A Usability Study on Low-Cost Virtual Reality Technology for Visualizing Digitized Canadian Cultural Objects: Implications in Education

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Abstract: A small cultural object from Algoma University's archive was digitized using a commercial 3D scanner and was visualized using a low-cost and easy-to-use virtual reality (VR) headset and a free online 3D graphics viewer. We ran a preliminary usability study with university students to see whether our VR setting may positively affect the object's visualization and analysis and in turn support learning about local Canadian culture. Initial results showed that in general the VR setting and the 3D model were effective, efficient and satisfactory to use, motivating students to keep using it in further courses. It will be interesting to see in future studies whether the technology integration in the classroom, technology acceptance, learning with VR technology, likeness, motivation, and other issues change over time in an educational setting.

Introduction

A number of museums, libraries, archives and cultural heritage research institutions (such as the Museum of Anthropology at the University of British Columbia in Canada and the Smithsonian Institution in the U.S.) are digitizing their cultural objects, not only for the sake of preserving cultural heritage, but also to make information on the object collection easily accessible to researchers, scholars and students (Jones & Christal, 2002). Once an object is digitized in 3D, it is possible to show it on a web page using a desktop computer or even shown on a smart phone's web browser. The 3D models can also be displayed using virtual reality equipment, which may be effectively used to support analysis of 3D models of cultural objects (Santos et al., 2014), due to support for user's immersion, engagement, interactivity and 3D graphics quality, among other characteristics of VR (Ott & Freina, 2015). This allows researchers, students and interested people to inspect the 3D models from many angles, interacting with the digitized object virtually. The 3D model can also be accompanied with a description of the digitized artifact and extra information such as pictures on how the object was used by an ancient culture (Bustillo et al., 2015). However, digitizing cultural objects is not trivial, since special care must be exercised when manipulating ancient objects due to their fragility. In addition, most of the generated 3D model files are large, and new and efficient techniques are needed for improving the 3D object digitization and visualization, among other challenges (Santos et al., 2014).

The objective of this paper is to describe the development and user testing of a digitized cultural object intended to apply it in educational settings using affordable, efficient, effective and engaging virtual reality technology. Our motivation is to see if the tools and techniques used in our VR setting and 3D scanning process are feasible and usable and for showing 3D models of cultural objects in courses where Canadian culture is taught. Permission to scan and use the cultural object described in this paper was sought and obtained.

Usability and Educational Virtual Reality Technology

Llorens Rodriguez & Alcaniz Raya (2015) point out the importance of running user studies within the development of virtual reality applications, in order to analyze its users' motivation and the overall system usability. Past research has found that if technological applications in education (such as virtual reality) have a high degree of usability, it will support learning more effectively, and will improve student's intrinsic motivation and likeness about its use (Zaharias, 2004; Zaharias, 2006; MacFarlane et al., 2005; Virvou & Katsionis, 2008). The International Organization for Standardization (ISO) defines usability as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" (ISO 9241-11, 1998). In addition, researchers have studied virtual environment usability for more more than two decades, demonstrating that usable virtual environments lead to better user acceptance and user interactions in a virtual environment, improving participants' overall productivity (Kaur et al., 1998). For instance, virtual reality medical simulators that have been improved in their usability have positively supported skill transfer and learning in medical education (Alverson et al., 2005; Le, Pedro & Park, 2015).

3D Digitization Process and 3D Model Viewing

In order to test the usability and educational feasibility of our VR setting, we digitized one object that belongs to Algoma University's Engracia de Jesus Matias archive (Algoma University Archive, 2017), located in Sault Ste. Marie, Ontario, Canada. The object is a wooden figurine carved circa 1942 in the shape of a bunny rabbit, measuring 3.2 x 7.7 x 10.2 cm. The object has historical and cultural significance about the local aboriginal culture.

We used a Matter and Form 3D scanner (Matter & Form, 2017) for digitizing the cultural object. This is an easy to set up and affordable scanner (it costs less than US$600) and captures details of about 0.43 mm in color. The scanning process took approximately a couple of hours, since it was a quite precise and intensive process. The object was scanned using two passes both in upright and lying positions, for capturing all the object's details in 3D. The software that came with the scanner made the merging of the two passes automatically. The obtained 3D model was saved using .OBJ format, which is commonly used by many 3D modelers and virtual reality applications. The 3D scanner set up and the scanned object are shown in Figure 1.

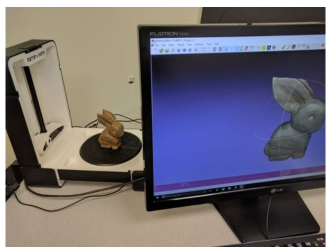

Figure 1: Matter and Form 3D scanner and the scanned object.

After the cultural object was scanned, the resulting 3D model was uploaded to a free web site (sketchfab.com) that is used to publish and share interactive 3D models. Sketchfab provides a specialized viewer based on WebGL 3D graphic library that allows to display models on the web in 3D. The website also allowed to include the object's textual and metadata description. The 3D model can be viewed on any desktop and mobile web browser that supports WebGL. Moreover, in Sketchfab, people can watch and interact with the 3D models using very low-cost VR headsets such as the Google Cardboard (e.g. see Fabola et al. (2015)) and similar ones. In order to use it with low-cost VR headsets, the model is opened on a smart phone's web browser and then the phone is inserted in the VR headset. By wearing the VR headset, people can watch the model in stereo and interact with the model by moving the headset around, thus using the smart phones' sensors and accelerometers for navigating around in the 3D model. The Sketchfab page containing the 3D model of the scanned bunny is publicly available at: https://sketchfab.com/models/44ce7f1dfdd94aeaba8ffd5951275598. We opened the latter web link and displayed the scanned 3D model on a Nexus 5 smart phone, shown in Figure 2. The phone was inserted in the VR headset.

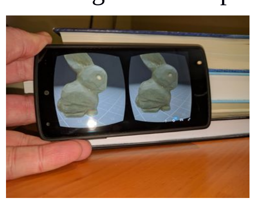

Figure 2: Smart phone showing the 3D model.

User Testing of our Virtual Reality Application

We ran a usability test with six 4th year students from the Bachelor of Computer Science of Algoma University, Canada, with an age average of 24 years old (five males and one female). Just one of them had used a VR headset (a Google cardboard) before, and most of them were occasional video game players. Generally, 5 or 6 participants are enough for uncovering most of the usability problems of an interactive product (Nielsen, 2000). Participants used an EVO Next VR headset, model no. MIC-VRB03-101 (https://merkuryinnovations.com/merkury/evo-next-bluetooth-controller/#black), which costs less than US$40.

We applied a user testing method called Think Aloud Protocol (Rubin & Chisnell, 2008). It is a practical method where each participant is performing tasks as part of a user scenario and the experimenter asks the participant to vocalize (say out loud) his or her feelings, thoughts and opinions while interacting with the product (the VR application). This method is useful because the usability specialists can get valuable qualitative data about what motivates participants to use the analyzed application. We also applied the System Usability Scale questionnaire (Brooke, 2013). It is an industry-standard and reliable questionnaire consisting of 10 Likert scales with five response options (from Strongly agree to Strongly disagree) that has been used to evaluate the usability of many types of digital products, including VR technology. A participant interacting with the 3D model is shown in Figure 3.

Figure 3: A student wearing the VR headset and interacting with the scanned 3D model.

Procedure

The VR application was tested one student at a time. We recruited students by asking them to participate voluntarily in our usability test. The test was conducted in a quiet classroom. Each student was initially explained the main purpose of our VR application testing, intended to be a tool to be used in further Canadian culture courses for supporting teaching and learning. The main task for the participants was to navigate around the 3D model, paying attention to the object's shape, carving features an color details. To do that, we previously set up the "Orbit" navigation mode in Sketchfab, where the participant looked at the object from many angles by moving his/her head left to right and up and down. Participants in the study were asked to try out the VR headset for some minutes and we asked them to say out his/her feelings, thoughts and opinions about the VR application. After using it, students were asked to fill out the System Usability Scale questionnaire (shown in Table 1).

		Strongly disagree 1	2	3	4	Strongly agree 5
1	I think that I would like to use the VR application frequently.	☐	☐	☐	☐	☐
2	I found the VR application to be unnecessarily complex.	☐	☐	☐	☐	☐
3	I thought the VR application was easy to use.	☐	☐	☐	☐	☐
4	I think that I would need the support of a technical person to be able to use this VR application.	☐	☐	☐	☐	☐
5	I found the various functions in the VR application were well integrated.	☐	☐	☐	☐	☐
6	I thought there was too much inconsistency in the VR application.	☐	☐	☐	☐	☐
7	I would imagine that most people would learn to use the VR application very quickly.	☐	☐	☐	☐	☐
8	I found the VR application cumbersome (complicated) to use.	☐	☐	☐	☐	☐
9	I felt very confident using the VR application.	☐	☐	☐	☐	☐
10	I needed to learn a lot of things before I could get going with this VR application.	☐	☐	☐	☐	☐

Table 1: System Usability Scale questionnaire.

Preliminary Usability Testing Results

Figure 4 shows results of the System Usability Scale questionnaire applied to all the six participants.

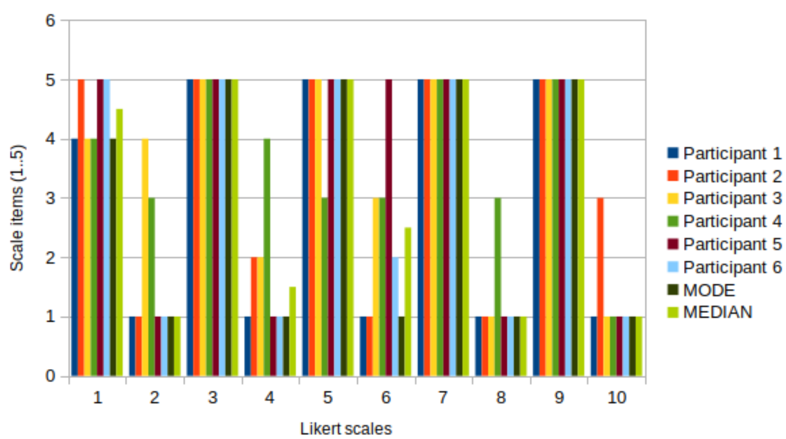

Figure 4: Summary of results of the System Usability Scale questionnaire (1=Strongly disagree...5=Strongly agree).

The System Usability Scale questionnaire was scored, where 0=very bad usability and 100=excellent usability. The score result of all the questionnaires, on average, was 88. This means that the score is in the 80th percentile, and according to Sauro (2011) it is considered as very high usability.

It is interesting to note that during the usability test (using the Think Aloud Protocol) participants were asked what they thought about the original (real) size of the scanned object (they did not see the scanned object before the test). All of the participants answered that the rabbit’s size was big, of about one meter in diameter or so. However, the size of the scanned object is small, which is 3.2 x 7.7 x 10.2 cm. Our future developments will include reference objects or points for helping students estimate the real size of scanned objects.

All the participants perceived the 3D model quality and resolution as enough for future educational applications about learning Canadian culture. This was verbally asked during the testing session. In addition, all of them declared that the VR headset was comfortable. However, most of the participants found that the display needed more brightness.

Conclusions

The 3D scanner and VR headset that we described in this paper were easily used and set up and can be afforded by schools with a limited budget.

The user testing of our educational virtual reality application such as the SUS questionnaire and the Think Aloud Protocol methods allowed us to get important insights on how students used and liked our VR setting. Those usability testing methods are cost-effective and fast to implement, and are intended to improve a computer interface, including virtual reality environments and their applications.

In summary, the following shows the findings from the usability test with the six participants, where the three main usability parameters were covered (computer interface efficacy, efficiency and user satisfaction):

- Efficacy and usefulness. The participants truly believed that the virtual environment watched on the VR headset would help them learn more about Canadian cultural objects. The goal of the 3D model effectively supporting an educational experience was accomplished.

- Efficiency. Although participants' navigation around the 3D models presented some lag, all of the participants did not perceived this as a serious issue regarding the 3D visualization of the models using the VR headset. Further testing will include a more powerful smart phone to minimize lag. In addition, The participants were not confused with the virtual environment navigation.

- User satisfaction. Most of the participants agreed that using the digitized objects was a novel, motivational and satisfactory educational experience, and most of them would like to use our VR application in further courses.

It is important to note that the "novelty effect" may have influenced our usability test results. Thus, it will be necessary to run longitudinal usability tests with our virtual reality application to confirm our findings. Another aspect that will be worth investigating in the near future is how students adopt and accept VR technology in regular courses where Canadian culture is taught. Although there are extensive studies in the literature about technology acceptance in general, for example see Norman (1999), it will be interesting to see whether the learning curve, technology integration, acceptance, learning with technology, likeness, motivation, and other issues change over time in an educational setting.

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