw/isaw-papers/7/reinhard/ (Accessed: 30 May 2016).

Reunanen, M., Díaz, L. and Horttana, T. (2015) 'A Holistic User-Centered Approach to Immersive Digital Cultural Heritage Installations: Case Vrouw Maria', *Journal on Computing and Cultural Heritage (JOCCH),* 7(4), pp. 24.

Schettino, P. 'Re-defining the concept of immersion in digital immersive environments'. *2015 Digital Heritage*: IEEE, 409-412.

Schubert, T., Friedmann, F. and Regenbrecht, H. (1999) 'Embodied presence in virtual environments', *Visual representations and interpretations*: Springer, pp. 269-278.

Schuemie, M. J., Van Der Straaten, P., Krijn, M. and Van Der Mast, C. A. (2001) 'Research on presence in virtual reality: A survey', *CyberPsychology & Behavior,* 4(2), pp. 183-201.

Set, C. (2013) 'Use of "The Elder Scrolls Construction Set" to create a Virtual History Lesson', *Game Mods: Design, Theory and Criticism*.

Sherstyuk, A. and Treskunov, A. 'Head tracking for 3D games: Technology evaluation using CryENGINE2 and faceAPI'. *Virtual Reality (VR), 2013 IEEE*: IEEE, 67-68.

Sherstyuk, A. and Treskunov, A. 'Natural head motion for 3D social games'. *Virtual Reality (VR), 2013 IEEE*: IEEE, 69-70.

Slater, M. (1999) 'Measuring presence: A response to the Witmer and Singer presence questionnaire', *Presence: Teleoperators and Virtual Environments,* 8(5), pp. 560-565.

Slater, M. and Garau, M. (2007) 'The use of questionnaire data in presence studies: do not seriously likert', *Presence: Teleoperators and Virtual Environments,* 16(4), pp. 447-456.

Stone, R. 'Serious gaming—virtual reality's saviour'. *Proceedings of Virtual Systems and MultiMedia annual conference, VSMM*, 773-786.

Szabó, A. (2013) 'Multimedia Performance Reconstruction as a Challenge to Theatre History Writing', *Information Technologies for Performing Arts, Media Access, and Entertainment*: Springer, pp. 164-174.

Tost, L. P. and Champion, E. M. 'A critical examination of presence applied to cultural heritage'. *The 10th annual international workshop on presence*: Starlab Barcelona S.L., 245-256.

Tredinnick, J. and Richens, P. 'A fulldome interactive visitor experience a novel approach to delivering interactive virtual heritage experiences to group audiences in fulldome projection spaces, evaluated through spatial awareness and emotional response'. *2015 Digital Heritage*, Granada, Spain: IEEE, 413-414.

Turner, P. and Turner, S. (2009) 'Triangulation in practice', *Virtual reality,* 13(3), pp. 171-181.

Wise, A. and Miller, P. (1997) 'Why Metadata Matters in Archaeology', *Internet Archaeology*, pp. Online.