Virtual museums - technologies, opportunities and perspectives

Mihaela Anton, Gabriela Nicolae, Alin Moldoveanu, Oana Balan

University POLITEHNICA of Bucharest
Splaiul Independenței, Nr. 313,Sector 6, Bucharest, Romania
E-mail: mihaela_1402@yahoo.com, nicolaegabriela16@gmail.com, {alin.moldoveanu, oana.balan}@cs.pub.ro

Abstract. Virtual Reality is a very popular concept all over the world. There are many areas whose activity involves this technology: games, cinemas, museums, medicine, aviation. Although Virtual Reality was more used in games and medicine, in the last period many museums started to adopt it. The museums represent a cultural heritage and also a trust worthy information source in people's lives. Therefore, it is important to attract the audience, especially the young. A very good method to make it possible is to build virtual museums. Our article describes how the virtualization of museums impacts human life, what are the opportunities offered by this change, the steps to build a virtual tour and what are the expectations regarding this subject in the future. In this paper, we also demonstrate how 3D technologies can be used to preserve and display the cultural heritage and as proof we have a dedicated chapter with the top five most amazing virtual museums.

Keywords: virtual museum, 3D artifacts, adaptive reality.

1. Introduction

1.1 What is Virtual Reality?

Virtual Reality (VR) represents the technical image of reality, as it is perceived by our sense organs. Using VR people can interact with a reality that does not exist, a reality created using a computer. In technical terms, Virtual Reality is a three-dimensional, interactive computer-generated environment which can be explored by people using some special devices such as a VR headset or VR glasses.

The concept of VR was born in the years '60. According to Thomas DeMichele(2016), Sensorama was a mechanic device invented by Morton Heilig in 1957, through which people could see an interactive theater experience. Over time, VR has evolved to sophisticated devices that can

recreate historical artifacts or simulate an aircraft accident. The evolution of technology leads to a new perspective of how people can simulate different situations of real life to see and solve problems that cannot be otherwise solved.

The greatest advantage of virtual systems is that there are only virtual risks. These systems provide a reasonable, non-dangerous and adaptive reality.

Virtual Reality can be used in several disciplines like sport, education, architecture, arts and entertainment. For example, in education, virtual environments can be created to help teachers to better explain the lessons. The 3D images allow students to experience and discover an immersive reality in their classrooms. It is proven that students learn better if they do something and they are not limited to word descriptions from books.

1.2 What is the impact of VR on society and culture?

Nowadays Virtual Reality is a very common concept around the world. Everybody has heard about it, but nobody knows what it means exactly. The most well-known field that can be related to Virtual Reality is the gaming industry. A game is more exciting and more addictive when played on a VR platform. Once people have tried this technology, the common games became boring and less challenging. However, the technology grew so fast and changed the business perception, since the companies with well-known applications wanted to implement Virtual Reality with their apps. The technology has been involved in many other areas such as aviation, medicine, movies, automobiles and museums.

One of the oldest applications built with Virtual Reality makes people feel like they are in a real plane and is used for pilot training. Nowadays, before flying a real plane, the pilot simulates it. After this training, the pilot should pass some mandatory tests before boarding a plane.

Surgery is a domain where Virtual Reality is of great help. Every healthcare provider has contracts with companies that develop medical VR applications. The applications were designed for surgeons and help them examine the entire patient's body and identify exactly where tumors are. The VR applications can treat mental issues and phobias. They simulate environments and put the persons face-to-face with their fears. Little by little they begin to get used to the environment and see that their fear dissappears. This phenomenon encourages them to get over the stress and helps doctors to

determine quickly the real causes of the problems. As well as pilot training, there is doctor training. These applications simulate a surgical intervention, so that a student can practice before he will be in charge of a real one. The student will promote only if he passes the virtual exam.

More and more cinemas adopt the VR technology and people are very excited about it. Besides using VR platforms, the cinemas install speakers in the whole room to amplify the feeling that you are more than a viewer. The suspense is double, and the horror movies are far scarier, but an experience like it cannot be replaced by anything.

According to Urvish Macwan (2017), Virtual Reality technology is used in automobile manufacturing to allow visualization 3D images of the car's prototype by all the concerned engineers. They can explore the entire car: exterior, interior, and then make their own suggestions or corrections. This approach can reduce the costs generated by the design of a real prototype before the modifications are applied.

1.3 The virtual museum and the aim of the article

Museums started to adopt the VR technology as well. Nowadays, some of them are using different VR platforms to display their collection of items. With the VR headset the people can access the museum from home, therefore they no longer need to travel to a certain city to visit a museum. This saves money and time.

P. Petridis and M. White (2005) consider that virtual museums represent virtual collections of artifacts and multimedia objects designed in virtual tours. Using this technology, the curator can easily create many exhibitions and then post on a website, where the visitors can explore and interact with them. This new approach to visiting a museum leads to a decrease in the costs of designing and managing the exhibitions.

In the 21st century, VR technologies started to gain the attention of people who want to discover new things and also preserve their cultural heritage. Thus, using affordable devices and also some photography software, people can create a basic VR application and expand it to interact and understand how ancients lived or how a dinosaur looked like.

The purpose of this article is to show how virtual museums changed the perspective of a classical museum and how people interact with this news in the cultural area. We will demonstrate how 3D technologies and VR devices amaze and captivate the visitors and also what the impact of these new

technologies on people's life is.

In this paper, we will also present a top of the most beautiful virtual museums of the world such as the National Museum of Natural History, National Museum of Iraq and The Louvre.

Even though all look interesting and attractive, these technologies can have a bad influence on the people's perceptions about what belongs to real life and what not. Also, to achieve good and scalable results, it is important to make them available to as many people as possible. So, the democratization of VR should assume some solid standards in order to be understood and used by everyone.

2. Technical perspective on virtual museums

2.1 Concepts and definitions

Over the years there have been several definitions of what a virtual museum is - the website of a physical museum, an environment that exposes photography and art, a museum without walls or a copy of the physical museum that contains 2D and 3D images from the museum's exhibition. Also, there have been various terms to call this concept - Web museum, online museum, digital museum, cybermuseum or electronic museum.

According to Silvia Ramos Rodriguez(2009) all these explanations have been attempts to describe a virtual museum, but over time the technology evolved and with it, the virtual museum. Today, in order to capture and hold the interest of audiences of all ages, the virtual exhibition is complemented by other multi-sensory information such as text, images, sound or video. It is professionally built in order to better reflect the real artifacts. Due to that, the virtual environment can represent any type of museum - historical, scientific, technological, artistic etc.

Nowadays, the virtual museum can be defined as a collection of digital resources within the artistic-cultural field, offered by using the World Wide Web and HTML technology. The resources may include drawings, paintings, photographs, recordings, newspaper articles, transcript of interviews, video segments, numerical databases, graphs and anything which can be digitized.

Traditionally speaking, it is a way promoting people's work in a cultural space. A good reason is that people are connected online every day. Practically technology is part of their life, therefore there is no better way

than to promote your museum.

There are three categories of virtual museums: the brochure museum, the content museum, and the learning museum.

The brochure museum offers data related to a museum, location, open hours and event scheduling in order to guide people to visit the real museum.

The content museum is a site created to offer information about all collections. The data are stored in a database. There is accurate and detailed information about the exhibitions.

Sylaiou Styliani and Liarokapis Fotis (2009) described the learning museum as a website that offers visitors different possibilities of view. These options are presented according to their age, background, and knowledge. Furthermore, the site is linked to additional information about some subjects that can be interesting for the visitor. The purpose is for the user to visit again the site and to establish a connection between the virtual exhibition and themselves.

The virtual museum does not represent a danger for the real museum because the objects presented are digitized, it cannot offer real artifacts to users. However, designing a virtual museum is a great idea because it solves many problematic situations such as those described below.

Certain museums exhibit non-permanent collections, and it can be frustrating for people because they cannot travel every time. On the other hand, the museum space does not allow the storage of all collections exposed over time, so some artifacts become inevitably unavailable to people. A solution for this unconventional situation is the virtual exhibition. Thus, all collections can be seen by all people from any place with Internet access.

Another case, solved by the virtual tour, is the people's desire to see a famous museum but the time or the money does not allow them to do so. People can enjoy viewing their favorite collection with only two things - a computer and Internet access.

From a content point of view, there are3 types of virtual museums:

- digital presentation of a real museum
- virtual tours of a real museum
- websites that offer better examinations and possibility to share knowledge with specialists

According to F-MU.S.EU.M.(2009) the structure of a virtual museum must contain information regarding the exhibitions, the locations of artifacts and also the collocation of them. To build the website it is important to carry

out a closer view of how the information is placed on the website, which exhibitions are liked by the people, how people purchase the tickets to access the private virtual tours.

The virtual visitors need additional explications during the virtual tours which can be given using educational pop-ups that can be accessed during the virtual exhibitions.

The majority of museum systems are based on web standards and technologies that help museums to build a solid representation of the real exhibitions. These standards are based on keeping the information in collections stored in the database and how they can be integrated with Virtual Reality solutions such as VRML or 3D technologies.

Thus, a virtual museum is based on 3D reconstructions of artifacts, audio and video guides, digitization of images and text explications for the artifacts. The 3D representations promote the exhibitions, gain more visitors for the site and present a realistic view of the real museums.

Another advantage of implementing a virtual museum is the safety of the original artifacts. They also offer the opportunity to share the information all over the world using a simple click of the mouse. The services besides the virtual museum offer presentation, accessibility, research and maintenance of the whole product.

However, there is some inconvenience to build a virtual museum, such as the availability of the content in fewer languages, less experience in developing the pedagogic tours and poorly prepared stuff in elaborating educational contents.

2.2 How is a virtual museum built ?

There are many aspects of building a virtual museum. One of them refers to how to design the virtual museum, how many representations it will contain, which technologies are necessary and what technical support is needed.

Based on the article wrote by Elin Ivarsson, a physical museum is represented by 3 main principles: *collect, preserve* and *display*. Each of them is important because they help the museum to become an institution of education for all types of learning.

Since the virtual museums are the virtual representation of the physical museums, the 3 principles are followed in online too.

The most important stage of building a virtual museum is collecting the objects to be displayed and also the audio and video materials. Speaking of a

virtual museum, the collecting stage refers to taking photos and videos of the physical artifacts and exhibitions. Then the curators will process the materials using professional software to create the virtual tours.

Despite the real collection, a virtual one does not necessarily have to be based on physical artifacts. So, the virtual collections can be extended with other information that can help the visitors and also the scientific community. This information could be obtained by tracking the web logs. This action can help the museum to record the user's audience and then analyze the impact of the online representations to the visitors.

To create the virtual content it is important to follow 3 steps:

1. Develop a fitting web interface to support the virtual content.
2. Load the meta-data that contain the real museum

Include the database agreements

The second stage refers to preserving the content of virtual artifacts and exhibitions. This step seems to be easier than to preserve the artifacts from a physical museum, because the objects are not real, and do not need special attention to resist in time. But there are some issues in preserving the virtual content.

Firstly, it is important to update the content constantly and to make sure that the collections are up to date and can be seen using the new technologies and devices.

Secondly, the storage of virtual materials needs to be updated because the size of files tends to become larger with the introduction of new, and better quality file formats. So, the storage will become more cost-efficient.

The stage of displaying the virtual collections is also critically because the visitors must interact easily with the site. The accessibility is vital for the success of the virtual museum. So, the design of the virtual tours must be interactive and attractive for the visitors.

Another aspect of increasing the audience of the virtual museums is putting together combined exhibitions and share them with several museums. Also, real museums share their artifacts, but this action should be difficult because the objects could be damaged during the transportation for one to another museum. But, using the virtual technologies is more easily and quickly to borrow the "artifacts" and it would also be available to the world.

In order to make the transition from a real museum to a virtual museum, one needs:

- a complete database that contains all the archives of the museum

- video representations of real artifacts
- storage devices such as CD-ROMS, DVD-ROMS, external HDD
- network support: servers, computers, peripheral devices
- anti-malware software
- website to host the virtual museums
- VR software and 3D technologies
- audio and video guides
- video and photo cameras

With all this equipment the IT team and the museum's curator could design and develop a virtual museum which can be seen all over the world.

2.3 Tools and frameworks for building virtual museums

The advanced technology allows the use of sophisticated tools in developing different types of virtual museums with customizable interfaces. The first model involved a static exhibition of text and some photos.

Over time, the presentation evolved into dynamic content, getting closer to reality and gaining more and more users. The structure of virtual exhibition is defined by two components: the Virtual Galleries and the Cultural Objects. The most important features of a virtual presentation are:

- multiple contexts, to allow users a connection without issues
- an easy understanding of instruction for use
- permanent learning segments
- combining learning and leisure in a balanced manner
- avoidance of big text pages to relate to the learning experience

Imaging technology

The virtual museums need high-resolution images in order to present a lot of information about the virtual objects. The multiplicity of showed features depends on the resolution of digital images. It produces big files that are very hard to manage. Also, the bandwidth does not allow the transmission of large files over the internet. As a solution, image servers are used, that involve a "Russian Doll" imaging architecture and offer the user scalability and interaction possibilities.

The server's principle consists of storing more resolutions of the same

image in only one file and then render it progressively. The image format that has contributed to the evolution of imaging architecture were FlashPix and JPEG2000. A lot of museums and cultural institutions are using this format.

An important detail is the opportunity to store metadata. JPEG2000 contains techniques of FlashPix, and it allows scalability, a progressive render of an image, protection of the content and the possibility to fill the gaps generated by the addition of metadata.

Web3D exhibitions

According to Sylaiou Styliani and Liarokapis Fotis, the World Wide Web technology offers users the permanent access to the virtual museum environment. Also, the advanced Internet connections allow the transmission of media files related to virtual exhibits. The technology that capacites visitors to WWW visualization contains Web3D. It holds tools such as VRLM and X3D used to develop an interactive virtual museum. Open standards from Web3D contain VRML97 and X3D. These standards allow real-time 3D communication.

From a technical point of view, VRML is neither VR neither a modeling language. It is a 3D interface format which defines viewpoints, animation, hierarchical transformations, fog, texture mapping, light sources, geometry, material properties and animation. Also, it can be said VRML is a multi-platform that holds technologies to publish 3D pages and mix three dimensions, two dimensions, text, and multimedia into a logical model.

Another option that can be used to build a virtual museum is QuickTime (QTVR). The features are similar to VRLM's characteristics, and it can connect with other files through the hotspot.

X3D is a technology which offers a lot in the virtual context. On the internet, it allows real-time communication of 3D data. The most important feature of it is the capacity to put into a single file the descriptions of runtime behavioral and geometry. X3D can be described as a VRLM97 with all the best. The reported negative behavior about VRLM97 was repaired on X3D. Moreover, it contains all the innovations related to graphics hardware.

A virtual museum can be simply built using dynamic Web pages in collaboration with 3D VRLM technology and some multimedia information, but if a more 3D format is needed, the adequate solution is COLLAborative Design Activity (COLLADA). It is an open standard XML schema, as X3D and the graphics applications that are using this technology benefit from the

opportunity to exchange digital assets. In contrast to Web3D, COLLADA allows more advanced physics functionality - collision detection and friction.

OpenSceneGraph is an open source multi-platform used by various technologies to build a virtual museum. It performs in 3D graphic, providing to a 3D environment the support of using simultaneous audio, text, 3D scenes and video.

3D game engines are also used to create a virtual space, and it is remarkable by physics support and superior visualization. In some educational domains, it is used a concept called serious games known by the capacity to allow the collaborative use of 3D spaces. The most powerful abilities of serious games are manifested in the visual expression of information, interactivity, and entertainment, areas of communication and collaboration mechanism. Contrary to VRLM and X2D, the usage of OSG and 3D game engines bring an impressive realism to a virtual environment. On the other hand, these technologies have two disadvantages: advanced programming skills are needed and for mobile devices no support is provided.

Virtual Reality exhibitions

Virtual Reality simulates a real or imaginary environment created in 3D aiming to generate the illusion of reality. Over time, the creation of a virtual environment has become much easier and cheaper. To build a virtual environment just common hardware elements are needed (PC, touch screen, a sensor device, inertia cube), some application software and right browser plug-in.

Virtual exhibitions can be presented as 3D galleries on the Internet, or they can be a stand-alone interface. On the market related to VR software there are tools and libraries, such as Cortona, that allow a fast and efficient generation of a virtual museum, but from small and medium-sized museums's point of view, the creation and the storage of virtual exhibitions is a big financial effort.

Augmented reality exhibitions

Besides the visualization of virtual exhibitions, the online visitors can interact, navigate or create museum collection in an augmented reality environment. The users can move objects in the real environment using advanced software methods or tracking systems. The principal strength of AR is the capacity to create the effect that all is real and to obtain it the virtual information is overplayed upon by video frames captured by a camera. Using

human-computer interaction, the visitors can touch the virtual exhibits through tactile manipulation of fiducials. ARCO system holds various tools designed to virtualize a museum, to make touchable the virtual artifacts and so on.

Mixed reality exhibitions

Mixed reality represents the composition between VR, AR and real space. The artifacts from the real world and those from the virtual world are exposed on the same display. It offers the opportunity to visualize both the real and virtual environment. Situating Hybrid Assemblies in Public Environments is a project that implements the mixed reality to increase the socialization and learning especially about cultural objects. The interaction and visualization of exhibits are possible through the periscope - a portable mixed reality interface.

Haptics

Haptics involves more than just a touch. It is about the possibility to feel the shape and the texture of an object. The University of Southern California's Interactive Art Museum implemented this technique. The visitors were able to touch and feel the virtual objects, due to a device called Phantom which is a desk-grounded robot. It simulates the fingertip contact with virtual artifacts through a pointing device, and when it feels collision with those objects, it returns back to the user's fingertip.

Use of handheld devices in museums

There are a variety of handheld devices - cell phones, PDA, tablets and so on. Due to the evolution of optics in recent years, museum-based applications have been created. The interaction with the virtual objects is realized through a stylus or menu interface. Also, external sensors (digital compass, inertia cube, accelerometers) allow the users to discover, in a virtual manner, information about the location of objects in the museum.

3. Opportunities offered by virtual museums

3.1 Functionality and Bussiness perspectives

Virtual museums are represented by digitized data. More and more traditional museums started to build digital components that reflect the structure of the museum. The goal is to expose the artifacts worldwide. There are several reasons why the Internet must be involved in the activity of a museum:

- through the Internet, a museum gains worldwide publicity
- the Internet establishes a connection between museums and the public
- virtual museums keep all collections, so the visitors can also see the exhibitions withdrawn from the real museum
- the Internet is a cheap alternative to the real museum
- use of the Internet provides remote access to scholarly research of exhibitions in online databases

Werner Schweibenz (1998) said that the telecommunication technology is fully integrated into the people's lives, so including it also in the museum's activity will offer the opportunity to add a digital dimension to the traditional museum. Therefore, the transition involves the exposure of artifacts and the publishing of information on the Internet. It will contribute to the growth of the multimedia industry and will increase the opportunities for museums to break the barriers and to get closer to the public. People are interested in the virtual exhibitions and the information offered by museums, but also all the virtual visitors have a high standard regarding the representation of a traditional museum in a virtual manner. Therefore, the museums should be very careful regarding the collections they exhibit and the data they provide. The exposure of a museum on the Internet offers the possibility to broaden its audience and also to keep in touch with the public. This approach, from a business point of view, represents two real big advantages.

4. Overview of most interesting virtual museums

Next, we will present the 5 most amazing virtual museums.

4.1 National Museum of Natural History

This is the most interesting virtual museum because the visitors can see both

permanent and past exhibitions using some panoramic images that can be explored using an on-screen map or interactive arrows. The virtual tours have a map in the right corner which can help them to navigate easier through the museum's rooms. The online tours are explicit and interactive, and the images are amazing. These tours certainly create the feeling that you are there in the museum.

Figure 1 - Virtual tour of National Museum of Natural History

4.2 Hintze Hall, NHM London

Visitors can interact with the online exhibitions through a 3D scan of the physical Hintze Hall in London's Natural History Museum. The exhibitions have multiple focus points with annotations to share more information. The online tours look like online games, the builds are 3D representations of the real one and visitors can move and see the artifacts.
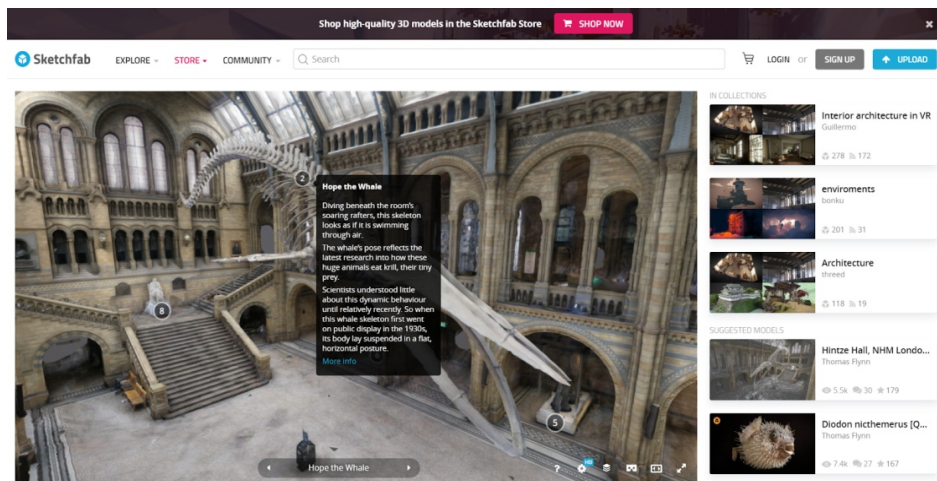
Figure 2 - Virtual tour of Hintze Hall, NHM London

4.3 The Louvre

We can see some images and virtual tours from the Louvre too. In this case, the virtual museum presents 360-degree images of most important things to see from the Louvre.

Figure 3 - Virtual tour of Louvre Museum

4.4 The Museum of Natural Sciences

Another type of virtual museum is created using Google Street View. This

platform has many virtual museums exhibitions and has a huge collection of 360-degree images from this museum in Belgium. The panoramas have also annotations with details about artifacts or places.

Figure 4 - Virtual tour of The Museum of Natural Sciences

4.5 Metropolitan Museum of Art

The Metropolitan Museum of Art has a VR tour made of 360 videos. These videos are available on their youtube channel. There is some additional information for helping people to understand the video tours.
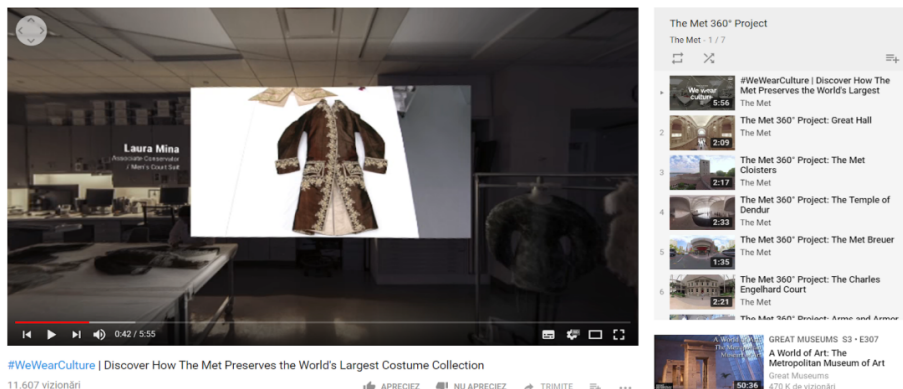

Figure 5 - Virtual tour of Metropolitan Museum of Art

4.6 Discussion

In the last few years, many famous museums all over the world developed the concept of a virtual museum using the VR environments. Some of them choose to make virtual tours using interactive online maps. Others share image galleries of their artifacts. Table 1 presents a comparison between these five museums, taking into account their interactivity, existence of 3D artifacts and additional explanation which can help visitors to understand easier the stories of the artifacts.

Tabel 1. A comparison between museums

Name	Is interactive	Additional information about the artifacts	3D artifacts
National Museum of Natural History	Yes	Yes - display a popup with details	Yes
Hintze Hall, NHM London	Yes	Yes - display a popup with details	Yes
The Louvre	No	Yes - display a popup with details	No
The Museum of Natural Sciences	No	No	No
The Metropolitan Museum of Art	No	Yes - vocal guides	No

5. Trends and perspectives

As mentioned above, the VR technologies facilitate the people access to cultural heritage from the museums. Most of the virtual exhibitions present monuments or objects, reconstructions of ancient lifestyle and also paintings by famous painters. These exhibitions can be seen using some special equipment that can help users to have an immersive experience and feel like they are on a real tour.

Consequently, at this time the majority of virtual museums do not provide a total VR experience, because the costs to buy all the equipment are high and there is also need to find and teach people how to use them. This exhibitions only provides static 2D images of rooms and some zoom on these images. Dr. Greg Jones (2002) said that the interaction of visitors and the virtual tours are

not so good as they claim to be, because the visitors cannot approach the artifacts and examine them closely.

Nonetheless, VR technologies can dazzle the visitors and offer an immersive experience from their home. This opportunity is still attractive because people are still fascinated by the new but we must take into consideration that people are used to the evolution of technology and this could be a temporary reaction. That is why the museum's managers should understand the risk of being less impressed by the VR technologies used by their museums in the future and try to exploit the potential of VR. Also, they should improve progressively the devices and the software and used it responsibly.

So, the specialists consider that in the future, all the virtual museums will be represented by on-line immersive 3D rendered environments that will improve a lot the visitor's experience and place them into a truly immersive environment.

6. Conclusions

In conclusion, VR represents a great opportunity for both people and museums. Firstly, using these technologies can improve people's accessibility to cultural collections and exhibitions all over the world without effort and without spending a lot of money.

Secondly, the museums could use VR to preserve the old artifacts and objects that need special attention. Thus, people can have access to these artifacts without actually being in the same rooms. VR offers an environment which can be used to create real-time tours of physical museums using tools as audio, overhead, whiteboard interfaces and on-line presentations.

Even though the implementation of this new technology involves high costs and IT specialists, we consider that virtual museums are the future of real museums and VR could be a good investment for increasing the audiences, especially the young.

We have seen in this paper that virtual museums still have some issues to solve in order to become what specialists want them to become, but a good collaboration between museum curators and IT developers will achieve the expected results. Virtual museums cannot replace the real-world museums but could become an extension of physical exhibitions.

Acknowledgement

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