CARAVAGGIO IN ROME: A QOE-BASED PROPOSAL FOR A VIRTUAL GALLERY

Chiara Di Stefano and Federica Battisti

Roma Tre University
Department of Engineering
Via Vito Volterra, 62 00146 Rome, Italy

ABSTRACT

The spreading of low-cost and easy-to-implement systems for Virtual Reality, make it possible for a large number of consumers to experience this technology. The application fields span a wide range and recently the educational aspect started having a significant impact. In this paper we design a framework that allows the user to visit a virtual museum in which all canvases painted by Caravaggio and conserved in Rome are displayed. The aim of this project is two-fold: on one hand we provide the user with the possibility of having a personalized and educative exploration of an artistic content, while on the other hand we assess the acceptability of this virtual reality-based application by the final user. The system has been implemented in three different versions, one based on a standard interaction between subject and PC, while the other two rely on the use of Google Cardboard, a low-cost framework for virtual reality rendering. In order to assess the Quality of Experience of the users of the system, we performed subjective experiments that showed pros and cons of the proposed system and highlighted some guidelines towards the use of VR for serious gaming. The synergic cooperation between Art History and ICT gave to this project a peculiar aim in which both disciplines' interests and needs are profitably combined to build a Digital Humanities project. The result is a product, which is philologically accurate and at the same time innovative in terms of technologies used.

Index Terms — Digital Humanities, Virtual Museum, Digital Heritage, Quality of Experience

1. INTRODUCTION

Recently, mobile Virtual Reality (VR) applications are gaining popularity also beyond the gaming field. In fact, thanks to the rapid increase in the computational processing and graphic capabilities of the mobile devices, the possibility to render VR content is becoming more widely spread. Recently several low-cost VR platforms appeared on the market, such as the Oculus Rift [1] and the Google Cardboard [2]. The easiness in accessing this technology, coupled with the availability of free development platforms, such as Unity [3], widened the application field of the virtual reality.

In the state-of-the-art several applications have been devised. In the medical field for example, it could be used for training doctors [4] or for rehabilitation purposes [5]. More generally, VR could be exploited for practising any kind of complex procedure, from military [6] to sport training [7]. Virtual reality has also already been successfully applied in the artistic field. As an example, in [8] a proposal for a virtual visit of a real museum to be rendered through a head mounted display (HMD) is presented. The system provides a map of the museum to be visited based on a set of stages obtained by a stereo camera and displayed on the HMD. In [9] a web-based framework for realizing a virtual environment is proposed. The adopted cross-platform technology can be used both for gaming or for education purposes by exploiting the first-person POV (Point-Of-View) paradigm, which allows an immersive experience to the user. The aspect of designing such ambient for virtual museums has also been investigated in [10]. As shown in [11], an environment which is familiar to the user could be interpreted as friendly and the rules of behavior that he/she has to follow could be easier to understand. In the above mentioned works, a fundamental task was to provide the user with a friendly and immersive experience. In order to study this aspect, in [12] the authors analyzed the time to complete the navigation task and evaluated the user experience scores for three different navigation techniques: continuous motion, through a magnetic switch and with a Bluetooth controller.

In this contribution we aim at moving a step further by analyzing the user Quality of Experience (QoE) in a virtual and cultural space. In particular, we refer to QoE as the "degree of delight or annoyance to the user of an application or service. It results from the fulllment of his or her expectations with respect to the utility and / or enjoyment of the application or service in the light of the user's personality and current state" [13].

In this work, we selected as case study all Caravaggio's canvases present in Rome. A tourist interested in visiting all of the Caravaggio's masterpieces based in the city, considering bookings, queues and an average time to rest, could take three or four days to see all of the twenty paintings which are located in nine sites among hidden churches and less known museums.

Virtual Art Galleries can be a possible solution. They are already widely adopted by museums and art galleries which offer different approaches to complete or partially replace a traditional visit. Some recent proposals [14] are oriented to provide a sort of 'personal museum' in which the user can move and in which he/she can put on the walls his/her favorite works of art. Differently, [8, 9] are two examples in which the focus of the project is on the historical accuracy of the contents. Both approaches rely on providing the users with educational tools that could complement the experience of a visit of real places like the Calabria Region in Italy or the B&M Theocharakis Foundation for the Fine Arts and Music in Greece. With respect to the existing approaches, our proposal's aim is not at being a virtual reconstruction of something that already exists but wants to collect together all Caravaggio's canvases in Rome to propose a unicum that, on one side, could help a visitor to locate the works, while on the other side could provide an intense and immersive experience for people who cannot see the canvas in person. The immersivity of such a system is

also increased thanks to the availability of artistic databases from which the canvases can be downloaded at very high resolution. The trend started by the [15] with the release of more than 400.000 items of their collection available in Creative Commons to share and promote the knowledge of art. The increasing availability of downloadable images in Creative Commons that can be used to build virtual models, provides the user with the feeling of being in presence of the canvas itself and not of a low resolution reproduction. Thanks to its flexibility, our project is a proof of concept for a framework that could be applied to other cities, other artists and for several different scopes (i.e. educational purposes, [16, 17, 11]).
The paper is organized as follows: Section 2 presents the system architecture and three different solutions for the human-machine interaction. Section 3 details the tests that have been performed for assessing the effectiveness of the proposed method. Finally, Section 4 draws the conclusions and presents the future work.

2. SYSTEM ARCHITECTURE AND HUMAN-MACHINE INTERACTION

In the proposed system, we designed a virtual museum in which the user can freely navigate and explore the canvases and their details. The implementation of the system relied on the use of a low cost VR platform and the software Unity [3]. In the following subsections, the details about the definition of the physical space and the implementation details are reported.

2.1. The physical space

In the definition of the physical space to be represented, we focused on building a space that could be felt as familiar for the viewers; in particular we followed the paradigm of the Serious Games, that is the application of the gaming framework to other fields beyond pure entertainment. More specifically, in order to follow the Serious Games' aesthetics [18], we provided a space to be crossed - with walls and corners hiding the canvases - in order to offer an immersive experience. Following the guidelines in [19], the virtual museum we created is composed by seven rooms that ideally reflects the placement of the canvas in the city (shown in Figure 1). In more details, nine locations were mapped to seven rooms and in order to build a space in which void and full areas were balanced. In absence of space continuity, we decided to put together canvases ideally linked by argument (e.g. Madonna of the Pilgrims with The Entombment of Christ). Each canvas is provided with a caption plate in which author, title, year, size and localization are written. To build the exhibition space, according to art and critique aesthetic theories, we followed the curatorial idea of "White Cube" as described in [20], a non connoted space in which the canvases are illuminated with a soffuse artificial light that helps the immersivity of the viewer. The structure of the museum is in Figure 2 (a), while Figure 2 (b) gives the detail of a single room.

2.2. Google Cardboard and LEAP motion

The main innovation with respect to the available systems used for artistic purposes, is the possibility to deliver to the user a complete experience of immersion and interaction with the virtual world.
As mentioned in the Introduction, the Google Cardboard system allows to provide the user with an immersive experience in a virtual world with a user friendly and low-cost set up (its price can range from 15$to 65$). It integrates an external structure, that can be made in paper or plastic, and two 45mm plastic lenses as

Figure 1. Location of the Caravaggio's canvases in Rome.

shown in Figure 3 (a). In order to access the virtual world, the user needs to place a smartphone inside the viewer and to start a Google Cardboard-compatible app. The task of the app is to play simultaneously the views for the right and the left eye, and to compensate the barrel distortion that the plastic lenses create. The limitation of this system is in the reduced interactivity provided to the user. For this reason, we improved this capability by integrating the use of the LEAP motion [21]. This is a cheap and light sensor that can be easily be attached to the Google Cardboard viewer and used for translating hand gestures in movements in the virtual world. This sensor is suitable for our purposes since it has near-zero latency, and thus it is particularly useful for real time applications. Moreover, it has been specifically designed for tracking the movements of the hand and it is very accurate in detecting even the smallest variation. The integrated system we used is shown in Figure 3 (b). The LEAP motion is positioned on the frontal part of the VR viewer. In this way the user interacts with the environment in a natural way since the hand gestures are performed in front of the subject.

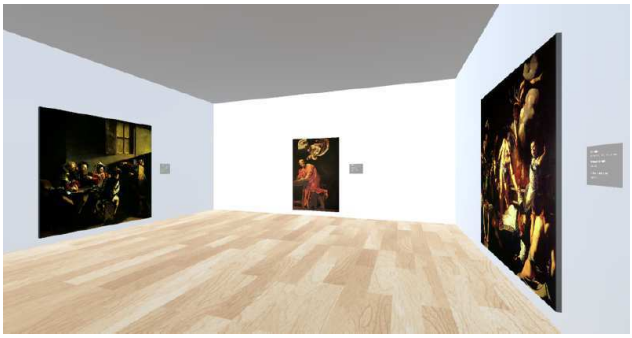
2.3. Navigation

As previously mentioned, in order to provide the user with a more realistic experience, there is the need to provide him/her with the possibility to interact with the virtual world and to freely move around. To this aim, three different interaction schemes are considered:

- PC: virtual world rendered in a PC screen and navigation through keyboard and mouse;
- VR: virtual world rendered in Google Cardboard and navigation through gamepad;
- VR + LEAP: virtual world rendered in Google Cardboard and navigation through LEAP motion controller (Figure 3).

In the first interaction mode, the user can freely move in the virtual museum by using the arrows on the keyboard (left, right, back and forth). The mouse is used for accessing the extra information on the canvas that are placed on the walls. In the other two interaction modes, the users wear a viewer and can interact with a gamepad or by performing specific hand movements in front of the LEAP motion. As a proof of concept, in the latter case, the interaction has been based on a very simple gesture recognition. More specifically, when the hand is open in front of the viewer, as shown in Figure 4 (a), the user moves forward in the space while, when the hand is closed and the thumb is up, as shown in Figure 4 (b) it is possible to move backward. It is anyways evident that the

(a)



(b)

Figure 2. The physical space of the virtual museum: (a) aerial view of the virtual museum, (b) detail of a single room.

(a) (b)

Figure 3. (a) Google Cardboard platform, (b) Google Cardboard and LEAP motion integration.

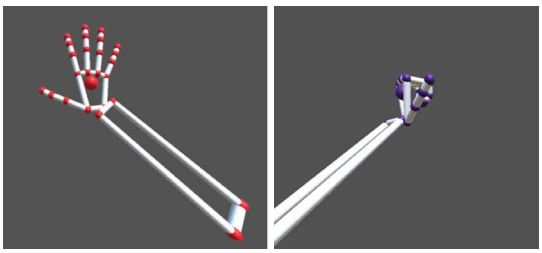
PC experience results to be less immersive than the ones in which the Google Cardboard is used.

3. SYSTEM ASSESSMENT

In order to test the usability and the QoE of the proposed system, preliminary subjective tests have been carried out.

3.1. System set up and subjects

To verify the performances of the proposed application on different operative systems, we used two smartphones, the Samsung Galaxy S7 Edge and the IPhone 6s. We selected 10 users from the Department of Engineering whose age was between 21 and 35. All subjects had experience with virtual reality and gaming. We asked all users to explore the virtual museum by using all three navigation systems. The navigation was completely free and no constraints on path or time were given to the subjects. The main reason for this choice was to give them the possibility to get familiar with the task and understand the interaction mode.



(a) (b)

Figure 4. Hand gestures used for the interaction with the LEAP motion: (a) forward, (b) backward.

In order to collect the users' QoE we asked them to fill in a questionnaire evaluating their experience on a scale from 1 to 5 where 1 corresponds to *Very bad* and 5 to *Very good*. The questionnaire was designed to focus on three main aspects:

- immersivity of the experience
- the easiness in using the different navigation systems
- the validity of the proposed approach in the considered scenario.

Moreover, we provided the subjects with a section for collecting comments or suggestions for improving the systems and to verify the presence of physical annoyance (i.e. dizziness, headache,...).

3.2. Results

Table 1 reports the results collected by the subjective tests. The immersivity provided by the VR mode has been rated as *Good* and it has been the most accepted; in fact, 75% of the users chose it as their favorite navigation mode and, thanks to the interaction provided by the gamepad, the subjects rated it as the easiest to use (4.9) and as the most immersive. This result is mainly due to the fact that the subjects we selected were familiar with gaming and consequently the interaction through the gamepad resulted extremely easy.

	Immersivity	Usability	Utility
PC mode	3.7	4.7	2.7
VR mode	**4**	**4.9**	**4.6**
VR + LEAP	3.7	2.8	3.6

Table 1. Average subjective scores.

The PC mode has been evaluated as easy and intuitive to use since it is based on the classical human-machine interaction that can be experienced daily. Anyways, the subjects rated the utility of this application with a very low score and this was expected since this navigation mode misses the immersivity provided by the other two modes.

The VR + LEAP mode has been evaluated as less intuitive and less user friendly than the other two modes because of its complexity in using hands for browsing the scene. Anyways, the use of the Google Cardboard provides the user with a good feeling of immersivity. Even if the subjects who participated to the test were all familiar with virtual reality, two of them, during the test, had some lacrimation and eyes complaint that we controlled by lowering the brightness of the device. Beside this problem that was possible to fix during the test itself, two other subjects experienced dizziness in the VR and VR + LEAP interfaces. An explanations for this is that when the subjects move in the virtual space, in reality they

are sitting or standing still. Consequently, the different inputs collected by the senses are in contrast thus resulting in the feeling of dizziness. Overall, the VR mode had an evaluation of 4.5 points but only the 60% of the users said that they would download this application from an e-store. One of the main reasons could be that the users we selected were all familiar with the VR technology and gaming but they were not deeply engaged with art history. Anyways, the collected score show that the perceived QoE is high and encourage the use of this technology.

4. CONCLUSIONS

In this contribution, a framework for the design and exploration of a virtual museum was presented. Specifically, as proof of concept, all canvas painted by Caravaggio that are conserved in museums and churches in Rome have been selected as content to be shown. The aim is to provide the user with the possibility to explore those canvases, and the related artistic and historical data, in a user friendly environment to grant a good QoE. In a first phase of the project, the space to be rendered has been designed based on state-of-the-art studies, and created through the Unity development platform. Three modalities for navigating into the virtual museum were implemented. Subjective tests for assessing the usability and acceptability of this way of experiencing the artistic content have been performed. The collected subjective scores and comments demonstrate the appealing of the users towards the use of virtual reality for artistic purposes. However, the subjective tests highlighted the need for improving the human machine interface and the overall immersive experience. Future work will address the use of a different hardware set up based on the HTC Vive. This system allows the user to interact in a more realistic way with the virtual world especially thanks to the capability of physically walking through the rooms of the museum. Moreover, the resolution of the HTC Vive is increased with the respect to the one available in the mobile phones, thus providing more natural and less annoying experience.

5. ACKOWLEDGEMENT

The research in this paper was partially funded by the national research grant 'Smart Environment - Cultural Social Network - Task 1.1 Cultural Heritage' funded by the region Lazio (Italy). The authors would like to thank Walter Ciabocco for his support in implementing the system and performing the subjective tests.

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