Virtual Museums as a New Type of Cyber-Physical- Social System

NISIOTIS, Louis <http://orcid.org/0000-0002-8018-1352>, ALBOUL, Lyuba and BEER, Martin

Virtual Museums as a New Type of Cyber-Physical-Social System

Louis Nisiotis[1,2][0000-0002-8018-1352], Lyuba Alboul[1,3][0000-0001-9605-7228] and Martin Beer[1,4][0000-0001-5368-6550]

[1] Sheffield Hallam University, United Kingdom
[2]L.nisiotis@shu.ac.uk, [3]l.alboul@shu.ac.uk, [4]mdb.shu@gmail.com

Abstract. Museums are institutions that primarily care for cultural heritage exhibition, preservation and conservation of historical artifacts. However, simply displaying artifacts and provide complex information to describe them is simply not sufficient to effectively engage museum visitors. To improve visitors engagement and their overall museum experience, the use of technology utilized by museums, introducing the concept of Virtual Museums. This paper discusses the use of Virtual Reality through the use of smart phone devices as a mean of a Cyber-Physical-Social system to support, improve and enhance the visitors' experience. The RoboSHU prototype, its current development stage and future work are presented, together with the future research directions of the research team.

Keywords: Virtual Museum, Virtual Reality, Smart Phone VR, Google Cardboard, Cyber-Physical-Social Systems.

1 Introduction

Museums are institutions responsible for cultural heritage preservation, artefacts exhibition, restoration and conservation, allowing everyone access and be educated about culture and history. The main aim of a museum is to allow visitors understand historical events that took place over time by providing accurate information supplemented with visual elements to engage and educate them. In modern days however, museum visitors demand more interactive, immersive and stimulating experience from what the traditional museology has to offer, which is mainly limited to displaying artefacts in glass cases accompanied by complex descriptions [8]. In the era of the 'museum experience' in which the visitor is seems as a consumer, visitors' satisfaction is crucial to support museums continuity [9]. With the recent advancements in technology, museums have started using smart phones, tablets and VR to support and enhance their visitor's experience, introducing the concept of Virtual Museums [1]. Virtual museums refer to the "*digital spatial environment, located in the WWW or in the exhibition, which reconstructs a real place and/or acts as a knowledge of a metaphor, and in which visitors can communicate, explore and modify spaces and digital or digitalized objects*" [2], and have drawn a lot of interest over the past few years [1, 3-7]. One of the recently introduced technologies is the use of Virtual Reality in general, and smart phones enabled VR in particular. This paper presents a Smart Phone VR prototype that has been developed to investigate the potentials of such technology to support and enhance museum experience, aiming at introducing the concept of a Cyber-Physical-Social system that support social, interactive and immersive experience to visitors.

2 Theoretical Background

Virtual Museums support a mixture of traditional museum practices, utilizing a wide range of communication modes and current technological trends [8], which can customize visitors experience in a museum to improve their overall satisfaction [9-11]. Among the different technologies, the use of VR has been drawing a lot of attention and used in the field of cultural heritage, conservation, restoration, digital storytelling and education [12]. VR is a technology that involves a user interacting with a computer generated artificial 3D environment, in which the users movement is tracked in real time through sensors, and updating the visual input, sound and the environment [13]. VR technology is used in museums to display, reconstruct, as well as perform virtual restoration of artefacts, cultural heritage locations and archeological sites that may have been damaged or perhaps not even exist anymore [12, 14-16]. VR is identified capable of helping visitors adapt to information about artefacts and exhibits [17], and can provide highly immersive and realistic experiences when compared to tools and techniques used in traditional museology [18], due to the technology affordances of immersion and presence. The feeling of immersion refers to "*a form of spatiotemporal belonging in the world that is characterized by deep involvement in the present moment*" [19] and relates to the experience of a technology that is exchanging sensory input from reality with digitally generated input [20], expressing the full absorption of the user into a digital dimension, which stimulates interest, pleasure, cognitive and emotional engagement [21]. Presence is a similar notion, but distinct from immersion [22], and concerns "*the subjective experience of being in one place or environment, even when one is physically situated in another*" [23]. Presence is the subsequent reaction to immersion, which leads the users reaction to the virtual environment to be the same way as the real world [24]. These unique attributes allow the development of virtual experiences that may be difficult or even impossible to reconstruct in the real world, supporting motivation for technology adoption [25].

Since its initial introduction in the 1950's, VR was being a very expensive technology that was challenged by many technical issues and requirements. However, with the rapid development of technology it is now finally an affordable and mature customer-ready technology [26]. Despite some initial resistance to adopt [9], VR has been now increasingly used in museums to improve their visitors' experience and interactions with cultural heritage [12].

2.1 Technical Characteristics of VR

The technical characteristics of VR require the use of hardware equipment to generate the virtual environment and to display information, and there are a number of tools to support this approach. The CAVE (Cave Automatic Virtual Environment) for instance, is a supreme quality immersive technology featuring a room in which the walls, floor and ceiling are projection screens and the user can freely navigate and interact. Similar technologies are the Power Wall and Reality Deck [27] providing the highest level of immersion [30, 31]. Such systems are already in place to support cultural heritage education to allow students visit 'live' archeological sites (see [28]) However, these systems are very expensive and are not mobile as they require the utilization of dedicated spaces [20, 29]. The use of Head Mounted Displays (HMD) is a more affordable and mobile technology which provides highly immersive experience to users [29]. HMD such as Oculus Rift and HTC Vive offer head tracking and interactivity with the virtual environment, are customer level, and provide very high graphics resolution, simulation and quality of experience to users. For example, Oculus Rift [30] is a HMD which uses a positional tracker camera sensor to track the user's position as well as a magnetometer, gyroscope and accelerometer to accurately track the head movement. The limitation of this technology however relates to the need of a high spec computer to be connected with the HMD to generate the virtual experience. With the significant technological advancement over the past few years, the opportunity for using smart phone devices to generate VR experiences is also now possible and is a more compact and cost effective option. This technology is utilising the processing power and high quality screen of modern smart phone devices to generate VR experiences, and with the use of low cost display units such as the Google Cardboard, Daydream, Samsung Gear VR and others, can display good quality VR immersive experiences [31]. For instance, Google Cardboard [32] is a handheld device where the user puts his/her smart phone into a cardboard box with lenses, and the visual information is updated using the gyroscope and accelerometer information of the smart phone. However, unlike Oculus Rift, the Google Cardboard can track head rotation but not position.

The ability to transform smart phone devices into VR headsets offer affordable and portable ways to experience VR and open a wide range of possibilities of utilising this technology to support virtual museums and experience the past [33]. It has been identified that to date, there is only a small number of museums who have managed to explore the potentials of VR, mainly due to affordability of developing and executing a virtual environment [18]. Therefore, the use of smart phone enabled VR technology is available to be used as a more accessible and cost effective solution.

2.2 The Virtual Museum Prototype

In order to gain a better understanding of the affordances of VR in the topic of virtual museums, we have developed a prototype and we are experimenting with different technologies. The prototype is named RoboSHU[1] (Fig. 1) and aims at promoting

[1] http://virtualshu.com/roboshu

the history of robotics in: i) desktop 3D virtual world, and through ii) VR technologies. RoboSHU features informational boards and exhibits designed by students, aiming at informing visitors about the history of robotics, provide information about the research conducted by the Sheffield Robotics group, and the current state of the literature. The virtual museum prototype was first presented in [34].

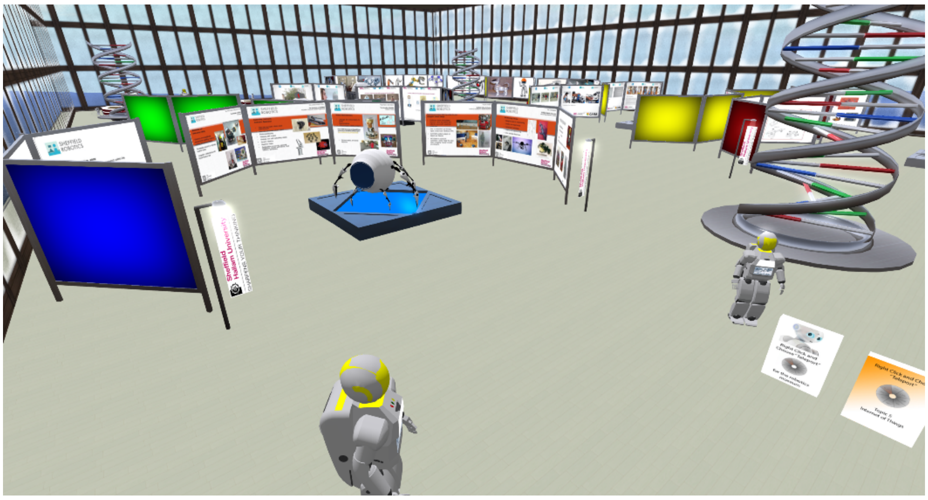

Fig. 1. The RoboSHU.

RoboSHU was first implemented as part of an existing Multi User Virtual Environment (MUVE) named VirtualSHU. This is a is a multi-user 3D virtual world in which users can interact with the environments, its objects, and each other through the use of a graphical representation of their selves called the Avatar. VirtualSHU (Fig. 2) is used to support the delivery of a computing module at our university, for students' dissertation projects, and for research purposes (see [35-38]). The environment is developed using OpenSimulator, an open source MUVE platform, and can be experienced in Desktop 3D and VR mode. In the 3D desktop mode, users are using a computer and a monitor to experience the visual aspect of the virtual world, and use a keyboard and a mouse to interact with the environment and each other. RoboSHU is located on a dedicated area within the VirtualSHU environment, and visitors can visit, navigate, coexist, communicate and interact with other visitors and the virtual museum. Communication is established through the use of Instant Messages, nearby public messages and through Voice over IP.

In the VR mode, the environment can be experienced using the Oculus Rift HMD. Navigation and interaction can be done through the use of an Xbox 360 controller or with the keyboard and a mouse.

In addition to the 3D desktop and VR mode, we have ported the RoboSHU Virtual Museum into a smart phone enabled VR experience using Unity3D Game Engine [37]. We have developed an Android application, which is not yet publicly available; as it is still in a development stage (see Fig. 3).

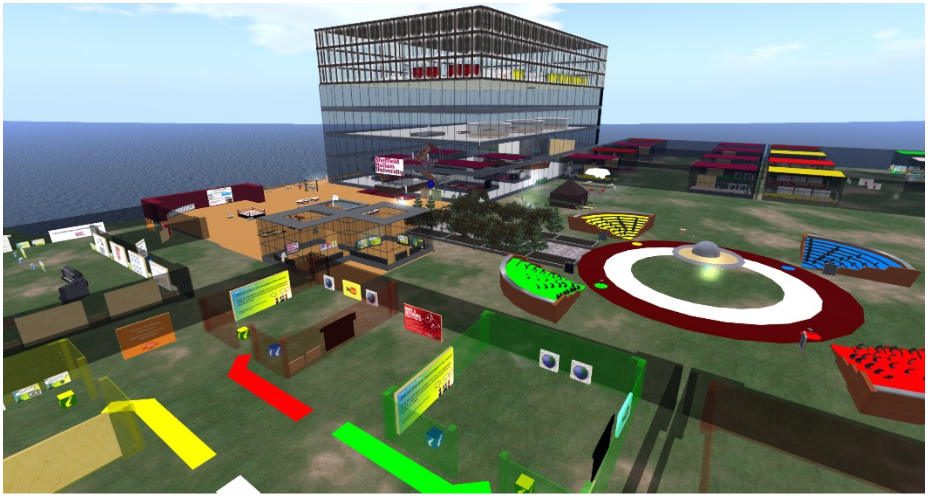

Fig. 2. The VirtualSHU.

The application is targeting modern Android powered smart phone devices and the environment can be experienced with the use of the low cost Google Cardboard or similar low cost HMD device. The latest version of the Google Cardboard features single button functionality through an internal mechanism that generates a touchscreen input, which has been used for user navigation in the virtual environment. Interaction with the environment and artefacts is taking place using the graphical user interface of the virtual museum, in which the visitor has to focus their view for a few seconds in hotspot areas in order to interact with them.

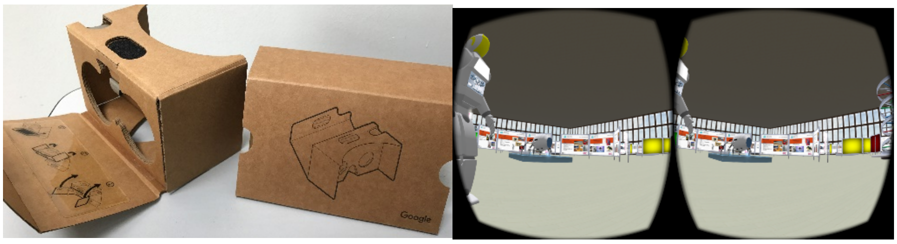

Fig. 3. The RoboSHU Through the Google Cardboard HMD.

3 Conclusions and Future work

The concept of a Virtual Museum can be seen as a union of intertwined and interrelated spaces. 'Navigating' through those spaces, observing their exhibits, interacting and communicating with other visitors in those spaces will lead to forms of new immersive, interactive and personalized experiences to enhance our understanding of the world around us and our cultural roots. The Virtual Museum will be able to connect the audience to events and/or objects, or phenomena, separated either in time or in space or both, as well as provide 'rendezvous' among members of the audience, via various media and mediums.

In this paper we focus mostly on technical aspects of developing a VR museum prototype, however the concept of the Virtual Museum can be perceived in a much broader sense, as a type of a Cyber-Physical-Social society, that can be applied to a plethora of domains [39, 40].

For future work, we are concentrating on developing RoboSHU in several ways. First of all, we aim to include more exhibits and additional information relevant to the history of robotics to improve the educational efficacy of the virtual museum. Moreover, we are concentrating on providing additional functionality to the environment to provide greater user interactivity between users and the environment. To date, the handheld VR prototype is a single user experience, and we are experimenting in converting it to a multi user virtual world to support the concept of a Cyber-Physical-Social system. Furthermore we aim to conduct a series of evaluation studies to investigate the usability and technical aspects of the environment as well as the users' perception of presence and immersion during the VR experience. Another research direction aims at connecting 'virtual robots' that 'live' in the museum to some of real robots that we have in our Robotic lab.

Acknowledgements

We would like to acknowledge Enohor Igbeyi, a PhD student at the Centre for Automation and Robotics Research, Sheffield Hallam University, for her contribution to the design of RoboSHU.

4 References

1. Jensen, L., Konradsen, F.: A review of the use of virtual reality head-mounted displays in education and training. Education and Information Technologies 23, 1515-1529 (2018)
2. Pujol, L., Lorente, A.: The Virtual Museum: a Quest for the Standard Definition. Archaeology in the Digital Era 40 (2012)
3. Shaw, J.: The virtual museum. Installation at Ars Electrónica. Linz, Austria, Karlsruhe (1991)
4. Schweibenz, W.: The" Virtual Museum": New Perspectives For Museums to Present Objects and Information Using the Internet as a Knowledge Base and Communication System. Isi 34, 185-200 (1998)
5. Carlucci, R.: Archeoguide: augmented reality-based cultural heritage on-site guide. (2002)
6. Petridis, P., White, M., Mourkousis, N., Liarokapis, F., Sifiniotis, M., Basu, A., Gatzidis, C.: Exploring and interacting with virtual museums. Proc. Of Computer Applications and Quantitative Methods in Archaeology (CAA) (2005)
7. Styliani, S., Fotis, L., Kostas, K., Petros, P.: Virtual museums, a survey and some issues for consideration. Journal of cultural Heritage 10, 520-528 (2009)

8. Lorente, G.A., Kanellos, I.: What do we know about on-line museums? A study about current situation of virtual art museums. In: International Conference in Transforming Culture in the Digital Age, pp. 208-219. (2010)
9. Galdieri, R., Carrozzino, M.: Natural Interaction in Virtual Reality for Cultural Heritage. In: International Conference on VR Technologies in Cultural Heritage, pp. 122-131. Springer, (2018)
10. Pagano, A., Armone, G., De Sanctis, E.: Virtual Museums and audience studies: the case of "Keys to Rome" exhibition. In: Digital Heritage, 2015, pp. 373-376. IEEE, (2015)
11. Choi, H.-S., Kim, S.-H.: A content service deployment plan for metaverse museum exhibitions—Centering on the combination of beacons and HMDs. International Journal of Information Management 37, 1519-1527 (2017)
12. Carrozzino, M., Bergamasco, M.: Beyond virtual museums: Experiencing immersive virtual reality in real museums. Journal of Cultural Heritage 11, 452-458 (2010)
13. Coelho, C., Tichon, J., Hine, T.J., Wallis, G., Riva, G.: Media presence and inner presence: the sense of presence in virtual reality technologies. From communication to presence: Cognition, emotions and culture towards the ultimate communicative experience, pp. 25-45. IOS Press, Amsterdam (2006)
14. Levoy, M.: The digital michelangelo project. In 3-D Digital Imaging and Modeling, 1999. In: Proceedings. Second International Conference on, pp. 2-11. (1999)
15. Sideris, A., Roussou, M.: Making a new world out of an old one: in search of a common language for archaeological immersive VR representation. In: Proceedings of 8th Int. Conference on Virtual Systems and Multimedia (VSMM), pp. 31-42. (2002)
16. Grün, A., Remondino, F., Zhang, L.: Reconstruction of the great Buddha of Bamiyan, Afghanistan. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 34, 363-368 (2002)
17. Reffat, R.M., Nofal, E.M.: Effective communication with cultural heritage using virtual technologies. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 5, W2 (2013)
18. Lepouras, G., Vassilakis, C.: Virtual museums for all: employing game technology for edutainment. Virtual reality 8, 96-106 (2004)
19. Hansen, A.H., Mossberg, L.: Consumer Immersion: A Key to Extraordinary Experiences. Handbook on the Experience Economy 209 (2013)
20. Freina, L., Ott, M.: A Literature Review on Immersive Virtual Reality in Education: State Of The Art and Perspectives. eLearning & Software for Education (2015)
21. Sorensen, C.G.: Interface of Immersion-Exploring Culture Through Immersive Media Strategy and Multimodal Interface. In: Proceedings of the DREAM conference - The Transformative Museum, pp. 409-421. (2012)
22. Lombard, M., Ditton, T.: At the heart of it all: The concept of presence. Journal of Computer-Mediated Communication 3, 0 (1997)
23. Witmer, B.G., Singer, M.J.: Measuring Presence in Virtual Environments: A Presence Questionnaire. Presence: Teleoperators and Virtual Environments 7, 225-240 (1998)
24. Slater, M.: A note on presence terminology. Presence Connect 3, 1-5 (2003)
25. Mikropoulos, T.A., Natsis, A.: Educational virtual environments: A ten-year review of empirical research (1999-2009). Computers & Education 56, 769-780 (2011)

26. Fradika, H., Surjono, H.: ME science as mobile learning based on virtual reality. In: Journal of Physics: Conference Series, pp. 012027. IOP Publishing, (2018)
27. Lee, H., Tateyama, Y., Ogi, T.: Realistic visual environment for immersive projection display system. In: Virtual Systems and Multimedia (VSMM), 2010 16th International Conference on, pp. 128-132. IEEE, (2010)
28. Ott, M., Pozzi, F.: ICT and cultural heritage education: Which added value? In: World Summit on Knowledge Society, pp. 131-138. Springer, (2008)
29. Gonizzi Barsanti, S., Caruso, G., Micoli, L.L., Covarrubias Rodriguez, M., Guidi, G.: 3D visualization of cultural heritage artefacts with virtual reality devices. In: 25th International CIPA Symposium 2015, pp. 165-172. Copernicus Gesellschaft mbH, (2015)
30. Oculus Rift, https://www.oculus.com/
31. Cochrane, T.: Mobile VR in education: From the fringe to the mainstream. International Journal of Mobile and Blended Learning (IJMBL) 8, 44-60 (2016)
32. Google Cardboard, https://vr.google.com/cardboard/
33. Fabola, A., Miller, A., Fawcett, R.: Exploring the past with Google Cardboard. In: 2015 Digital Heritage, pp. 277-284. IEEE, (2015)
34. Alboul, L., Beer, M., Nisiotis, L.: Merging Realities in Space and Time. In: Virtual Reality Summer School 2017, Lecce, Italy. (2017)
35. Nisiotis, L., Kleanthous, S.: The development and evolution of transactive memory system over time in MUVEs. In: 10th Computer Science and Electronic Engineering Conference. IEEE, (2018)
36. Nisiotis, L., Kleanthous Loizou, S., Beer, M., Uruchurtu, E.: The Development of Transactive Memory Systems in Collaborative Educational Virtual Worlds. In: Immersive Learning Research Network, pp. 35-46. Springer International Publishing, (2017)
37. Nisiotis, L., Kleanthous Loizou, S., Beer, M., Uruchurtu, E.: The use of a Cyber Campus to Support Teaching and Collaboration: An Observation Approach. In: The Immersive Learning Research Network (iLRN) Conference 26-29 June 2017. (2017)
38. Nisiotis, L., Kleanthous Loizou, S., Beer, M., Uruchurtu, E.: The Development of Transactive Memory Systems in Collaborative Educational Virtual Worlds. In: Beck, D., Allison, C., Morgado, L., Pirker, J., Khosmood, F., Richter, J., Gütl, C. (eds.) Immersive Learning Research Network: Third International Conference, iLRN 2017, Coimbra, Portugal, June 26–29, 2017. Proceedings, pp. 35-46. Springer International Publishing, Cham (2017)
39. Alboul, L., Beer, M., Nisiotis, L.: Robotics and Virtual Reality Gaming for Cultural Heritage Preservation. In: Resilience and Sustainability of Cities in Hazardous Environments, pp. 335-345. (2019)
40. Alboul, L., Beer, M., Nisiotis, L.: Merging Realities in Space and Time: Towards a New Cyber-Physical Eco-Society. In: Dimitrova, M. (ed.) Cyber-Physical Systems for Social Applications. IGI Global (2019)