Robotics and Virtual Reality Gaming for Cultural Heritage Preservation

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Published version

ALBOUL, Lyuba, BEER, Martin and NISIOTIS, Louis (2019). Robotics and Virtual Reality Gaming for Cultural Heritage Preservation. In: DORBAN, Flavio, (ed.) Resilience and Sustainability of Cities in Hazardous Environments. GVES, 335-345.

Resilience and Sustainability of Cities in Hazardous Environments
©2019 GVES, Napoli – New York, ISBN 978-88-903183-1-3

Robotics and Virtual Reality Gaming for Cultural Heritage Preservation

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Abstract. This paper reports on the open session held during the International Conference on Resilience and Sustainability of Cities in Hazardous Environments, where the aim was to discuss how the modern technology of robotics, virtual reality, and gaming could help in preserving cultural heritage sites. There is a plethora of achievements in this technology, but how and whether their fusion can add a new dimension to the preservation of cultural heritage sites and untimely contribute to their resilience and sustainability in our rapidly changing world is open to discussions and further research investigations.

Keywords: Cultural heritage, robotics, virtual reality, serious games, sustainability

1. Introduction

Culture plays a fundamental role in economies, in particular in urban economies, through monetary and non-monetary values. According to the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Universal Declaration on Cultural Diversity, culture is "*the set of distinctive spiritual, material, intellectual and emotional features of a society or a social group that encompasses art and literature, lifestyles, ways of living together, value systems, traditions and beliefs*" [1]. Culture is an integral part of our society.

Cultural Heritage is not just a historical site or a collection of objects, either historical or artistic or both. It is part of our ecosystem and a window into our past, and however **paradoxical it may appear** it is a window into our future. Our identities are formed by our cultural roots and the life of the communities is intertwined with our cultural past.

The UNESCO defines cultural heritage as "*the legacy of physical artifacts and intangible attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations*" [2].

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In some cases a cultural heritage site is a landmark and pride of communities living nearby, such as Pompeii or Ironbridge [3], and there are a lot of efforts made in various countries and communities to protect and preserve such cultural sites.

With the developments in modern technology we can, however, create new approaches, not only to protect cultural heritage sites and make them available for a wide range of public, but also to produce a framework, a kind of Cyber-Physical Social System that aims at connecting the audience to events and/or objects, or phenomena, separated either in time or in space or both, as well as provide 'rendezvous' among the members of the audience, via various media and mediums. In addition, this can lead to the development of new types of storytelling, allowing the visitors to create their own narratives as well as communicating with each other.

During the open session of the conference, three technologies were proposed for discussion: Robotics, Virtual Reality (VR), and Serious Games (SG).

2. Background

Robots are often associated in popular press with either impressive Hollywood humanoid characters or with machines that are capable to do repetitive tasks, such as industrial robots. In reality, however, the recent research in the domain of robotics has allowed for robots to become complex creations used in variety of contexts. Robots are also moving out of research laboratories and are used in such applications as service providers [4], robot assistants [5], and robot guides [6].

Nevertheless, one of the most important robotic applications is robot exploration of environments. There is a diversity of environments, such as archeological sites, large indoor environments, urban environments, monuments, etc. Robotics systems are versatile and complex and are used in search and rescue [7], surveillance [8], and monitoring. For instance, heritage sites are often large and may be exposed to a plethora of geological, landscape, and other hazards. Robot exploration of hazardous environments can help in the collection of data for improving digitized databases, assisting and protecting human resources, and providing remote access to restricted areas. Unmanned Autonomous Vehicles (UAV) can provide aerial surveys of archeological sites and automatic image processing can help identifying hidden regular shapes and/or possible safe paths for human workers.

Virtual reality (VR) technology has been applied to the protection of cultural heritage for about two decades [9-11]. This allows anyone with a web connection or a virtual reality headset to visit some of the world’s most famous heritage sites, without leaving their homes. Creating virtual versions of heritage locations through VR may also help preserving site records or aiding in reconstructions if heritage locations are damaged in the future. The data collected by robots, sensors, and other means will help in creating a three-dimensional (3-D) representation of historic sites. Further modifications can be applied in order to visualize the site at it was initially and analyze the hazards (and/or disasters) that led to its current state. This can help to prevent similar events in other places. In addition, a 3-D model of a cultural-heritage site can contribute to better management and organization of the scene [12]. Combining VR

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and gaming technology can create a realistic representation of the site at various moments of time by adding characters (avatars) to the 3-D representation, thus creating a 3-D+time scene reconstruction. This will allow visitors to 'explore' and to 'see' events in the past. However, the main challenge is to determine how to link the real and virtual worlds so that the visitors relate to every world simultaneously in such a way that they have rewarding and enjoyable visits.

Open session feedback

The feedback from the conference audience confirmed the interest in the ideas regarding the use of robots, VR, and SG presented above, and provided further insights to their applications.

Robots as explorers, such as drones together with telemetry, could observe inaccessible places, access damage and reconstruct models of sites and objects with telemetry. Various sensors can be used, such as RGB and IR cameras, and 3-D lasers. In addition, robots can be used for transportation by air and by land.

Robots as guides can interact directly with people and provide information regarding a cultural site, its historical past, and its present state. In addition, robots can indicate safe routes and potential hazards. Robots can also provide a link between a particular location at a cultural site and artefacts from this site deployed in a museum. This can be accomplished by using communication networks between robots and the WiFi networks at a museum.

Virtual reality together with serious games can, in addition to simulation of a particular heritage site, be used to raise awareness of potential challenging situations, and can ultimately lead to the development of tools that can simulate various potential disaster situations and help with educating the public and in emergency planning.

In the following sections we explore the potential approaches of how to present our cultural heritage in a new way whilst preserving the areas and artefacts, and how to make available spaces, objects and narratives, and background history and influences that are associated with a historical site or an artefact to allow people experience history first hand. A site can be located remotely or does not even have to exist as it existed in the past. We would like to move away from the vertical system of the 'Authorised Heritage Discourse' [13] to the multi-view approach of Cyber-Physical-Social eco-Systems noted in the introduction

3. Pompeii, Vesuvio, and Campi Flegrei

The city of Naples is jammed between the two volcanos, Vesuvius (Fig. 1) which is very well known due to its disastrous eruption in AD 79 that destroyed and buried the cities of Pompeii and Herculaneum, and the less known super volcano Campi Flegrei or the Phlegraean Fields on whose deposits the city is built. Naples' western edge is literally living inside the Campi Flegrei’s caldera.

Figure 1. The Somma-Vesuvius volcanic complex in the background, with the city of Naples in the foreground.

The ruins of Pompeii (Fig. 2) are partially open to the visitors and are a celebrated heritage site that inspired many painters and scientists to portray its past. Robots, VR and SG can contribute to the reconstruction of this past and create the city in a Virtual Space as it was before and during the eruption.

Figure 2. The Forum at Pompeii.

As noted above, robots can act as guides, monitor and scan the areas, and act as links to the reconstructed city in VR. In Fig. 2, two types of robots can be seen. A robot-guide on the ground (the robot at the lower left corner) can 'meet and greet' visitors, answer their questions, and direct them to the locations of interest. Robot-drones (above the image) can scan the area and submit resulting images to the robot-guide on the ground, so that the robot can display them to the visitors (for example, using the screen on its chest). Robot-drones can guide visitors to a requested area, because for a ground robot is difficult to travel on the roads of Pompeii due to their uneven structures. In the case of robot-drones, the safety requirements should be applied with utmost care [14]. In addition, the data collected by robot-drones can be used for generating and updating a 3-D model of the site.

Most of the artefacts found in Pompeii are part of the collections of the Naples National Archaeological Museum, and in VR these artefacts can be allocated to the places where they were found. The 'virtual' Pompeii can be filled with automated characters that would 'represent' citizens of ancient Pompeii. Visitors can be represented as avatars and robots and can be connected to their avatars as well and can act as virtual guides. More details can be found in [15]. Therefore, in addition to visualizing historical sites such as Pompeii, the area can be closely monitored and a framework can be developed that could simulate and potentially predict future eruptions which could be integrated into VR and SG.

We should note that the full 'immersion' into the VR space is not necessary. A person can just do manipulations on a computer similar to playing games and navigate avatars by pressing buttons on the keyboard. It would also be useful to have the possibility of using Head Mounted Displays and experience 'being there' at the dedicated locations on the premises.

4. Virtual Museums

Museums are institutions that primarily care for cultural heritage preservation, exhibition and conservation of historical artifacts, making culture accessible to everyone [16]. The purpose is to enable visitors to understand key events that took place in history by presenting accurate complex information in engaging and entertaining ways. However, simply displaying artifacts in glass cases and expect visitors to read complex descriptions of their origin is not sufficient. Thus, the need to improve and modernize display methods to be able to compete with the entertainment industry and overcome the outdated principles of traditional museology is stressed [17]. The museum experience is now shifting from the traditional museum 'featuring displays' and having 'museum visitors' to the era of the 'museum experience' and 'museum consumer' [18]. Consumer satisfaction is crucial, and to avoid the negative financial and cultural implications of declining visitor numbers, museums employ different types of technology to attract and retain visitors. Some of the latest technologies adopted include the use of smart phones and tablets, augmented reality, and recently VR, introducing thus the concept of Virtual Museums [19].

4.1 Virtual Reality for Virtual Museums

The topic of Virtual Museums has drawn a lot of interest over the past few years, with many scholars attempting to form definitions, raising a debate as to the status of information conveyed and the utilized technology [19-24]. Pujol and Lorente [25] have considered many of them and have proposed that a Virtual Museum refers to "*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 com-*

municate, explore and modify spaces and digital or digitalized objects". Virtual museums offer a mixture of traditional museum practices, a range of semiotics communication modes, trends, and different technologies [26]. Furthermore, virtual museums have been classified according to their content i.e. archaeology, the duration (permanent or temporary), type of interaction (interactive or not), level of immersion (immersive or not), distribution type (online and offline), scope (education, entertainment, etc.), communication style (descriptive or narrative), and sustainability [27].

In virtual museums, the use of VR has been gaining a lot of attention among other technologies, especially in the field of cultural heritage, conservation, restoration, digital storytelling and education [16]. VR can help museums to overcome a number of challenges and limitations [28], and allow the presentation and reconstruction of artefacts and historical environments that may have been damaged over time [29], archeological sites that no longer exist [30], perform virtual restoration of already damaged artefacts without affecting the actual exhibit [16], and used as assistive devices for restoration [31]. VR allows more vivid and realistic experience when compared to the traditional multimedia presentation tools used in museums [32]. Studies have shown that the use of technology to customize the way visitors explore and experience a museum could improve their overall satisfaction [33-35], and VR can help a visitor to adapt to the cultural proposal and the information about the artefacts [36].

After decades of challenging technical issues and expensive requirements, VR is now finally a customer-ready technology, and despite some initial adoption resistance [33], is now increasingly used in museums due to the technology's unique affordances of immersion and presence to improve visitors' experience and interactions with cultural heritage [16]. Immersion concerns the experience of a technology that exchanges sensory input from reality with digitally generated input, such as audio and graphics [37]. It is defined as "*a form of spatio-temporal belonging in the world that is characterized by deep involvement in the present moment*" [38], and expresses the full absorption of the user into a new and digital dimension, which stimulates the interest and pleasure that are cognitively and emotionally engaging the user [39]. The notion of presence is similar to, but distinct from the concept of immersion [40]. Presence is defined as "*the subjective experience of being in one place or environment, even when one is physically situated in another*" [41], and is the subsequent reaction to immersion which leads to the users brains reacting to the virtual world in the same way as in the real world [42]. The attributes of presence and immersion, in combination with the ability to develop and experience situations that may be difficult or even impossible to experience in the real world and/or deviate from reality, are affordances that support motivations for technology adoption [43].

The technical characteristics of VR require hardware equipment to generate the virtual environment and to display information. The optimal hardware configuration for a high quality experience that will provide the highest level of immersion in the virtual setting requires the use of expensive VR systems such as CAVE, Power Wall and Reality Deck [44]. These are supreme quality immersive environments using multisided projections, which provide the highest level of immersion [45,46]. However, the main issue is the high cost of purchasing the equipment, which is static and requires a lot of physical space to be deployed [47]. The solution of Head Mounted

Displays (HMD), such as Oculus Rift, HTC Vive and hand trackers to allow gestures in the virtual world (i.e. Leap Motion), are good options to provide high quality experiences to users. These devices are affordable and can provide very good graphical quality [47]. Nevertheless, the main issue is that to run these devices requires high performance computers to generate the experience. A more compact and cost effective option is the use of VR ready smart phones that are powered by the users' smartphones and with the use of VR apps, rather than the dedicated built-in computer and display units such as Google Cardboard and Samsung Gear VR [48].

To date, there is only a small number of museums which have managed to explode the potentials of VR, mainly due to affordability of developing and executing a virtual environment, as this is a time consuming process that requires the collaboration of many experts from multiple disciplines [32].

4.2 Virtual Museum Prototype

In order to investigate and better understand the affordances of VR, we have created a Virtual Museum prototype that promotes the history of robotics in VR. The RoboSHU (Fig. 3) is a multi-purpose, multi-user virtual environment in which users can interact with the environments, its objects, and each other through the use of their Avatar. The environment is designed using the Opensimulator platform and users can experience it through a desktop and a monitor or in VR using Oculus Rift. RoboSHU is hosting the Robotics Museum featuring informational boards and exhibits designed by students, and aiming to inform visitors about the history, general information about the research conducted by the Sheffield Robotics Group and the Robotics Department at Sheffield Hallam University, and the current state of robotics knowledge.

In the Desktop mode, the Virtual Museum can be accessed through a computer, using its monitor, keyboard, and mouse. The computer's monitor is delivering the visual aspect of the environment, and the navigation and interaction is utilized through the use of the mouse and keyboard (Fig. 4). In VR mode, the user can access the environment through Oculus Rift and use an Xbox 360 controller for navigation and interaction (Fig. 5).

Further to the Desktop and VR mode, we have ported the Robotics Museum to a Smart Phone VR prototype, which allows the environment to be experienced with the use of an Android smart phone device and a low cost HMD such as the Google Cardboard. The environment was ported using the Unity 3D Gaming engine, and is currently targeting Android devices. The user can navigate the environment through the use of the touch input mechanism of the Google Cardboard and interact with artefacts by focusing for a few seconds on virtual hotspots. Future work aims at further developing, improving, and evaluating the environment, as well as adding additional functionalities and greater interactivity.

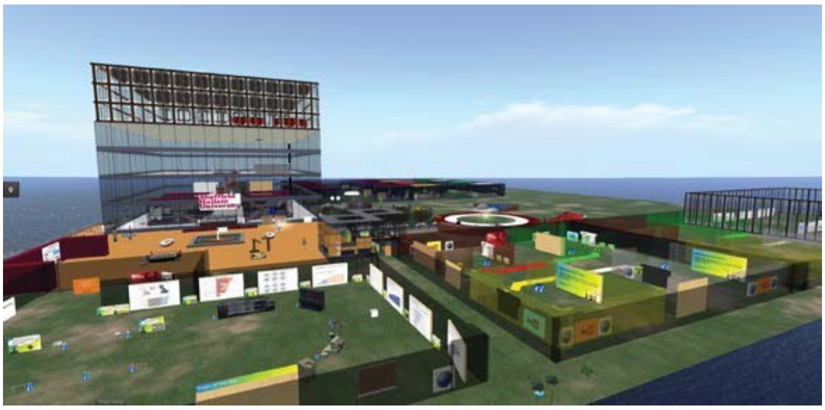

Figure 3. Virtual Sheffield Hallam University (SHU).

Figure 4. Desktop View of the Virtual Robotics Museum at Sheffield Hallam University.

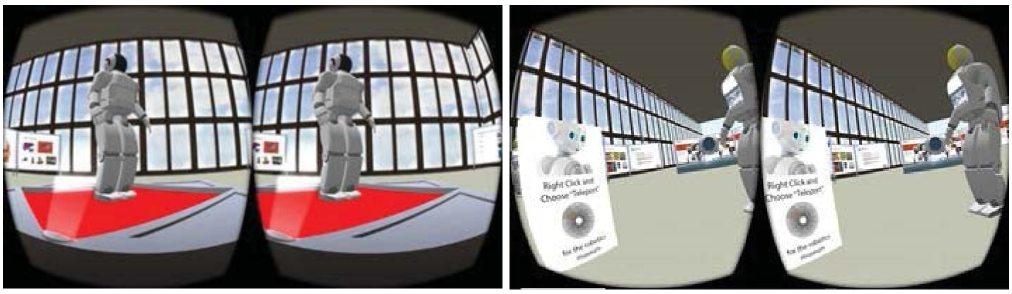

Figure 5. VR View of the Virtual Robotics Museum at Sheffield Hallam University.

5. Conclusions

In this paper we presented some initial principles of a new type of a multifaceted Cyber-Physical-Social System that will be able to intertwine diverse technologies

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such as Robotics, Virtual Reality, and Gaming. This system will encompass both physical and virtual environments, including real and artificial agents and elements, capable of interacting dynamically, reflecting, and influencing each other and with the interactions engendered by human behaviour. Its primary application is cultural and creative industries, but the proposed framework is applicable to many other domains. Among those, we can mention large shopping malls, education, personnel training, health care, and exploration of remote environments.

At Sheffield Hallam University we are currently working on creating a VR Museum of History of Robotics and connecting 'virtual robots' that 'live' in the museum to some of real robots that we have in our Robotics Laboratory.

6. Acknowledgements

The authors would like to thank their colleagues, Professors Jacques Penders and David Cotterrell, for useful comments. We are also very grateful to the members of the 'Interwoven Spaces' and 'Resilient Europe' proposal teams and CybSPEED consortium team [49] for the discussions that inspired the current article.

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