Personalized Augmented Reality Experiences in Museums using Google Cardboards

Marinos Theodorakopoulos*, Nikos Papageorgopoulos*, Andriana Mourti*
Angeliki Antoniou†, Manolis Wallace*, George Lepouras†, Costas Vassilakis†, Nikos Platis*

*Knowledge and Uncertainty Research Laboratory
University of the Peloponnese
Tripolis, Greece 221 31
Email:gav@uop.gr
Web: http://gav.uop.gr

†Department of Informatics and Telecommunications
University of the Peloponnese
Tripolis, Greece 221 31
Emails: angelant@uop.gr, gl@uop.gr, costas@uop.gr
Web: http://dit.uop.gr

***Abstract*—In this paper we examine the suitability of the Google Cardboard as a means for the delivery of personalized cultural experiences. Specifically, we develop the content and create the application required in order to provide highly personalized visits to the Archaeological Museum in Tripolis, Greece. We also examine the usability issues related to the use of Google Cardboards. Early results are promising, and based on them we also outline the next steps ahead.**

I. Introduction

In a conventional museum, a lay visitor finds herself in front of an exhibit which is accompanied by an information label. For example, in the Archaeological Museum of Tripolis, when presented with the exhibit in Figure 1, the visitor sees:

> Index number 2967: Headless statuette of a young girl. She bears a chiton reaching to the feet with an upper belt. The garment is held onto the chest with straps. She holds a bird in her left hand, while she leans on a stele with her right hand (she leans on a small pillar). Material: Marble. Found in the Bouleuterion of Mantinea. Hellenistic era work (4th–3rd century B.C.). Dimensions: Height 0.65m Location: Room 15, 1st floor.

Of course, via the process of curation, the museum holds a lot more information regarding this item. This may include the history of the exhibit as an item (where it was found, who found it, what destruction and restoration cycles it has gone through, how it came to belong to the museum), the context of the exhibit (what/who is depicted, what the artist meant to convey, what other theories exist regarding its meaning or intentions), the context of the creation (who ordered it, where it was created, which techniques were used for its creation), the context of the artist (who taught him, who inspired him) and so on. Various museum information standards, including the Cataloguing Cultural Objects (CCO) standard [1] and the SPECTRUM standard [2] organize this additional information into concrete structures and describe best practices for populating these structures.

This additional information cannot be presented in the conventional setting for several reasons:

- usually, there is limited space on the information labels placed next to the exhibits;
- information other than the most general facts, regarding the title and the creator of the item, may not be of interest to everyone;
- including too much information for all items would lead to a cluttered exhibition, inflicting cognitive overload for the visitors.

These concerns can be addressed by following a more personalized approach to the delivery of the content, allowing each visitor to enjoy a personalized and tailor-made experience, but this often leads to other concerns related to the technological means that can be used to either model the user or deliver the personalized experience [3].

Regarding user modeling, the work presented herein is envisioned within the framework of the CrossCult project [4], which includes provisions for implicit user modeling for the selection of the most suitable content for each visitor, mainly through games [5] and social media mining [6]. Regarding the delivery of the personalized experience, which is the main focus of this paper, we examine the suitability of the Google Cardboard as a low-cost option [7].

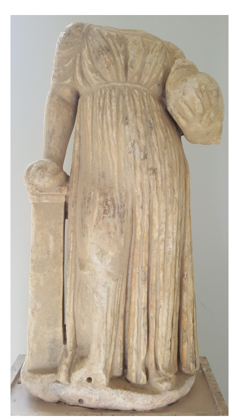


Fig. 1. A sample item from the Archaeological Museum of Tripolis

978-1-5386-0756-5/17/$31.00 © 2017 IEEE

II. The use case

The Archaeological Museum of Tripolis is a small, relatively unknown and severely underfunded museum in Greece; thus, it is a prime case study for our work, as:

1) The museum is located far from the country's main tourist attractions. So it needs to become an attraction itself, by promising a diverse and unique experience.
2) Due to the limited budget, any costly solution has be ruled out.
3) The perspective audience is so small that the museum needs to also explore ways to have returning visitors, whilst being financially unable to make frequent updates to its collection and exhibition.
4) There is a very small number of exhibits, limited not only by the small total number of items owned by the museum, but also by the very small actual exhibition space. Therefore, in order to provide a museum visit of a decent time duration, worthy of the ticket the visitor will pay for, more information needs to be presented for each item.

In order to address each of the above concerns, in this work:

1) We develop an augmented reality application that can deliver a novel, diverse and stimulating experience.
2) We choose the Google Cardboard as a means for low-cost delivery of the augmented reality experience.
3) We specify multiple presentations based on the same exhibits. Thus, a visitor can return to the museum more than once, each time being presented with a totally different experience. The fact that an augmented reality approach is used allows for the different experiences to co-exist in the space without blending with each other, as the content that is delivered to each user does not affect other users that are in the museum at the same time.
4) We extend the descriptions that are presented to the visitors. More importantly, we totally remove the pieces of information that simply state the obvious and offer no information to the visitor (for example, that the exhibit of Figure 1 is a headless statuette) and focus on the more interesting facts of the documentation, such as the deductions that can be made (for example, the social status of the depicted woman).

The personalization factor is strong with the application dynamically suggesting and delivering the right content for each visitor, based on the user profile information that we have gathered from earlier interaction and/or the information that can be gathered from the visitor's social media accounts [6].

III. The content

Each individual exhibit in a museum has many stories to tell; for example, the item in Figure 1 may be used to discuss: daily life in antiquity, education, women's social status, the children's role in family and society, fashion and styling, fabrics, materials used to make statues and statuettes, marble and its uses, statue making techniques, and so much more. And when individual exhibits are combined, the number of stories they can tell is merely countless. In a conventional museum setting only one story can be highlighted; our goal is to make the immense treasure of knowledge included in all the stories available to the public.

Thus, in order to best support the use case described in Section II, the core concept around which information is organized is no longer the individual exhibit but rather the story told by the exhibition as a whole. The curators, having studied the items that are currently on display, have designed different stories that could be told by a museum guide.

As an example, let us examine again the statuette of Figure 1. This exhibit can be included in a visit focusing on appearance. In this case it can be accompanied by the following text:

> Archaeologists know that this is a young girl. Although the head is not surviving, her clothes reveal her age. Young girls in ancient Greece usually wore a long dress, all the way to their feet, which also had an upper belt, attached to the body right under the breast. Older women wore more complicated clothes; for example, they had a himation, a mantle or a wrap, which they wore over their chiton, which was their dress, and if they were married they also half-covered their hair with a veil.
> In this room, you can see examples of older womens' appearance too, and you can compare it to the one of the young girl you see here.

But the same exhibit can also be included in a story focusing on daily life. In that case it can be accompanied by the following text:

> This is a statue of a young girl from Mantineia. We know she is a young girl, because of her dress and the upper belt she is wearing under her breast. From the time of her birth she stays with her mother and the other females of the house together with her young brothers and sisters. She will stay with her mother until she is married. From her mother and the other females of the house, like her grandmother, female family friends, female relatives and the female slaves, she will learn to be a proper woman like her mother.
> Imagine being there. What can a young girl do inside the house?

IV. Application

In order to deliver the different stories designed by the museologists, as outlined in Section III, we need to select a medium that allows for concurrent and independent delivery of content to different visitors (making the placement of monitors close to the exhibits a poor choice), an approach that is not limiting or putting a burden on the visitor (making the use of heavy head mounted displays a poor choice) and finally a solution that can be implemented with limited financial resources (making the use of equipment such as Google Glasses a poor choice). In our work we choose to use Google Cardboards for the delivery of the personalized content; these can be combined with the visitors' mobile phones, thus alleviating the need (and cost) for specialized museum guide devices.

In order to reduce the effort required by the user, we move beyond the conventional audio guide scenario, in which the user has to indicate the item for which she wishes to receive information. In our approach, we use the phone's camera in order to automatically identify the exhibits that the visitor is observing. Thus, the user places the phone in the Cardboard and simply walks in the museum, either holding the Cardboard in front of her eyes, as seen in Figure 2(a), or, ideally, wearing it in hands-free mode using straps, as seen in Figure 2(b).

Based on the detected user profile, and/or the user selection, a single story is selected as the underlying concept of the entire visit, and the text to be displayed at each location is determined based on that. The text is read to the user through the phone's speakers, although it is best when visitors also use a Bluetooth earpiece, so that users can be located close to each other without disturbing each other's experience.

On top of this base service, the application also offers additional features designed to enhance the visitor's experience, as follows:

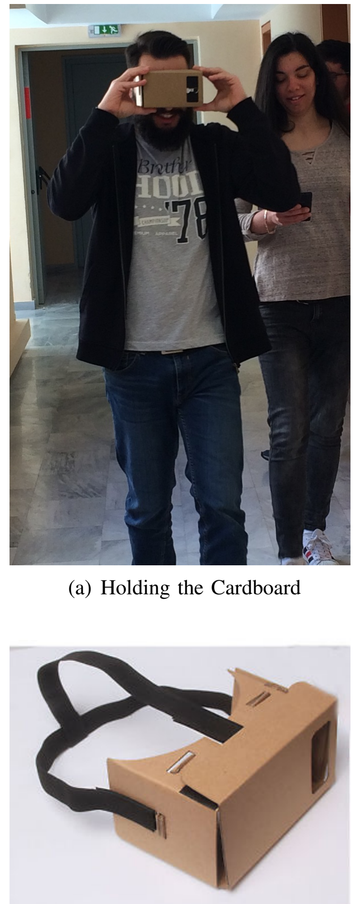
- the text can also be displayed in the user's view, facilitating the provision of the experience to visitors with limited or disabled hearing;
- a personalized soundtrack can be added to the visit;
- audiovisual material can be added to the augmented reality, such as photos of similar or related exhibits in other museums;
- special audio effects can be used to facilitate understanding or enhance immersion, such as the sound of fire and boiling water when observing a pot;
- related videos can be embedded.

The application, which can be downloaded by visitors for free, has been developed using unity3D [10], which is provided free of charge for the scale of usage that is possible in the museum. For the automated identification of the exhibit that the user is observing we have used Vuforia [11] which is also free for the development and testing phase and is provided at a relatively low price for the production phase. One drawback, though, is that the combination of Vuforia with unity3D leads to lower image quality.

V. Research Methodology and Design

The development of the content described in Section III has been straightforward, given the small size of the museum and the abundance of information about the exhibits that was already accumulated and catalogued by the museum staff. Also, the application described in Section IV has been developed in a short time and, from a technical point of view, works excellently, save for the image quality issues mentioned above: exhibits are identified automatically even in poor lighting conditions, the correct content is delivered and the audio is very clear.

But this does not necessarily indicate that the use of Google Cardboards in the way we have described will be loved, or even accepted, by the users. In order to examine the suitability of the approach, we have designed and executed a usability test, to see how easy, intuitive and pleasant it is to use the Cardboard in such a setting.



(a) Holding the Cardboard

(b) Head mountable cardboard

Fig. 2. Different ways to use the Cardboard

A. First Experiment

Our goal in this experiment was to use an empirical study to evaluate people's experience, feelings, reaction and behavior with respect to the combination of Google Cardboards and augmented reality.

1) Description of Experiment: In this test, participants are given Cardboards with mobile phones running an application developed specifically for this experiment. The application is programmed to identify specific visual targets in the space where the experiment is conducted and provides an auditory signal, similarly to how the application would have worked in a museum setting.

Participants are first asked to travel a predetermined route without removing the Cardboards from their face. This route has a training role, as it is used to help the participants familiarize themselves with walking with the Cardboards.

In a second route, the participants are asked to locate three items distributed over a large area in three different rooms. During this step the participants are directed to the location of the target points, so that the emphasis is not on searching for the targets but rather on walking with the Cardboards while observing what is on the walls. In a third and final round, the participants are asked to travel the first route again.

2) Research hypotheses:

a) First Hypothesis: The time intervals in the participants will be a bit faster in the last route, as two routes using the Cardboards were preceded.

b) Second Hypothesis: The Cardboards will make the participants feel in some point disoriented.

3) Participants: Overall, 14 individuals took part in the first experiment. The recruitment was on a voluntary basis from students.

4) Gathered data: During the execution of the experiment, participants were monitored and the time that it took to travel each segment of each route was tracked. Observations made by the proctor of the experiment were also noted.

Follwing the experiment, a questionnaire was used to estimate the user experience and applicability of Google Cardboards in places such as a museum. The majority of the questions were in the format of a typical Likert scale, with five ordered response levels. The survey unfolded in a logical order, so that respondents would find it interesting and engaging, to help establish rapport and motivate them to continue to participate in the survey. Pre-testing was used to verify and optimize the questionnaire.

The final questionnaire consisted of 27 questions. Topics covered in the questions included information about the participant and their general prior experience with virtual reality in order to detect if their usability was more effective. Regarding the experiment itself, the collected data concerned the difficulty, feelings, dizziness, adaptability and ease of use, handling, senses, fundamental difference or similarity to real world, reality perspective and naturalness, fatigue, stress, being fun, movement and speed.

An unscripted discussion followed the completion of the questionnaire, giving participants the opportunity to expand on their responses with their own opinions on the application.

5) Results: Throughout the experiment, a number of observations of the participant's behavior and experiences were made while using the Cardboards. Specifically, according to the questionnaire responses, from the scale 1 to 5:

- users noted 3 on average about how difficult their movement with the Cardboards was,
- participants considered the third route relatively easier, answering 4 on average; some participants noted during the experiment that they had more confidence in their movement.
- users felt that their movement was slower than without the Cardboards answering on average 4.

As the analysis further revealed, after the performances of the experiment involving 14 participants, the findings supported the first hypothesis, suggesting that their time intervals were different, as you can see below:

1st Route $M = 0.945$ and $SD = 0.295$

3rd Route $M = 0.627$ and $SD = 0.316$

$t(13) = 6$, $p = 0.0017 < 0.01$.

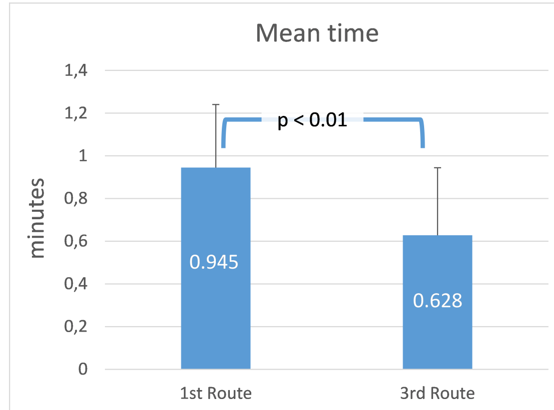


Fig. 3. Time deviations

As we can see above, there is a very high statistical significance implying that the time needed to complete the third route is significantly shorter.

However, concerning the second hypothesis, there was an indication of usability inconveniences and problems. For instance:

- The participants marked on average 3, between 1 to 5, on the question if they felt disoriented at certain points.
- According to their free answers about their experience with the task and by the observations during the experiment there was a difficulty turning the corners and some felt a loss of balance to a small extent.

B. Second Experiment

Of course this last point is particularly alarming, as it will render our approach unusable if it cannot be overcome. The question is whether the source for the dizziness is the approach used, i.e., using the Cardboards, or the low image quality. In order to clarify this we designed and conducted a second set of experimental routes.

1) Description of Experiment: This time we used the second version of the application that did not use Vuforia and was able to exploit the full analysis supported by the mobile phone's camera. Samples are seen in Figures 4 and 5. A new set of participants was used and they were asked to walk the same route twice, with this version of the application.

2) Research hypothesis: To this AR simulation, it was hypothesized that the participants will feel less dizzy using the version of the application without Vuforia.

3) Participants: 11 individuals took part in this experiment.

4) Gathered data: The process of the second experiment was the similar to that of the first experiment: The same questionnaire was used, so that data is comparable.

5) Results: Through the survey's answers, from the scale 1 to 5, users pointed 2 on average about feeeling disoriented (dizzy or nauseous). Furthermore, a participant pointed that the source of the dizziness was when he was looking down to the floor.

C. Tools

To make our results reproducible, but also for the sake of clarity, we provide here links to the software and methodological tools we employed to conduct this research.

- **The questionnaire:** http://gav.uop.gr/docs/smap2017files/questionnaire.pdf
- **The application used in the first experiment:** http://gav.uop.gr/docs/smap2017files/experiment1.apk
- **The application used in the second experiment:** http://gav.uop.gr/docs/smap2017files/experiment2.apk

We are currently working on a dynamically configurable version of the application, which will be made available as open source once it is completed. In the mean time, we will be happy to provide the sources of the current implementations to any interested party.

VI. Discussion

Amongst the findings, the following points stand out:

Everyone completed all rounds successfully and the time difference between the first and the third round (i.e., how long it took to travel the same route with no prior experience and after having used the Cardboard for a while) was important. This significant finding seems to be due to a learning effect, since participants got used to the cardboard and therefore the time needed dropped. This is also in link with their reports on the survey where they found their movement in the last round faster and easier.

However, we should note that we have run a minimal experiment with students as participants; so, although we have a significant sample that allows us to determine those above, broader experimentation is required for further assessments.

Also, participants in general agreed that using the Cardboards was tiring because after a while it started to make them dizzy.

The results of the second implementation of the experiment suggest that there is a difference between the low image quality and high image quality versions as far as dizziness is concerned.

Finally, some minor distortion in the perception of space still remains (most participants report that they perceive the corridors are being narrower than they really are). In addition, some users considered that the framing was the reason for the dizziness.

VII. Conclusion

In this work we developed multiple descriptions for exhibits in the Archeological Museum of Tripolis, each presenting a different aspect of the exhibits, and built a mobile application, based on unity3D and Vuforia, in order to serve this content to visitors. Content delivery is performed in an AR setting, with the use of Google Cardboards.

Our work includes a series of usability tests for the Cardboard. These experiments indicate that using the Cardboard

Fig. 4. Image quality when using Vuforia

Fig. 5. Image quality when not using Vuforia

to deliver AR content in a museum setting is an interesting option, but only if the application is rendered in high quality. Overall, the Cardboard is not ideal and cannot compete with technologies such as Google Glasses. But in settings where resources are limited they can be a competitive choice, as neither the hardware nor the development tools are expensive.

Our work, of course, is far from complete. First of all, we have only provided here a glimpse of our experiments and findings. Moreover, additional testing will be required to assess whether, regardless of the ease of use, when given the choice visitors will use the augmented reality in the museum or prefer to navigate the exhibits without it. We will also examine whether the museum visitors prefer to wear or hold the Cardboards, or if they alternatively prefer an augmented reality application without split screens and Cardboards. The exhaustive usability testing described here and the detailed statistical and qualitative analysis of the data produced by these tests is beyond the scope of this paper and will be included in a latter, stand-alone publication.

Acknowledgments

This work has been partially funded by the project CrossCult: “Empowering reuse of digital cultural heritage in context-aware crosscuts of European history”, funded by the European Union’s Horizon 2020 research and innovation program, Grant#693150.

References

[1] Cataloguing Cultural Objects Commons (2017). What Is CCO? http://cco.vrafoundation.org/index.php/aboutindex/, accessed March 19th, 2017.

[2] Collections Trust (2011). The SPECTRUM Standard, v4.0. http://collectionstrust.org.uk/resource/the-spectrum-standard-v4-0/, accesed March 19th, 2017.

[3] Liliana Ardissono, Tsvi Kuflik, Daniela Petrelli. 2012. Personalization in Cultural Heritage: The Road Travelled and the One Ahead. User Modling and User Adapted Interaction 22(1-2) pp. 73-99.

[4] C. Vasilakis, A. Antoniou, G. Lepouras, M. Wallace, I. Lykourentzou, Y. Naudet, Interconnecting Objects, Visitors, Sites and (Hi)Stories across Cultural and Historical Concepts: the CrossCult project, 6th International Euro-Mediterranean Conference (EuroMed 2016), October 31st-November 5th, 2016, Nicosia, Cyprus.

[5] S. Bampatzia, I. Bourlakos, A. Antoniou, C. Vassilakis, G. Lepouras, M. Wallace. (2016)Serious games: Valuable tools for cultural heritage, Games and Learning Alliance Conference (GALA 2016), Dec 5-8, Utrecht, The Netherlands.

[6] S. Bampatzia, A. Antoniou, M. Wallace, G. Lepouras and C. Vasilakis, Using Social media to stimulate history reflection in cultural heritage, 11th International Workshop on Semantic and Social Media Adaptation and Personalization (SMAP 2016), October 20-21, 2016, Thessaloniki, Greece.

[7] MacIsaac, D. (2015). Google Cardboard: A virtual reality headset for $10?. The Physics Teacher, 53(2), 125-125

[8] Dr. Poorang Piroozfar, Mr. Amer Essa, Dr. Eric R. P. Farr, The application of Augmented Reality and Virtual Reality in the construction industry using wearable devices (CITC-9), March 5th-7th, 2017, Dubai, United Arab Emirates

[9] Mahdi Nabiyouni, Siroberto Scerbo, Doug A. Bowman, Tobias Hllerer, Relative effects of real-world and virtual-world latency on an augmented reality training task: an AR simulation experiment, January 2017, USA

[10] https://unity3d.com/

[11] https://www.vuforia.com/