Accessible Museum Collections for the Visually Impaired: Combining Tactile Exploration, Audio Descriptions and Mobile Gestures

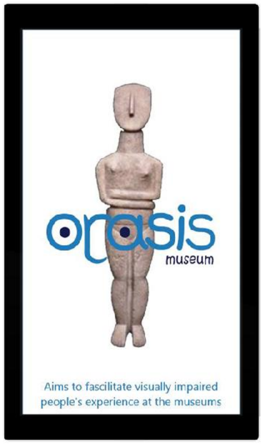

Figure 1. The first page of the app.

Figure 2. Main options of the app.

Giorgos Anagnostakis, Michalis Antoniou, Elena Kardamitsi, Thodoris Sachinidis, Panayiotis Koutsabasis, Modestos Stavrakis, Spyros Vosinakis and Dimitris Zissis
University of the Aegean
Department of Product and Systems Design Engineering
Interactive Systems Design Lab
Syros, Cyclades, Greece.

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Abstract
This paper describes an affordable approach and prototype system that can enhance the accessibility of museum exhibits to visually impaired users. The approach supports the navigation in exhibition halls and the tactual exploration of exhibit replicas using touch-sensitive audio descriptions and touch gestures on a mobile device. The required technology includes 3D printed exhibits, attached touch sensors, Arduino boards, and a respective mobile app. A preliminary usability evaluation with ten users (blind, visually impaired and blindfolded) revealed a positive user experience with satisfactory and similar performance.

Author Keywords
Visually impaired users; blind users; museum; exhibit; mobile device; audio guide; Arduino; tactile exploration; gesture control

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User Interfaces – Input devices and strategies, evaluation;

Figure 3. The visit to the museum during contextual research.

Figure 4. A blindfolded user during evaluation.

Introduction and Related Work

People with visual impairments include the blind, those with visual diseases or injuries and those with low vision; notably very few people have perfect vision throughout their lifetime [8]. People with visual impairments are discouraged to visit museums because their experience is very limited. When they do so, they are in need of a tour guide; they rarely have the chance to touch exhibits to realize their form; and there are usually only a few braille or audio descriptions available presenting information that can be easily found on the Web anyway. Visitors with visual impairments are one of the most difficult categories to address in museums [3].

In the last few years, several museums have taken initiatives to address this problem. The Smithsonian museum has issued guidelines for accessible exhibition design [6], which include that (Guideline II.b.) "*Items essential to the exhibition's main theme must be accessible to people by tactile examination (e.g. touching artifacts, reproductions, models) and/or comprehensive audio description.*" The Victoria & Albert museum in London [2] takes a holistic approach to provide inclusive access for all visitors, which includes removing physical barriers, staff training, providing tangible objects, braille descriptions and tactile books. Recently, the Prado museum in Madrid is offering 3D printed copies of six famous paintings in which users can touch and feel the form and glyphs [1]. On the other hand, several tactual museums exist that primarily address blind visitors (e.g. Tactual museum in Athens [7]), but still do not integrate digital and interactive technologies.

Recent advances in 3D printing, sensor and mobile technology open new possibilities for further supporting the experience of visually impaired visitors. 3D replicas of museum artifacts can be easily produced to allow for tactile exploration [5]. These models can be enhanced with touch-sensitive audio descriptions that provide an additional information channel whilst exploring their form [4]. Finally, a mobile app supporting easy-to-apply touch gestures can inform users about the contents of an exhibition room, direct them to the exhibits of interest and let them control the audio descriptions. In this paper, we present a design concept that integrates the above-mentioned functions, a low-cost prototype implementation (Figures 1 and 2), and the preliminary user evaluation results that are very encouraging.

Contextual Research

Initially, we performed desktop research regarding people with visual impairments and their particular needs, emphasizing in mobile technologies and cultural heritage. Next, we made a field visit the Museum of Cycladic Art in Athens, in which we interviewed two museum curators. One member of the design team was blindfolded to simulate the experience of a blind person, accompanied by a second member of the team who took the role of a tour guide (Figure 3). This method provided us with gains about the user feelings as well as the prospective content of audio descriptions. The latter should be based on simple language and simplified concepts and examples describing form, function and materials – rather than solely on cultural heritage information. Finally, we conducted a group interview with the members of the association of people with vision impairments in Cyclades. An important result was that most of them had not visited a museum for years due to accessibility issues. It was also

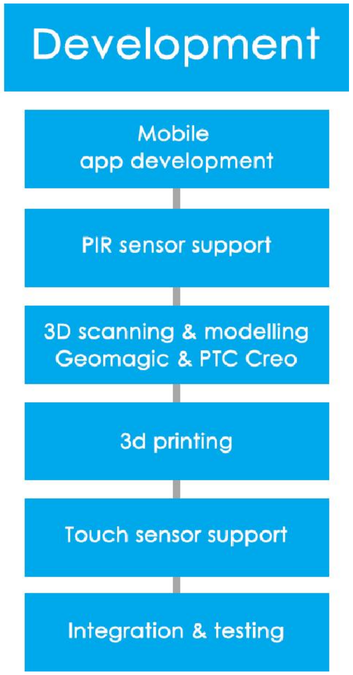

Figure 5. Overview of the prototype development phases.

mentioned that they have the need for free movement in the area and there is interest in understanding the form and texture of exhibits using tactile exploration. From the discussion, we concluded that mobile touch gesture control of audio descriptions was preferred to other alternatives (e.g. voice commands).

Concept Design

The main concept of the proposed system is that blind and visually impaired users can approach and explore exhibit replicas presented in an exhibition room using mobile gestures (Figure 6). Initially the mobile app informs the user about the museum room and available thematic areas and exhibits using audio. Despite that there is content on the smartphone screen, a blind user may use the phone as a multi-touch pad to manipulate the audio interface though a simple gesture set. This enables any user to make discrete use of the technology in a possibly crowded and noisy environment. After the user selects a thematic area and an exhibit, the system provides navigation instructions relative to the user position by taking advantage of preinstalled sensors in the room. As soon as the user navigates in front of the selected exhibit, she can tactually explore its form. The exhibit is enhanced with capacitive sensors in predefined segments. A respective audio description presenting details of the form and material as well as related cultural facts starts playing automatically when the user's hands reach each segment. An example audio description (translated from Greek) is the following: "The left arm is folded above the stomach. It is a common phenomenon for the Cycladic idols, however we do not know much about the symbolism of that position. It is likely to symbolize a position of respect, which derives from religious standards."

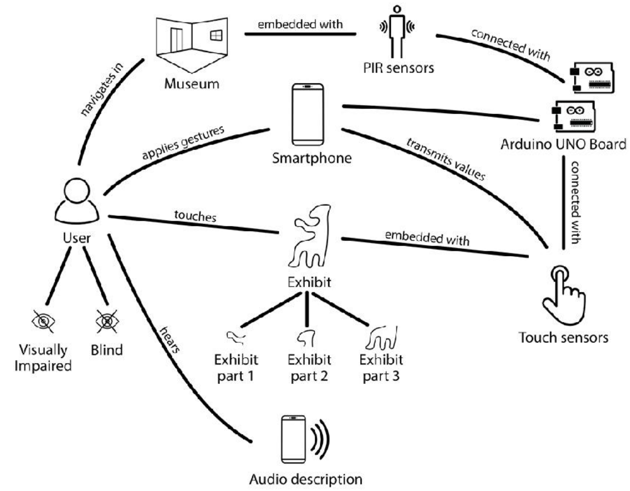

Figure 6. Concept model of the proposed approach.

Prototype development

The system prototype consists of one smartphone or tablet application, two Arduino UNO boards, PIR (Passive Infrared) sensors for aiding navigation, a 3D Cycladic figurine replica (reverse engineered with 3D scanning) and five capacitive touch sensors on the replica. The mobile app audio and text content was in Greek. The main gestures with corresponding operations for this prototype are:

- swipe to move between thematic categories,
- tap to pause/continue,
- double tap to select (after prompted), and
- press and hold to go to previous stage.

The successive phases of the development process are illustrated in Figure 5.

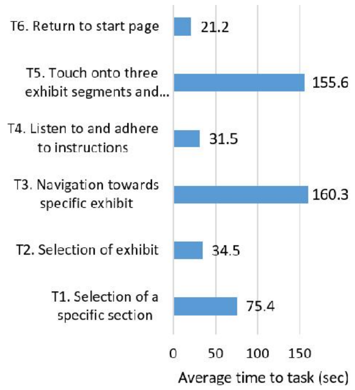

Figure 7. Average task time (all users).

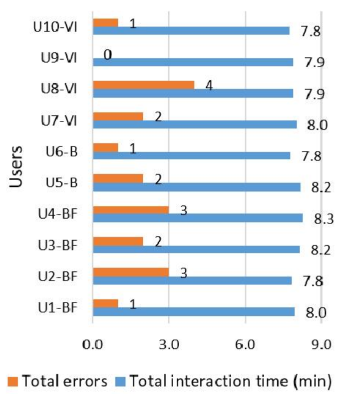

Figure 8. Total user interaction time (all tasks) for users (B: Blind; VI: Visually Impaired; BF: Blindfolded).

User Evaluation

Participants, Process and Measures

A preliminary usability evaluation of the prototype was carried out. A total of ten users took place, two blind, four visually impaired (> 5 degrees myopia, without their glasses or eye lenses) and four blindfolded. For the two blind users (one man 37 years, one woman 33 years), we conducted the evaluation in the office of the association of the visually impaired, while for other users (five women and three men, average age: 21) the evaluation took place in the computer lab.

For all users an identical process was followed, which included the phases of welcoming, familiarization with the system, task performance, retrospective interview. During the usability test we observed and recorded user reactions; during task performance, we measured task success, task time and errors. The users were asked to perform a total of six tasks: (T1) select a specific section to visit; (T2) select an exhibit; (T3) navigate to the exhibit; (T4) Listen to and adhere to instructions (about touching the exhibit); (T5) Touch onto three segments of the exhibit and listen to audio descriptions; (T6) Return to start page.

Results

After the retrospective interview, all users reported that they saw important value for this app. The blind users reported that this system opens up a totally new potential for museum visits and they really wanted to know whether a more refined version of this system would be installed in a museum. The visually impaired and blindfolded users reported that it was easy to manipulate the audio descriptions through gestures. Especially BF users were observed not to be able to fully concentrate with the given audio instructions about both navigation and touch on the exhibit, in comparison to the blind users – this was natural as they were not acquainted with this type of navigation.

The user performance has been analysed into (a) task success, (b) average task time (c) total user interaction time and (d) total number of errors. Task success was universal: all users succeeded in all tasks. The average task time (Figure 7) was quite fast considering that users spent most of their time to hear the audio descriptions. The total interaction time (Figure 8) was fairly similar for all users ranging from 7.75 to 8.25 minutes. This is an encouraging result showing that all users regardless of visual impairment, performed in a similar manner. Regarding the total number of errors (Figure 8), these ranged from zero to four for all users, which is also considered a reasonable range since that users performed several interactions.

Summary and Future Work

We have presented a design concept and a prototype system that enables people with visual impairments to access museum exhibits. The possibility to use tactile exploration to realize the form of exhibits combined with mobile touch gestures for controlling the audio description seems a promising and usable design option from our preliminary prototype evaluation results for all users – even those without severe visual disabilities. This is ongoing work that has limitations especially regarding the user navigation in the museum. Future work includes the extension of the app for various exhibits as well as the installation of the system to a museum along with field evaluation.

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