



# UNIVERSITY OF LINCOLN

Virtual reality in heritage preservation

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## **Abstract**

Endangered natural and cultural sites, such as The Great Barrier Reef and The Bamiyan Buddhas for instance, are visited by hundreds of thousands of visitors annually (Aggour, 2017; Refsland et al., 1998).

UNESCO (2008) defines cultural heritage as the following:

“Cultural heritage refers to monuments, groups of buildings and sites with historical, aesthetic, archaeological, scientific, ethnological or anthropological value. Natural heritage refers to outstanding physical, biological, and geological formations, habitats of threatened species of animals and plants and areas with scientific, conservation or aesthetic value. “ (UNESCO, 2008)

Although, tourism does provide necessary funds to maintain heritage sites, these cultural and natural symbols are constantly under mechanical pressure resulting them shifting away from their original form (Aggour, 2017). The combination of technological developments and the incentive for preserving these significant heritage sites established an innovative approach for preservation methods (Kalay et al., 2007).

The subject of this research is to uncover how virtual reality can be beneficial in preserving and rescuing endangered heritage sites. The work deals with such issues as the definition of virtual reality, the effects inflicted on endangered world heritage sites by tourism, examples for virtual traveling as well as existing solutions and whether virtual reality can be a substitute for traveling and visiting world heritage sites.

The thesis is carried out by researching existing case studies concentrating on the topic of virtual heritage preservation and the utilisation of virtualized heritage sites in entertainment. In order to gain wider insight and feasible data, the work was conducted utilising secondary data previously collected for primary purposes. Sources were discovered in Google Scholar and chosen according to the criteria listed in methodology. The chosen four case studies provide an excellent reflection on virtual heritage preservation methods as well as the evolution of virtual heritage preservation.

Based on the examined four case studies we are able to conclude that attempts with successful results for virtual heritage preservation are in fact great solutions for museums for showcasing the history for the general public. Further findings suggest that professionals in archeology did not find the immersion of the virtual reality useful in carrying out archaeological tasks (Haydar et al., 2010).

Key words: Virtual reality, VR, heritage preservation, innovative, progressive methods, entertainment

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## Introduction

The tourism industry has greatly benefited from the implementation of the newest, most ground-breaking technological advancements. Amongst these progressive technologies are augmented and virtual reality. Making virtual tours of cities around the world available for anyone and anywhere and the ability to simulate real life situations are perhaps a great example for tourism-related VR products. The evolution of VR technology resulted and will result the increase of related applications and hardware solutions to accommodate the needs of heritage preservation (Tussyadiah et al., 2018). Yung and Khoo-Lattimore (2019) concludes, that such benefits can be recognised in long-haul traveling, business travel as well as benefits fore people with physical disabilities and financial difficulties. Further benefits were found in substituting resource intensive sports, such as golf (Yung and Khoo-Lattimore, 2019).

Virtual reality is defined as a computer interface that creates a three-dimensional world containing three dimensional interactive objects. VR is also defined as a tool that provides access to simulated alternative dimensions. We can safely assume, that VR is meant to substitute the user's physical experiences with a replicated 3D simulation. Since the subjects of the VR experience are able to see, hear and touch things in the generated VR simulation, it makes them feel like they are experiencing the real thing. More importantly, the objects present in the simulation can be manipulated, making the experience feel even more real. (Sussmann and Vanhegan 2000)

Tussyadiah, Wang, Jung and Dieck (2017) argues, that VR is rather an enhanced overlaid digital content which allows the users to experience their desired attractions naturally. VR is meant to fully immerse the user into the digitally created environment. Many companies, such as Marriott have realised the opportunity and are offering a showcase of hotels and destinations using VR.

Reingold's (1991) theory suggests that authentic immersive virtual reality allows the user to move around in the computer-generated three-dimensional world, view it from different angles, mould it and interact with.

According to Tussyadiah et al. (2018), virtual reality (VR) is primarily enjoyed by the gaming community, but experts are entitled to raise the technology to a level of everyday experience. Today, budget virtual reality products are available on the consumer market, such as Google Cardboard or Samsung Galaxy Gear. These mobile device accessories are capable to simulate real-life situations, being advantageous for sustainable tourism by making it possible to virtually visit vulnerable cultural and natural sites. Virtual reality also has a great potential of becoming an effective tool for tourism marketing, by providing the customer a visual sense of what it feels like to visit a certain destination. (Tussyadiah, Wang, Jung & Dieck 2018)

Nevertheless, virtual reality is criticised for several reasons, one of them being the relatively costly hardware and software, acquisition of professionally trained staff and its' primitive portraying of the reality (Abdelmonem et al., 2017). Further criticism regarding virtual reality are whether the generated simulation can provide equally pleasant experience as physical reality, can it act naturally as the physical environment and can the issue of spending too much time in a simulation be eliminated (Cheong, 1995; Musil and Pigel, 1994; Verde, 2014; Catwright, 1994).

The study was conducted by investigating case studies about the virtual reality's effect on the tourism industry and its' potential for making landmarks which are protected due to cultural or historical significance accessible for the audience.

The goal of this research is to investigate the opportunities of using virtual reality in the tourism industry, particularly in the preservation of world heritage sites. This paper also deals with issues such as overcoming common issues known for professionals regarding virtual reality and the overall issues of experiencing virtual environment. The aim is to find answers whether the virtual reality environment is suitable to recreate and digitalise heritage and natural sites in a form that it could act as an alternative. Furthermore, it is crucial to find the challenges and weaknesses in virtual reality that could cause obstacles for the users.

As demonstration, this research introduces various existing VR technologies and realised projects in twenty years span. These examples also introduce solutions for identified challenges.

## Literature review

The incredible popularity and recognition of virtual reality as tool for progressive entertainment has seen rapid evolution in the last two decades, and it has become an instrument accessible for professional as well as commercial users. The advanced opportunities offered designed for entertainment purposes are widely recognised by the literature (for example, Aggour, 2017; Cignoni and Scopigno, 2008; Prideaux, 2002; Rheingold, 1991; Sussmann and Vanhegan, 2000; Tussyadiah, Wang, Jung, and Dieck, 2018). On the other hand, attempts to virtualise physical historic landmarks has been acknowledged by many professionals. Professionals in archeology have different expectations regarding virtual reality than the general public, and immersion is not necessarily as much of a deal breaking factor as it is for the commercial users. However, creating the digitalized versions of world heritage sites involve complicated 3D imaging and scanning processes, as well as remarkable skills in software engineering to achieve a much-appreciated immersive experience for the public. As disclosed by many authors in a variety of studies, (Aggour, 2017; Gaitatzes, Christopoulos and Roussou, 2001; Haydar, Roussel, Maïdi, Otmane, and Mallem, 2011; Koeva, Luleva, and Maldjanski, 2017; Refsland, Ojika, Defanti, Johnson, Leigh, Loeffler and Tu, 1998; Stein, 2015; Abdelmonem, Selim, Mushatat, and Almogren, 2017) virtual reality sets heritage preservation into a completely new perspective. Re-animating destroyed heritage sites and preventing the further preconstruction of ancient artifacts and landmarks are the key to preserve the culture left upon us by our ancestors.

As discussed by authors (Licciardi, 2012; Heba, 2012) the current society's fundamental values have shifted away from aesthetically pleasant constructions towards a building with more economical significance. This is due to the industrialisation and the technological development of our time. However, it is important to bear in mind that the uniqueness of the cities world-wide are within

the unique heritage sites, buildings and culture which reflects the culture's past and progression. Raising awareness for the importance of heritage preservation is proven to be relatively difficult (Licciardi, 2012; Heba, 2012). Author (Aggour, 2017) highlights that buildings in private hands does not necessarily have the required funds to upkeep their historically significant buildings, and rather have their building plots sold for companies with an attempt to build newly built high rise constructions as a substitute and for profit.

Despite the fact that tourism generates enough revenue to maintain these heritage and natural sites, certain natural sites such as the Great Barrier Reef's natural life cannot be easily restored, much like an architectural landmark. Nevertheless, the shifting of the heritage sites are relevant issues which are caused by weather conditions as well as overwhelming tourism due to the attractiveness of the status. Therefore, it is vital to develop methods to attempt to substitute physical interaction with these heritage sites. Virtual reality is perhaps the closest existing and currently still developing method that could possibly be utilized for this purpose. (Refsland, Ojika, Defanti, Johnson, Leigh, Loeffler and Tu, 1998).

Even though virtual reality has come a long way in the last twenty to thirty years, certain challenges must be addressed regarding the realism and seamless experience. It is argued in several papers what differs traditional virtual reality from the immersive virtual reality, it is necessary to overcome issues regarding the believable immersion of experiencing a physical location in a virtual environment. Several papers suggest that factors, such as limiting the time of simulation, creating a simulation with random events much like the real life and acquire unique cultural skills, which makes real life physical interactions so unique, and they cannot be replicated in a computer simulation (Cheong, 1995; Musil and Pigel, 1994; Verde, 2014; Catwright, 1994). However, professionals are familiar with the issue's VR lacks of and projects presented in this paper serve as a solid evidence of overcoming the limitations of the simulated environments (Aggour, 2017; Refsland, Ojika, Defanti, Johnson, Leigh, Loeffler and Tu, 1998; Gaitatzes, Christopoulos and Roussou, 2001). Further criticism (Abdelmonem, Selim, Mushatat, and Almogren, 2017) suggest that establishing facilities capable to run virtual reality experience is an expensive process and requires highly skilled staff. Regarding the issue of complexity, the technologically demanding nature of virtual

reality facilities and devices are disclosed by authors in a variety of case studies (Gaitatzes, Christopoulos and Roussou, 2001; Refsland, Ojika, Defanti, Johnson, Leigh, Loeffler and Tu, 1998).

## **Methodology**

The research was carried out by collecting and analysing relevant secondary data. Utilising secondary data provides viable information previously collected for primary purposes. This work reviews previously collected data uncovering existing successful examples for utilising virtual reality in heritage preservation. The obtained secondary data is analysed in a systematic method with evaluative steps beginning with the development of the research question.

The research methodology was carried out using Saunders et al. (2007) research onion pattern. The research onion provides layers in a descriptive detail of a research process. The layers can be tailored into nearly any type of research relative to on the data collection method, primary and secondary sources, time horizons, approaches and philosophical positions.

Illustrated in Figure 1; the Saunders et al. (2007) research onion diagram consists of six layers which are aimed towards getting a wider perspective on the research methods. The first layer of the onion is the philosophical stance. The philosophical choice will affect the ways data is collected and analysed in the research. The layer of philosophical stances consists of positivism, realism, interpretivism, objectivism, constructivism, and pragmatism.

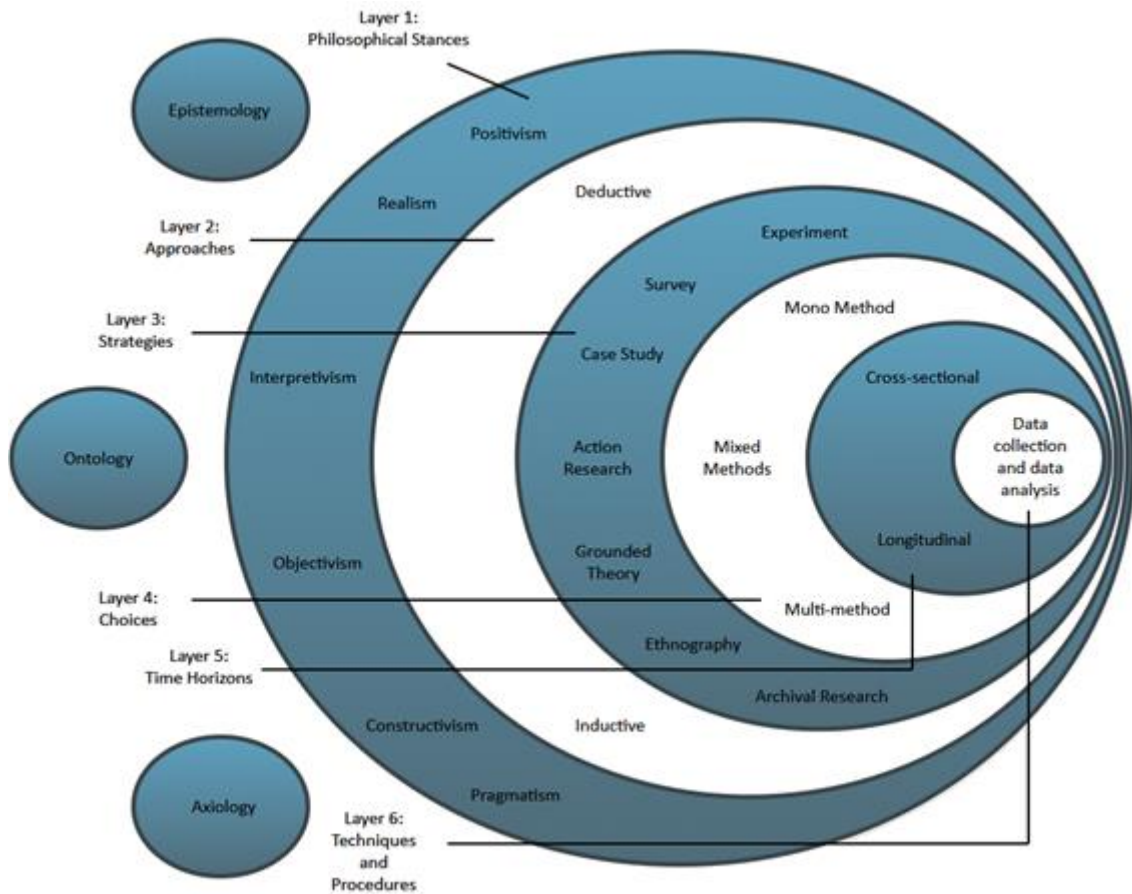


Figure 1. Research onion diagram (derived from Saunders et al. 2009 (University of Derby, 2020))

Ontology concerns the nature of the reality in a subjective manner. The ontological perspective also debates the way society perceives the reality and influences behaviour. Objectivism, constructivism, and pragmatism work under the ontological worldview (Saunders et al., 2007).

Epistemology mainly questions what the generally accepted knowledge is within the field of research. This generally accepted knowledge is recognized as the truth due to its record by testing the theories and treated as facts. Perhaps the most common form of researches is based upon epistemology due the position of the knowledge resting on undoubted evidence. Epistemology is associated with positivism, critical realism and interpretivism aspects of philosophical stances (Saunders et al., 2007).

Axiology on the other hand is based upon people's beliefs and their effect on the research, mainly referring to values and ethics. The researcher conducting work according to axiological worldview is setting their own values against the researched target group (Saunders et al., 2007).

Positivism is based upon theories which are generally accepted as scientifically proven and commonly accepted facts. Assumption as such are divided into three groups, each dealing with different aspects of societal structures and behaviour (Saunders et al., 2007). Positivism treats scientific knowledge as the ultimate and undoubted knowledge. Knowledge as such are thoroughly tested and are academically accepted facts. Realism differs from positivism in a certain aspect which questions the excellence of the scientific methods. According to positivism, scientific theories can be critically reviewed and potentially changed to a newer, more progressive method. Taking the nature of the research in consideration, the philosophical stance chosen is positivism, using established commonly accepted theories throughout the research to uncover the possibilities of virtual reality in heritage preservation (Saunders et al., 2007).

Interpretivism is intended to traditionally analysing pre-existing data fitting the subject matter. Objectivism embraces reality and refers to social entities as physical entities in the natural world. According to this perception, the building blocks of the society are relatively unchanging factors, such as economy, religion, and family, for instance. Constructivism believes the opposite of objectivism, and threats reality and society are constructed by social actors. Pragmatism on the other hand takes objectivism and constructivism and threats them as equally valid ways of approaching a research. By combining the two, pragmatism creates a practical approach to find solutions to the research problems (Saunders et al., 2007).

The second layer of Saunders et al. (2007) research onion diagram is approaches. The decision of the approach is built around the decision made in the layer of philosophical stances. At this stage, the researcher may assess their research aims, limitations of the research and if the case is so, personal viewpoint in order to make a decision. The approaches layer consists of deductive and inductive approaches. Deductive approach essentially starts by stating the question that

need to be answered and sets of the research purpose. In the core principle, deductive method derives answers from theory combined with data collection to demonstrate feasible knowledge regarding the subject matter. Using deductive methods in the research further complements the theory and case study driven strategy of uncovering progressive digital heritage preservation and its' utilisation in entertainment (Saunders et al., 2007).

Inductive research on the other hand is aimed towards creating new knowledge and theory. The direction of the process is the opposite of deductive. This method is especially useful in subjects which is scarcely researched (Saunders et al., 2007).

The third layer of Saunders et al. (2007) research onion diagram is strategies, which discloses the research style which will be used for collecting data. This layer is strongly associated with the chosen philosophical standpoint. The researcher may alternatively choose multiple strategies they want to collect information with. The listed methods for strategies are experiment, survey, case study, action research, grounded theory, ethnography, and archival research (Saunders et al., 2007).

The fourth layer of Saunders et al. (2007) research onion are choices regarding the methods of qualitative or quantitative research. Researchers may combine qualitative and quantitative methods to create a multi-method research. The qualitative methods, using case studies of digital preservation methods as evidence (Saunders et al., 2007).

The fifth layer of Saunders et al. (2007) research onion considers the time horizons, signifying the time period of the carried-out research. Cross-sectional measures the research at a single point in time and may be used in qualitative and quantitative forms. Longitudinal design on the other hand focuses on events happening over longer period of time. The longitudinal design used in this research is underlining twenty years of development span in virtual reality technology used in digital preservation.

The sixth, and final layer of Saunders et al. (2007) research onion diagram is data collection and analysis, which is intended to make a decision which will be leading on throughout the progression of the research process. Such decisions are for

instance target group, data collection methods and general questions the work is aimed to give answers for. The decisions made in this phase must fit the other remaining layers of the onion pattern and must be justified with valid evidence.

### **The Foundation of the Hellenic World**

The Foundation of the Hellenic World is a Greek non-profit organization aimed towards heritage preservation of the Hellenic culture. The organization utilizes progressive multimedia tools and technology to create unique archaeological experience. By using technologically advanced tools, the organization presents the evolution of Hellenic history and culture in an artificial environment for visitors with enthusiasm towards the subject. In order to provide realistically accurate image of the past, the organization created an assembly of archaeologists, historians, scientists, artists, and other professionals in this field (Gaitatez et al., 2001).

## Virtual Reality infrastructure

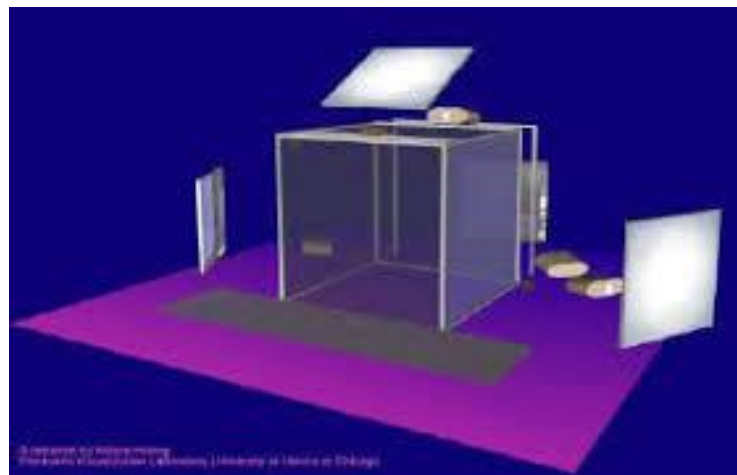
The organization's virtual reality team aims to use virtual reality as an educational tool, creating content for exhibition, as well as gaining greater comprehension of Hellenic culture. The aim is to combine 3D reconstruction of the past with innovative learning experience. In order to create content, two different virtual reality systems were used (Gaitatez et al., 2001).



*Figure 2. An example for an ImmersaDesk system at Foundation for the Hellenic World, Athens (Electronic Visualisation Laboratory, 1996)*

The ImmersaDesk system, illustrated in Figure 2, features a larger, 7,8 ft x 6,6 ft back-projected screen which is tilted in a 45° angle. In order to view the screen, liquid crystal shutter glasses are used. For interaction, the system features a head and hand tracker which is referred to as wand. The audio is delivered to the user by loudspeakers. Internal hardware wise the system runs on Silicon Graphics Octane computer terminal equipped with two R10000 processors with clock speed of 250Mhz (Gaitatez et al., 2001).

The second system used by the Foundation of the Hellenic World is a ReaCTor, illustrated in Figure 3, which allows multiple, even up to ten participants to experience the virtual journey. The system allows participants to see the virtual and the physical world simultaneously using stereo glasses. The unit allows complete freedom and mobility in the virtual world by using a similar type of wand controller as mentioned in the first example. The audio is delivered to the user by

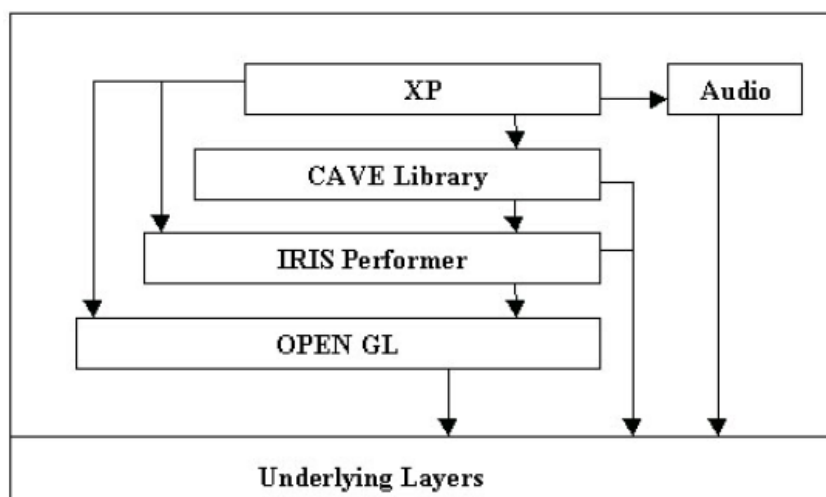


*Figure 3. An example for InfiniteReality2E system used in Foundation for the Hellenic World, Athens (Gaitatez et al., 2001)*

loudspeakers, identically to the first example. The system features a 9,8ft x 9,8ft x 9,8ft back-projection surfaces, creating a cube shaped environment to achieve full immersion. Hardware wise the system feature a Silicon Graphics Onyx2 display system powered by eight R12000 processors with a clock speed of 300Mhz supported by four InfiniteReality2E subsystems (Gaitatez et al., 2001).

Creating a truly immersive virtual experience requires the creation of models, which capacity can take up multiple hundreds of megabytes, depending on the size and level of detail. The details can differ in texture-mapping, quality of audio-clips, programming, and hardware. These factors are especially important in heritage preservation, since historic sites and events must be presented with as high level of detail as possible (Gaitatez et al., 2001).

To program a virtual reality software, object-oriented programming languages must be used, such as Silicon Graphics Performer and more common OpenGL. Typically, the programming of a virtual reality software can be considered extremely time consuming. In order to create shortcuts and save time, simpler developing methods exists to create and deploy 3D models into an interactive space. These include animation, navigation, sound effects and other factors, such as physics. In order to create large open environments in virtual space, XP framework is used to eliminate the time-consuming process of 3D map creation previously mentioned. Essentially, this tool allows engineers to reuse and modify previously created elements in order to create a new virtual environment and to add new features if needed, rather than creating it from scratch. As d displayed in Figure 4, for graphics the framework uses IRIS Performer and OpenGL as well as CAVElib for rendering the assets for a virtual reality hardware (Gaitatez et al., 2001).



*Figure 4. Visual representation of the InfiniteReality2E system and its' layers (Gaitatez et al., 2001)*

Multiple different types of nodes are used in order for the virtual environment to respond to the user's actions. These actions can be teleportation within the virtual environment, collision, moving objects or basic navigation. Nevertheless, the use of XP system was proven to be successful to carry out heritage preservation projects and adding new features (Gaitatez et al., 2001).

Other major projects carried out by the Foundation of the Hellenic World are the virtual journey through the ancient city of Miletus, the Ionian city of Priene and an

educational program of byzantine costumes with interactive features. The Magical World of Byzantine Costume features a virtual world, where users must match costumes with the appropriate character. The Olympic pottery puzzle project is another great example of interaction with the virtual world. In this scheme, the users may find and match pieces of pottery to re-build antique ceramics. Further developments include ambitious projects such as the recreation of Olympic Games and Cultural Olympiad in co-operation with universities (Gaitatez et al., 2001).

### **Virtual Great Barrier Reef**

The Virtual Great Barrier Reef is an ambitious project of recreating a narrative tour of the world-famous UNESCO Natural site, The Great Barrier Reef. The reef during the years of the project development in 1994 and 1995 received a considerable amount of 1.5 million visitors a day. It is also known, that during the mentioned years the reef generated over \$1 billion annually. This project was aimed to tackle the issue of the high number of tourists and the inflicted damage on the reef, as well as providing a substitute to view the reef without causing harm to the natural environment (Refsland et al., 1998).

### **Virtual reality architecture of the DOME and CAVE systems**

In order to create a surrounding immersive virtual experience, this project approaches the environment by using the DOME and CAVE technologies. The utilized system supports multiple user simulations, meaning several participants are able to participate at the same time. The DOME itself is a 360° dome measuring 15 meters in diameter, creating a surround experience (Gaitatez et al., 2001).

Essentially, the DOME zone is created by pre-recorded and partially computer-generated video images which is then projected on the DOME surface. The

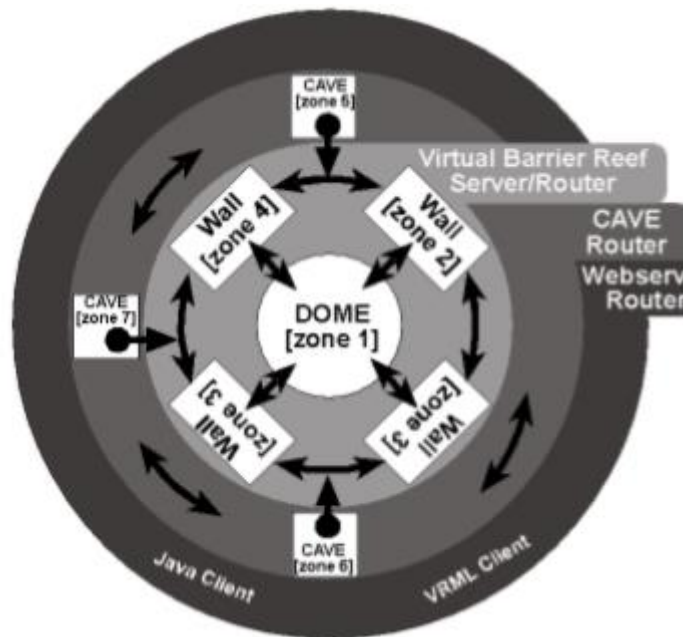


Figure 5 Relation between the DOME, CAVES, WALL zones (Refsland et al., 1998).

combination of computer-generated and pre-recorded footage helps to create a mixed illusion of marine wildlife. Considering the technical limitations, the animated coral and other larger computer-generated assets are set to update less frequently (Refsland et al., 1998).

The DOME unit, illustrated in Figure 5, is considered to be the centre of the environment. This unit sends and receives the most amount of data in order to render the virtual environment. Four WALL zones are perhaps the costliest and hardware wise most complicated layers. These zones make it possible to interact with the environment and the environment to sense the users' actions. A great example is the virtual wildlife's reaction on the human interaction. The three CAVE zones are separate areas which are designed to provide a more unique and immersive experience for the user. The user can experience mythical stories related to the reef and interact with the virtual marine wildlife. The CAVE system is connected via high-speed connection in order to sufficiently transport avatar data, status of environment and user and allow guides to interact with the user as a reef

inhabitant. It is also suggested that users from remote locations with CAVE systems would be able to connect to the virtual environment (Refsland et al., 1998).

The virtual environment is designed to provide a realistic image with non-repetitive image projection on the floor and the walls of the CAVE. Furthermore, the sound system is designed to create realistic sound of depth (Refsland et al., 1998).

In order to achieve authenticity, the device is connected to a series of sensors in the physical reef which is able to provide data for the climatic interface. This is especially important in imitating the temperature, air pressure and further conditions. These effects are achieved by applying effect pre-sets for different conditions. The strength of these effects depends on the real-time data received from the physical reef (Refsland et al., 1998).

### **Tracking hardware**

A variety of wearable equipment was created with the endurance of the physical impact of the high demand in mind. Methods were utilized from diving equipment to create durable tracking peripherals. The device features a belt which accommodates the wireless module, memory card slot, as well as the batteries to power the navigational hardware. The shutter glasses are programmed to be viewable for a limited time. The time limit symbolizes the imaginary “air” the divers have until their oxygen supply runs out. This helps to limit the time spent in the simulation for one user. As previously mentioned, the audio is delivered by loudspeakers, although, there are more sophisticated shutter glasses equipped with individual audio source. In spite of creating a memorable experience that can be shared, the device records the narrated footage on a memory card which is then handed to the user (Refsland et al., 1998).

## Simulated aquatic life

An exciting feature of this project are the simulated artificial marine wildlife. Uniquely, this simulation encourages the user to experience the reef as a fish and how is it like to be an inhabitant. From the perspective of artificial intelligence, two different examples were created. One of the examples are programmed to behave as the real-life counterparts. This also includes animal behaviour typical for each species and even lifespan and role in the ecosystem. The other example allows user to control a fish for certain extent. For instance, the user can control an animal, but the animal will remain restricted to its' typical behaviour and characteristics (Refsland et al., 1998).

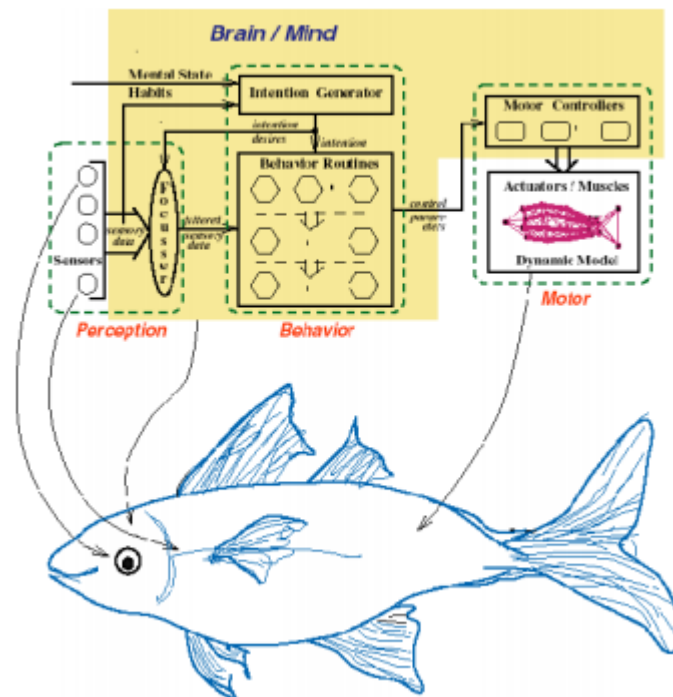


Figure 6 Artificial life's diagram of motor, perception and behaviour

As illustrated in Figure 6, the brain of an artificial life is controlled by three main functions, motor, perception, and behaviour. These three functions are vital to make a virtual sea creature behave as its' real-life counterpart. The motor system ensures that the animal's movements look realistic. In order to achieve realistic

movement that is unique to species, information is extracted from the bio-mechanical literature (Refsland et al., 1998).

The motor system carries out the actions of swimming forward, backwards, turning and even capable to adjusting the fin actions. As previously discussed, the project features a life-like environment with dynamic effects of weather and current, which has influence on how the motor reacts to certain scenarios (Refsland et al., 1998).

In favour of achieving the experience of interactive entertainment, it is crucial to reflect the animals' perceptual capabilities. In the natural circumstances, many animals rely on their vision as their primary source of orientation. However, in the artificial environment the artificial life's vision is replaced by a 2D projection of the 3D sphere. Nevertheless, there are species that does not rely on their vision as the primary source of perception. Factors such as extremely sophisticated sensory organs and perception distance which varies in species are difficult to comprehend. The replication of these processes in a virtual environment are difficult to program, and it might result unrealistic behaviour in certain species. Another great challenge is to imitate the animals' decisions in complex situations. In certain scenarios, the system might receive too much of sensory information all at once which can result in unrealistic decision making and overall behaviour (Refsland et al., 1998).

The behaviour system acts as a bridge between the motor and the perception systems, making sure the subjects act as a cognitive entity. It describes certain traits of the subject, such as the preference of bright or dark environment, and differentiates the traits of a female and male animal. However, as opposed to natural, more static behaviour, the system chooses a dynamic mental state pre-set to provide character and desires to the artificial life. Such as desire are for instance the desire to eat or to drink. To reflect the natural desires, the system must meet certain requirements. The system must include a range of variations of the desires in order to tackle the monotonous behaviour and dull entertainment experience. Furthermore, the desires must be stimulated by an internal or an external factor. The system also must make it possible to fulfil these needs and desires. These habits combined with the desires allow the synthetic life to act in order to fulfil the desire. A great example for this is the desire to eat. If the animal

feels the desire to eat, they gather sensory information of nearby food, and they chase to feed of a prey (Refsland et al., 1998).

### **The UNESCO world heritage site of Bamiyan**

The third project this work focuses on is the reanimation of the destroyed buddha figures of Bamiyan, Afghanistan and their remains in virtual environment. The figures which were destroyed in 2001 are listed as a UNESCO world heritage (UESCO, 2020).



*Figure 7. Buddha figure of Bamiyan before and after the demolition (Stein, 2015)*

Early proposals for preservation was introduced in 2002. The preservation process started in 2003 supported by the UNESCO Campaign for the Preservation of the Bamiyan Site and was funded by the Government of Japan. Several preservation proposal and damage assessments were carried out to conserve and maintain the murals and extensive cave systems which can be found at the same 1,5-kilometer-long heritage site. The virtualisation of the heritage site took place at the RWTH Aachen University in Germany where it was assessed to determine the significant damages caused to the heritage site. The preservation process involved an extensive scanning process with terrestrial laser devices. The textures necessary to create 3D images was extracted from historic images and drawings which was proven to be a successful method for restoration. The remaining debris from the buddha figures were placed under a temporary shelter in order to protect them from further damages as well as the natural forces, such as wind and water (Stein, 2015).

## **Methods of preservation**

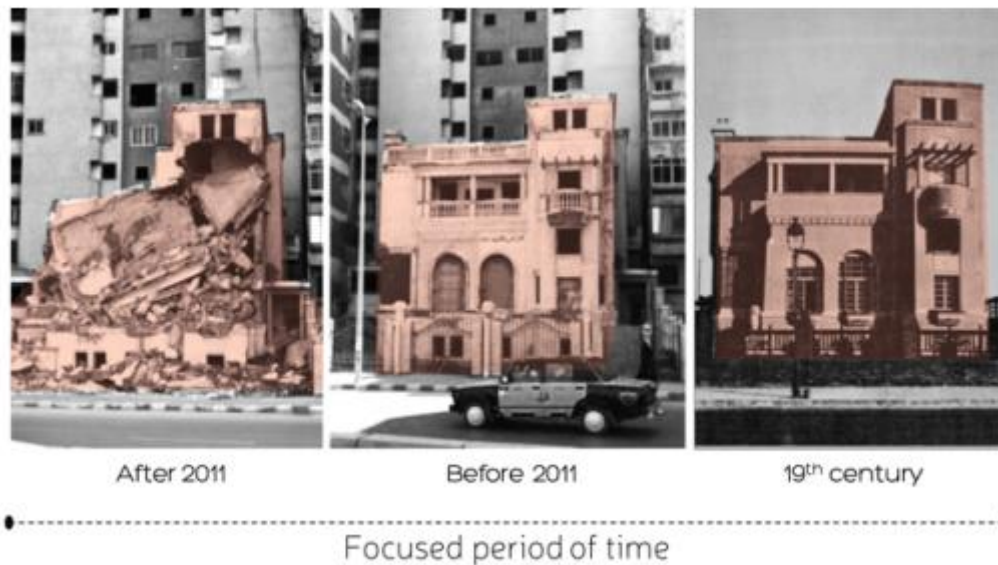
The project introduced a similar CAVE virtual reality environment as previously discussed regarding the Great Barrier Reef. In spite of getting precise model resolution, the point distance of precision was set to 8mm on the surface. In order to gather enough data for accurate model dimensions, a triangulation method of the Eastern Buddha was applied using Software QTSulptor v2.85. The software generated a model structure of 1.2 million triangle with 77 million measurement points. To require realistic look, texture images were attached to the 3D model. The Western Buddha, which suffered more significant damage due to detonations, was recreated by obtaining a 1/50 scale ink drawing carried out between 1972 and 1978 by Kyoto University of the Eastern Buddha. The contour lines of the drawings were clear enough to be manually digitalized by using Geometric Studio v.10 Software. The 3D models were ported into an immersive virtual reality system in Aachen University. The CAVE system in this scenario is a 3x3x3meter cube system which utilizes ten BARCO Sim6 Ultra projectors to project images onto the ceiling and walls. Much like the Great Barrier Reef project, the users wear light weight polarized glasses which is powered by an optical tracking system powered by six ARTtrack1 cameras. The computer system responsible of powering the projection of the images is a station equipped with two Intel Xeon processors with system memory of 4GB RAM and an NVIDIA GeForce 6800GT combined with a software application VISTAVR Toolkit. In order to accommodate 40 users, a space on 50m<sup>2</sup> was used to set up the projection. The middle of the room accommodates a 3D Space Mouse to make navigation accessible as well as zooming and flying (Stein, 2015).



*Figure 8. The final result of scan (to the left) and the integrated Buddha figure in 3D environment (Stein, 2015)*

### **The destruction of Alexandria's historic buildings**

Alexandria is facing an issue mainly caused by the high demand of urbanisation. The phenomenon of destructing historic buildings in order to accommodate newly built structures with greater capacity was and still remains an aspect world-wide. According to Aggour (2017), various companies carrying out construction of newly built high-rise real estate practices a method of providing financial support for the locals of Alexandria in exchange for demolition of historically significant buildings. Survey data also disclosed by Aggour (2017) shows that locals does not have satisfactory awareness of the significance of the historic architecture. A virtual reality attempt was launched to preserve these buildings also aimed towards the locals to prevent the destruction of the historic buildings, also demonstrated in Figure 8.



*Figure 9. The timeline of desolation of historic buildings in Alexandria derived from Save Alex, edited by the Author, 2013 (Aggaur, 2017)*

Tung (2001) highlights the concern that cities world-wide need to work towards preserving their past and heritage, since this factor is what makes cities unique and enhances identity. Even though Alexandria attracted many significant artists during the past time, inspiring and motivating creativity, the city has shifted its form to a duller, metropolis-like skyline (Heba, 2011). Heba (2011) also emphasises the significance of many historic buildings in Alexandria that perfectly reflect the progression of history in Egypt. Disclosed by Aggaur (2017), a number of high-rise buildings in the core centre of Alexandria are built taller than the maximum allowed height of a building in the area permitted by the government. However, in order to accommodate the lifestyle of nowadays residents, shifts such as widening the streets to accommodate traffic, installation of electricity, gas, water, telecommunication lines, were seen as a necessity. The shifting and destruction of historic sites demonstrates the change in people's lifestyle. For example, the city structure was a sign of welfare, history, and uniqueness in the Renaissance Italy and 18<sup>th</sup> century is overrun by the need of high-rise real estate with high capacity (Licciardi, 2012). Licciardi (2012) also states, that heritage preservation has become extremely complicated due to the number of stakeholders and the financial judgment of the preservation processes. In other words, factors may influence the decision whether a physical restoration and preservation is realistic and efficient in financial means, historic significance, and tourism aspects, for

instance. Overall, the interest of the society has moved from the value of elegance towards a more economic value of interest.

### **Deconstruction phenomenon**

The reason behind the lack of interest and effort towards heritage preservation in Alexandria were found in the lack of upkeeping funds. Furthermore, Aggaur (2017) states that from a financial perspective, the upkeeping of these buildings are not proven to be profitable. Significant absence in proper historic documentation of buildings were also identified, meaning there is little to no evidence for historic value for numerous buildings. The lack of evidence results a lack of grounds for objection against the demolition proposals. Considerable lack of awareness towards historic buildings was identified regarding the locals. The upkeep of these buildings was proven to be costly for the owners, who are willing to initiate demolition processes in order to gain economic boost.

### **The Case of Medieval Cairo**

Large number of important heritage sites of Cairo are in ever-increasing danger of climate effects, over tourism and commercialisation as well as lack of maintenance. Projects to preserve significant heritage sites in Egypt were initiated by the Egyptian Centre for Documentation of Cultural and Natural Heritage (CULTNAT). The project Culturama is designed to provide virtual experience by allowing the user to view a virtual world designed with historic accuracy and by magnifying certain areas of the virtual world to get a closer view.

The Culturama software runs on a device equipped with an interactive panoramic screen of 180 degrees. The panoramic screen consists of 10 individual screens that together adds up 10 metres in diameter. However, the digital models are relatively simple in detail and shape.

The HIP Pyramid project was aimed towards recreating the Giza plateau and the site of Dahsur with great accuracy and realistic scaling. The project was carried out by company Iconem using photogrammetry, laser scanning and drones in spite of creating accurate 3D models. The project was accomplished by international experts. The radiographic images as well as thermographic images were captured in order to determine wall density, voids within the walls and accurate visualisation of undiscovered constructions within the pyramid and monuments. Further projects were initiated in co-operation with Ministry of Antiquities and the Department of Islamic Monuments in Cairo in order to digitalise the Sultan Hasan Mosque, Bayt Al-Suhaimy, Shar'i AL-Muizz and Souk Al-Khayamiyyah, of which Al-Muizz virtual Tour was granted the Best Mobile App for Virtual reality in Egypt award.

Souk Al-Khayamiyyah market, illustrated in Figure 10. can be considered as an excellent example for implementing a heritage site into three dimensional spaces. A team of experts analysing the site made great efforts not only capturing the space's characteristics, but in addition researching the crafting and trading habits of the past as well. Regardless the great effort creating an authentic virtual experience with historic accuracy, the project's success divides the opinion of the stakeholders. Numerous government officials and local traders were slightly negative towards the project due to the fear of potential profit loss.



*Figure 10. Souk Al-Khayamiyyah market place and a vendor's booth as digitalised 3D model derived from AVRST & Virtual Heritage Cairo Project, 2017 (Abdelmonem et al., 2017)*

## **Virtual reality's application in heritage preservation**

Digital preservation technologies opened new ways to sustain heritage sites. Great efforts have been made towards accurately documenting heritage sites in the Cairo area mainly aimed towards tackling the issue of damages caused by tourism (Abdelmonem et al., 2017).

However, Virtual reality has received a large number of negative criticism due to its' costly hardware and software, professional training and unrealistic portraying of the reality. Abdelmonem et al. (2017) also highlights the importance of the presence of non-human controlled characters' presence in order to provide realistic experience, which is often overlooked by virtual reality projects.

Such projects were proven to be educationally beneficial, especially for students of archaeology, providing a hands-on experience, rather than theoretical courses. Furthermore, in professional aspect, developing a virtual archive can be beneficial in restoring historic sites (Abdelmonem et al., 2017).

Virtual heritage as it is referred to is a digitalised version of heritage sites, statues, monuments, buildings, and objects mostly appreciated for their aesthetic values. However, as described by Pujol and Campion (2013) culture and heritage contain aspects which are rather intangible, such as practises and habits, which are not as simple to visualise on a computer screen.

Virtual reality has numerous tourism related applications which underlie the six main areas of use, which are planning and management, marketing, entertainment, education, accessibility, and heritage preservation. It is not evident up until now, however it is predicted that virtual reality will influence further areas within the tourism sector. For instance, the use of VR to substitute tourism in the future is yet to be discovered by analysing the perceptions and the acceptability by the audience. Furthermore, it is evident, that the currently existing virtual reality applications have significantly impacted tourism and increased the opportunities of professionals and researchers (Guttentag, 2010). For instance, Foundation of the Hellenic World acquired a department designated for virtual reality offering a

variety of educational experiences in Greek culture, which is a great example of how VR can be used in archeology combined with education. Moreover, the number of heritage sites accessible via VR are constantly growing. Heritage sites can be recreated in three dimensional models with precise detail. VR and computer technology can also provide estimated knowledge about the original state of heritage sites, even after erosion and other forms of degradation. Cignoni and Scopigno (2008) highlights that VR can help to carry out restorations as well as able to estimate the necessary works and processes that needs to be carried out to restore a heritage site. The help of restoration and overall heritage preservation is especially important in popular tourist attractions. Prideaux (2002) emphasizes the overwhelming threat of the growing number of tourists and their negative effects and caused damage on heritage sites. These heritage sites are particularly intriguing for large number of tourists simply by the UNESCO world heritage site status.

Aside from reconstructing heritage sites, VR has been proven capable to recreate events that influenced our history, culture and our everyday life with great accuracy. For instance, "A Journey through Ancient Miletus" is an EU-founded program that allows visitors to experience the development of the city of Miletus and how it has changed over time. The audience can walk the ancient streets of Miletus or they can view the progress from the sky. The details of architecture become more comprehensive as the observer moves closer to it and are viewable from many different angles (Gaitatez et al., 2001).

Gaitatez et al. (2001) additionally highlights The Temple of Zeus as an outstanding example of applying VR in tourism, recreating, and preserving historic heritage sites. At this particular attraction visitors can admire the temple as well as the statue of Zeus of which unfortunately nothing remains of today and have been nominated as one of the seven wonders of the world.

According to a survey, conducted by Haydar et al. (2010) studying the professional aspects of virtual reality's application mainly in underwater archaeological researches, findings suggested that archaeologists are more interested about determining the period and layout of underwater artifacts. Numerous findings also

suggest that archaeologists require detailed visualization, free navigation and interaction with the artifact's parameters, dimensions, original location, and age.

Haydar et al. (2010) states that even though, computer technology is a tool commonly recognized by professionals in many fields to display findings from cultural heritage sites, virtual reality has a great potential to be utilized for carrying out actual archaeological tasks rather than applying it only for preservation tasks.

Haydar et al. (2010) proposes, that the immersive VR system lets the user better apprehend 3D objects. It offers kinetic depth making size, distance, and angle judgement simpler, since it is perceived as a real world as opposed to a computer screen. Computer screens can only return a two-dimensional image of a three-dimensional objects relative to the viewer's spectated angle.

As previously discussed, archaeologists are more interested about determining the period and layout of underwater artifacts, according the feedback in work of Haydar et al. (2010), archaeologists did not find immersive VR to be helpful in carrying out archaeological tasks. As opposed to archaeologists, the general public concerns found immersive VR to provide richer experience. The feedback also concluded that archaeologists found navigation to be easy in immersive VR. Interaction was also found to be easy, as well as accessing different tools.

Aggour (2017) experiments with virtual heritage using computer graphics and some degree of user interaction with heritage sites. It is stated, that in order to deliver a successful visual representation of a heritage site two main principles play part which are accurate representation of a heritage site and valid information of a heritage site. Most of the projects undertaken in virtual heritage aims to analyse previous graphical readings of the site after which the mapping of the location is completed by laser scanners, GPS, and photogrammetry. The main principle of virtual heritage is to provide interaction to the viewer instead of only providing images. Aggour (2017) highlights the benefits of virtual heritage by supporting the sense of belonging that users experience during the use of VR. Virtual reality can also give access to heritage sites that no longer exist. Furthermore, virtual heritage projects can be uploaded and accessed online, eliminating the restrictions of location, an issue that is present with physical exhibitions and museums.

## Challenges

As virtual reality's functions and benefits become clearer, museums consider it to be a vital feature of education, audio-visual presentation, and entertainment. However, virtual reality faces numerous challenges that need to be addressed. First and foremost, current VR technology is heavily restricted by the ratio of performance and real-time image generation. With other words, it is difficult to achieve seamless performance without compromising some of the image quality. Due to the loss of image quality, the experience suffers a less believable and realistic real-time rendering quality which can be a deal-breaking issue for certain customers. It is suggested that development must be concentrated towards displaying high quality images in virtual reality without loss of performance. This issue also suggests that the visitor must receive the highest quality images possible making sure the experience is perceived as close to the reality as possible. Regarding the performance issues of the VR, it is necessary to alleviate the performance concerns created by high quality images. In case of inconsistent frame rates, the visitors may get disoriented and confused. Therefore, the simulation flow must stay with a constant frame rate as well as possible. Current technologies allow developers to apply less detailed textures on distant objects which eventually changes to higher resolution image once the user approaches it (Gaitatez et al., 2001).

Another important factor that needs to be addressed is the feeling of free movement in the simulated reality. Although, it is possible to get jammed within a simulated reality, there are mechanisms built in the program to disable collision at any time convenient. Further issues were discovered in the general VR navigation environment. In order to avoid dull experiences and give freedom to users is to avoid using predefined paths and to use free navigation. By this, clients are able to feel freer within the environment. Koeva et al. (2017) states, that the importance of three-dimensional modelling is widely recognized amongst the professionals, modelling and visualization was proven to be challenging. The source of the challenges is mainly in data acquisition, integration, and representation. Cheong (1995) argues, that where the current technology of virtual reality is capable to provide sensory simulation and feedback of sight and sound, it fails to provide two

important aspect of the human sense, smell, and taste. Cheong (1995) also states that there are ideas to resolve these lacking features of the virtual reality headsets, the today's virtual experience is visually unrefined due to low resolution and inefficient movement physics (Koeva et al., 2017).

According to Cheong (1995), virtual reality can possibly meet or even exceed the expectations of the users, and provide solution for inconveniences, such as tiresome queues at airport customs, visitor harassment and the possibility of delayed flights, to name a few. Musil and Pigel (1994) assert that virtual reality will never be able to completely replace physical interaction. The reason is being, that visiting heritage sites for instance, is a social and cultural event which can only be accomplished by genuine human senses. Musil and Pigel (1994) also states that tourism by nature is an engaging event. This means that tourists are generally eager to learn native arts and crafts, handywork, local dances and other different authenticities. The previously introduced case of Souk Al-Khayamiyyah market place, where users can observe the work of local craftsmen is aimed towards tackling this issue (Aggour, 2017). These factors result a lasting impression for the visitors. Musil and Pigel (1995) also conducts in their argument, that within virtual tourism experiences, the tourist only acts as a passive observer and only absorbs certain kind of stimulations.

Verde (2014) also asserts that the real world too complex, arbitrary, and unclear to be reanimated in a virtual reality system. The activities people can carry out are software limited, and the infinite number of independent variables necessary for true immersion is currently unachievable with virtual reality. Due to the possible up rise of virtual reality in tourism, many countries which are dependent on tourism would lose their significance. The project of the Great Barrier Reef (Refsland et al., 1998) and the simulated aquatic life's goal is to create a virtual life cycle. Even thou the animals present in the simulation are programmed to act as their real-life counter parts, the artificial consciousness is aimed towards creating randomised events and encounters which the fauna would react to accordingly (Refsland et al., 1998).

Catwright's (1994) suggestion states, that virtual reality is in fact harmful for the human beings. Due to the immersion offered by virtual reality, the users may experience issues such as difficulty distinguishing reality from virtual space, identity, and other psychological problems regarding the mental state. To limit the time spent in the simulation, the Great Barrier Reef project has implemented a timer system that would limit the user's time spent in the simulation (Refsland et al., 1998).

## **Conclusion**

The shifting and destruction of historic sites manifests the change in people's lifestyle. For instance, the city structure was a statement of welfare, history, and uniqueness in the Renaissance Italy and 18<sup>th</sup> century is overrun by the need of high-rise real estate with high capacity (Licciardi, 2012). Although, as technology advances, it is crucial for heritage institutions to stay up to date with new solutions and trends in heritage preservation and entertainment. The aim of this research was to uncover the existing methods of heritage preservation in virtual environment. In the last two decades the rapid technological advancements made huge impact on how heritage preservation is interpreted and initiated new ways to preserve the past. As technology advances, it is crucial for heritage institutions to stay up to date with new solutions and trends in heritage preservation and entertainment.

This work has uncovered successful ways to preserve heritage sites by applying 3D imaging. Virtual reality has the potential for vastly changing the way professionals carry out archaeological work. The features most sought after by archeology professionals include such factors as detailed visualization, free navigation and interaction with the artifact's parameters, dimensions, original location, and age. Due to the technological limitations, the immersive experience was not found to be useful for professional in carrying out archaeological tasks. However, regarding the immersion it is clear to state, that immersive 3D virtual

experience provides a much more captivating experience for exhibitions and museum showcases.

Furthermore, could impact how audiences interact with heritage sites as virtual objects. Progressive solutions can and are necessary to minimize the pressure generated on endangered natural sites by the vast number of tourists.

Furthermore, it is stated that computer generated images in the virtual environment often suffer from the limitations of hardware and accessibility, it is important to engage in creating a believable virtual experience for the users. Issues such as low detail images, pre-defined paths, lack of freedom and interaction, stuttering and frame rate drops can all have negative impact on the user experience. To tackle this issue, it is vital to progress with the technology and motivate the users to prefer virtual over the physical experience.

The issue rarely discussed in virtual heritage sites is its' effect on the stakeholders. Important historic buildings which generate revenue for the state as well as individual traders in case of marketplaces may suffer significant profit loss due to the declining number of customers (Aggour, 2017).

Issues such as being a passive observer and having no interaction with local traditions (Cheong, 1995) are under development and outlines for adding educational features about customs of the past are being addressed (Aggour, 2017). Issues, such as the replication of natural unpredictability (Verde, 2014) are also under the development, and solutions for simulating natural behaviour is present the Great Barrier Reef project. The project also serves as a great example for limiting the user's time spent inside the simulation in order to prevent disorientation once the simulation is over. (Refsland et al., 1998).

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