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Research paper

Usability Evaluation of The Interactive 3D Virtual Reality Cultural Heritage Museum Display: Fountain of The Lions Software Application

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Abstract

In this usability evaluation of the Fountain of the Lions software application aimed to be used by museum visitors, the software is analysed using three established usability research methods: personas, a cognitive walkthrough (*task analysis*) with three participants, and an individual heuristic evaluation. Areas in which the software succeeds and areas which could use improvement are discussed based on the results of these analyses, including use of the methods.

Keywords: *Cultural Heritage, Virtual Reality, Usability, Museum, Interactive Exhibit.*

1. Introduction

Fountain of the Lions (*Fuente de Los Leones*) is an interactive software program centered around viewing and manipulating a 3D model [1, 2, 4, 7] of the historically and artistically important statues and fountain by the same name in the Nazaries Palace (*Palacios Nazaries*) in the Alhambra in Granada, Spain, see figure 1. The software application was developed by researchers in the Virtual Reality Lab at the University of Granada, Spain. The 3D model this program is based on was created based on data from before and after restoration, specifically to aid in visitors' understanding of the conservation and restoration process. This software program preserves the state of the Fountain of the Lions before restoration was undertaken and after the completion of the 2013 restoration. It was created for use by archaeologists, artists, tourists, historians and other visitors to the Alhambra who may be interested in viewing and learning more about this important fountain and its statues without having access to the physical structure up close. Users can manipulate the viewing angle and select and manipulate specific statues and areas of the Arabic inscription and texture on the fountain to view details about sections of the fountain and statues. The program also offers a translation feature so users can read the Arabic inscription (*in Spanish*). The program can be run on a PC with a large touchscreen monitor, with a mouse or controller, or in a 3D virtual environment using another input device. It also runs on a 3D Power Wall system, which includes six powerful projectors that provide a wall-sized screen, is used with 3D glasses, has an integrated geo-locative and motion sensor system, and allows for game controller [3] input. Its primary intended use is on a fixed touchscreen monitor installation in the Alhambra, at some future date, for use by visitors to the fountain in the palace there, near the fountain itself. This analysis is focussed on the touch-screen monitor setup.

Fig.1. Beta version of the Fountain of the Lions application, with one lion selected to go to detailed view of this lion.

2. Literature Review

Projects like the Fountain of the Lions program, combine modern technological innovations and research findings in archaeology, history and sociology in a way that increases the wider accessibility of the findings of such research to the population at large, in a

unique, persuasive manner, with demonstrable success. [1, 3, 5, 11-15]. In an extensive exploration of the opportunities afforded by archaeological modelling like Fountain of the Lions, Teichmann [6] detailed the benefits and complications of Cultural Virtual Reality (CVR). CVR models can be used to organize, store and dynamically represent and communicate complex geological, cultural, social and historical processes, projections, theories and ideas. According to Teichmann: "CVR models work as '*knowledge representations*' involving 'extensive reasoned approximation', which can identify gaps in the state of research. Virtual reconstructions allow the realisation of multiple hypothetical models that can coexist. They can be modified when new results or ideas come up, much cheaper than would be the case with real reconstructions. In this way *visualisation can serve as a tool to handle uncertainty and as a place of thinking*." [6] (p. 103, *emphasis added*).

CVR models offer an opportunity to represent a larger quantity and more diverse type of information than traditional (*2-dimensional*) maps and representations of locations and information about them. CVR models offer more interaction possibilities, increased accessibility, potentially better engagement and memory recall than traditional methods of representing similar information. CVR has also been shown to increase collaboration among scholars, combating the common academic tradition of the lone scholar model of research. However, there are also potential issues with CVR. The potentially highly realistic visual information and perceived realism of the models can lend a credibility to them that can uniquely discourage critical and sceptical thought during the consumption of the media. In general, it is impossible to completely accurately represent past experiences of people in places that no longer exist, in the past. Some CVR models are perceived as too sterile or too artistically rendered, which can prevent or enhance the engagement of users [8]. It can be difficult to communicate the inexact, approximate nature of archaeological representations without undermining their value to viewers/academia. Finally, there are inherent ethical questions and a noticeable lack of current best practices in the way CVR is used for this purpose currently, a situation that needs correcting [6, 16-20].

3. Methods

This is a qualitative usability evaluation of Fountain of the Lions, using three human-computer interaction evaluation methods undertaken in conjunction to analyse, redesign, and report on and discuss the unique successes and areas for potential improvement of the software application. Typical user interactions involve moving the point of view through the virtual space or around an artefact. The viewing angle can be manipulated by moving the head while wearing motion and geolocation sensors, as in a standard VR Head-Mounted Display (HMD) and as in the sensors in the Power Wall system. A cursor, manipulated by mouse or controller input, can be used to select or select and turn a specific statue, or section of text inscription on the fountain, etc. Zooming in and out allows for closer inspection and/or a wider viewing angle. In the touch-screen monitor setup, the viewing angle is manipulated with gestural touch input. On the main screen, users can navigate forward, backward and sideways using the arrow icons on the bottom left corner of the screen and can simultaneously change the viewing angle by touching and dragging one finger in the desired direction. On subsequent screens (*sub-menus*), users can pinch to zoom, swipe or tap and drag with multiple finger input to alter the viewing angle of the lion statues or the fountain. Finally, on the Transcription screen, users can swipe along either the 3D representation of the fountain or the close-up view of the inscription text to view a different section of the text.

Table 1: 2D Task Analysis Questions [2, 4, 9] and 3D Task Analysis Questions [9]

2D Task Analysis	3D Task Analysis
Will the user realistically be trying to perform this action?	Can the user form or remember the task goal?
Is the control for the action visible?	Can the user determine what to do?
Once the user finds the correct action in the interface, will they know it is the right one for the effect they are trying to produce?	Can the user view and locate the objects that are necessary to carry out the task?
Is the feedback appropriate?	Can the user approach and orient towards the objects to carry out the task?
Upon task completion, is there an obvious next action for the user to perform?	Can the user decide what action to take and how to take it?
	Can the user carry out the manipulation or action easily?
	Is the consequence of the user's action visible and understandable?
	Is it clear to the user what the next correct/needed action could be?
	Upon task completion, is there an obvious next action for the user to perform?

Given these complex usage scenario's, three usability evaluation methods were applied, providing a wealth of information: the development of personas, cognitive walkthroughs by three expert usability participants, and a heuristic evaluation. These methods are described below:

Persona descriptions were developed and used to engage in a detailed discussion of hypothetical users and their unique needs, perspectives and ways of interacting with the software application.

Cognitive walkthrough: involved analysing a series of primary tasks and rating the usability of each task, based on the verbal think-aloud method and scoring system elicited from the participants. During this cognitive walkthrough, each overall task was rated on a scale of 1 to 5, where. 1 = No, never; 2 = No; 3 = Maybe sometimes; 4 = Yes; 5 = Yes, always. Steps within tasks were not rated individually. Tasks undertaken in a primarily two-

dimensional (2D) virtual environment were assessed using a the 2D focused questions [2, 4] (see Table 1). Tasks undertaken in a primarily three-dimensional (3D) virtual environment were assessed using 3D focused questions [7, 9] (see Table 1).

Seven tasks and their subsequent task-steps were assessed:

1. Navigate the environment in View Mode (3D);
2. View and manipulate an individual lion statue in Detail Mode;
3. Select Fountain;
4. Select Engraving;
5. Select Compare;
6. Select Other Time;
7. About & Home.

The Heuristic Evaluation Method: The 10 usability guidelines (a.k.a. heuristics) used in this individual heuristic evaluation were developed by Jakob Nielsen [2, 4]:

1. Visibility of system status;
2. Match between system & world;
3. User control & freedom;
4. Consistency & standards;
5. Error prevention;
6. Recognition rather than recall;
7. Flexibility & efficiency of use;
8. Aesthetic & minimalist design;
9. Help users recognize, diagnose & recover from errors;
10. Help & documentation.

Each of these ten usability guidelines are rated on a scale of 1 to 5:

1. "*The user interface did not meet the guideline-at all*."
2. "*The UI did not meet the guideline*."
3. "*The UI partially met the guideline*."
4. "*The UI met the guideline*."
5. "*The UI met the guideline, with excellence*."

4. Results

Positive Persona A: Marina Fernandez

Profesora Marina Fernandez is a 42-year-old professor of Archaeology at the Autonomous University of Barcelona specializing in Spanish historical sites and artifacts. In her spare time, she enjoys reading about the latest trends in technological innovation. She is married to Hugo, with whom she has one son, Alvaro (who's 19). When the new Samsung Gear VR headset came on the market, she was an eager early adopter. Her husband lovingly says she spends too much time thinking about the future at home and about the past at work. Their family enjoys walking their dog Alejandro around Barcelona, going out dancing, and visiting museums.

Experience with the Software Application

Having access to the Fuente de Los Leones software application on her work computer in her office at the Autonomous University of Barcelona saves Profesora Fernandez time and money on travel to the physical location of the Fuente de Los Leones in the Palacio de Nazaries at the Alhambra in Granada and prevent problems with access during the process of its restoration. At the Alhambra, the fountain is off-limits to most visitors, within a palace that requires a special paid admission ticket, used within a strict scheduled visit time. It would likely be quite a process for Profesora Fernandez to visit Granada several hours away, especially just to look into a few quick questions or to reference/see a very small, specific part of the statues or fountain. She is not only saving personal expenses, but also saving the University money by accessing the software program rather than visiting the location in person. Surely, her employer enjoys the cost and time savings. Additionally, Profesora Fernandez doesn't have to discontinue her normal teaching and research schedules for travel as often when she can just open up the application on her computer from her office. She enjoys using the application to share and explore this important archeological site with her students in Archeology 101 and upper-level courses. Her students particularly benefit from being able to read the Arabic inscription on the Fuente de Los Leones in Spanish without having to slowly attempt to translate it by themselves. Due to Profesora Fernandez's enthusiasm for and experience with new, high-tech gadgets, especially virtual reality hardware and software with the Samsung Gear VR, she has very little trouble adjusting to using virtual reality hardware to view and interact with the Fountain of the Lions software application. Her experience with virtual environments also helps her teach her students to use the program and the hardware, even if they struggle a bit with an initial learning curve.

Fig. 1: Positive Persona Description A

Personas: Three different Persona descriptions were made, two positive and one negative: Positive Persona A: Professor Marina, 42, married and one teenager son. Positive Persona B: Isabelle, 11, likes new technology and interactive museum displays. Negative Person C: Jack, 68, computer illiterate, bad eyesight, low dexterity, Due to the page-count limit for this publication, we only print the Positive Persona A in detail (see Fig.1). The other two can be found described in full in [10].

Cognitive Walkthrough Results: Conducted by three usability experts. The scoring system was used to rate, on a scale of 1 to 5, how frequently the answer to each of the task analysis questions was yes (5), maybe (3) or no (1). (*The scoring system and questions are described in far more detail above in the Methods section*). The scores each participant (including the author) assigned to each question for each task (or group of tasks) are shown below, separated by task.

Task 1: Navigate the environment in View Mode (3D): participants move the view around, change perspective, zoom in/out, navigate the main menu, and select an area of the fountain to view in detail mode. All scores for Task 1, a three-dimensional task analysis, are shown in the Table 2. The column entitled P_1 shows the scores of Participant 1, the column for P_2 shows the scores for Participant 2, etc. Finally, the last column shows averages of all scores per question.

In summary, **t**he total average score across all questions for all tasks and participants was approximately 59.3 of 100. This was

calculated by taking the average of the three task score averages: Task 1 Score: ~86.6 of 100; Task 2 Score: ~43.5 of 100; Tasks 3-7 Score: ~47.7 of 100.

Cognitive Walkthrough: The total average score for the application across all questions for all tasks and all three participants on the cognitive walkthrough was approximately 59.3 of 100. There is some room for improvement. We are providing one result here as an example of the richness of user feedback that can be gathered using this method. *Task 1: Navigate the environment in View Mode (3D): t*he average overall score for all participants was about 36.6 of 45 possible points, or 81.3%. During user testing of Participant 1 on Task 1, the participant encountered errors immediately; the participant expected to be able to pinch to zoom, found that the application was responding slowly to touch input, and accidentally selected the lions and fountain multiple times while trying to navigate in View Mode (*main view screen*). (P_1 made the following comments during Task 1: "It's not entirely clear what to do."; "*Controls could be more fluid*."; "*There is no real walkthrough or direction*."; The main view screen "*looks like a static thing to view, not something that can be interacted with*."; "*The explorable area needs to be smaller, more limited, to prevent flying off into nothingness and getting lost.*"; "*Locomotion is a bit wonky*." and "*One-handed control might be better for controlling the viewpoint*.". Additional information was gathered by asking the participants about their overall impressions of the application after completion of all tasks, for example P_1: "Navigation and locomotion in main view are the most pressing problems.

It would be better to use standards that are typical of touchscreen mobile interfaces, including 2-finger input to zoom and pan view, 1-finger tap to select, 3-finger input for rotation of view, lock motion to a specific and visible handle point."; "*The problem with the navigation in main view mode is, it requires two hands to work independently*."; "Object manipulation works okay, even though navigation doesn't."; "Need more feedback and visual cues."; "Should default to the home screen after a period of inactivity."; "Is 'About' a placeholder?" and "Expected a detailed description of the application and its creators, more than is given in the 'Home' (a.k.a. Start Over) sequence of screens." and more [10].

Heuristic Evaluation: The heuristic evaluation resulted in an overall score of 62%. Due to the page count limit of this paper we only discuss the first two heuristics Aesthetic & Minimalist De-

Table 2: Task 1 *Navigate the environment in View Mode (3D)* scores

Task 1: 3D Task Analysis Results	**P_1**	**P_2**	**PW_3**	***avg.***
Can the user form or remember the task goal?	4	5	4	***4.3***
Can the user determine what to do?	3	4	4	***3.6***
Can the user view and locate the objects that are necessary to carry out the task?	4	5	4	***4.3***
Can the user approach and orient towards the objects to carry out the task?	5	3	3	***3.6***
Can the user decide what action to take and how to take it?	4	5	4	***4.3***
Can the user carry out the manipulation or action easily?	5	3	3	***3.6***
Is the consequence of the user's action visible and understandable?	5	4	4	***4.3***
Is it clear to the user what the next correct/needed action could be?	3	5	5	***4.3***
Upon task completion, is there an obvious next action for the user to perform?	3	5	5	***4.3***
Total Scores	**36**	**39**	**36**	***36.6***

Heuristic Evaluation Results: Nielsen's 10 usability guidelines are listed in table 4 with a score from 1 to 5 [2, 4]. The overall usability score was 31 of 50 possible point, ~ 62%. The software program excelled in the areas of error recovery and aesthetic user interface design, with a score of 5. It scored well on the areas of user control & freedom, error prevention and flexibility & efficiency of use, with a score of 4. And reasonably well on the areas of visibility of system status and match between system & world, which earned a score of 3. Finally, the areas which could use some improvement were: consistency and standards (*score 2*) and, most importantly, help & documentation which received a score of 1.

5. Discussion

Personas: Developing and analysing personas of potential users of the Fountain of the Lions software program generates a shared narrative for the team to analyse and discuss the vital elements of the system, keeping the end-user clearly in focus. Persona descriptions can be analyse and design ideas synthesized by deduction. These overall impressions illustrate the ways in which the application serves, or could better serve, the needs of users, separated by theme. In this case three themes were found: Capitalize on enthusiastic users, Increase accessibility for people with special needs and abilities, and localization / translation into more languages. Due to limits on page count for this paper, we report here the first theme only. The detailed findings on the other themes can be found in [10].

Capitalize on Enthusiastic Users: Many users with enthusiasm and familiarity with modern technological innovations will enjoy this software. To capitalize on such interest, it is advisable to include a screenshot feature and social media sharing functionality within the application, both to spread awareness and to gain publicity for the cultural heritage artefact or site, for users to share with their contacts, turning them into advocates for the application and the museum or site.

sign, and Help Users Recognize, Diagnose & Recover from Errors: *Aesthetic & Minimalist Design:* The software application is very pretty, with a minimalist menu design and a consistent, unique and well-chosen color and aesthetic overall. *Help Users Recognize, Diagnose & Recover From Errors:* The application is great in providing many opportunities for error recovery. Every screen besides the main view offers a "Back" button in the same place, in the top left corner of the screen. This is essential for the many times users will accidentally open a screen, as happened frequently during user testing, and want to return to the main view. There is usually enough feedback to be able to tell what happened when the user makes an error, so it is easier for them to recover. Thus, on the "*help users recognize, diagnose & recover from errors*" usability guideline, the application earned a top score of 5.

6. Conclusions

The Fountain of the Lions software application provides a beautiful, engaging and informative experience that will enrich the lives of visitors of Cultural Heritage Museums and Sites. In this usability evaluation, numerous areas in which the Fountain of the Lions application succeeds and areas in which it could possibly be improved were assessed. The primary areas in which the application could use improvement include navigation in the main view screen, feedback and visible cues throughout the application, documentation and help options, and language translations, among others. The three usability methods: persona descriptions, cognitive walkthrough and heuristic evaluation complemented each other and were all found suitable for this early stage of the software development cycle.

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