A Multi-Sensory Approach to Cultural Heritage: The Battle of Pavia Exhibition

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Abstract. In the last years, several museums and exhibits have adopted new kinds of interactive installations that present artworks in more attractive ways, especially for young visitors. At the same time, new communication technologies have been introduced to allow vision and motion impaired people to visit arts centers. In this work, we present the multi-sensory solutions we have implemented for the “Battle of Pavia” Exhibition, a collateral event of Milan Expo 2015. The installation combined different interaction methods to achieve two main goals: providing visitors with engaging experiences and allowing blind and partially sighted people to appreciate the exposed artworks. The used technologies include gesture communication, gaze-based interaction, 3D character reconstruction, virtual avatars, and 3D tactile images. This work can be also viewed in the context of digital humanities for cultural heritage. To the best of our knowledge, this is the first exhibit to gather such a high number of interactive technologies in a single installation. The positive response from visitors is a great spur to continue our research in this direction.

1. Introduction

Digital technologies for enhancing the fruition of museums and exhibits are becoming an important research field, with the main aim to connect people, culture, and technologies [1][2].

Multimodal visits of exhibitions have the purpose to enhance the visitor’s experience by inspiring self-motivated learning. This promotes creativity and engagement, but also requires new approaches to be developed for the design and implementation of digital spaces. Through different technologies, users can now interact with computers by means of gestures, voice, and eye input. Although the full potential of these Natural User Interfaces (NUIs) has not been achieved yet, their fast and steady enhancements are leading to cheap and reliable tools for content manipulation. NUls, that can be also viewed in the context of digital humanities for cultural heritage, can offer new experiential ways to enhance the visit experience, and be an important support for disabled visitors.
In this paper, we present a case study related to the exhibition “1525–2015. Pavia, la Battaglia, il Futuro. Niente fu come prima” (“1525-2015. Pavia, the Battle, the Future. Nothing was the same again”) held at the Visconti Castle of Pavia (Italy) from 14th June to 29th November 2015. Over 11,000 people visited the exhibition (10,556 tickets sold, including at least 400 family tickets).

The “Battle of Pavia Tapestries” are a collection of seven tapestries, each one describing a scene of the battle, permanently exposed at the “Museo di Capodimonte” in Naples (Italy). However, as a satellite event of Milan Expo 2015, one of them was presented in the exhibit at the Visconti Castle of Pavia. This paper describes our contribution to the exhibition, which, in addition to the real tapestry, included 3D printed characters, 3D “tactile images” for blind people, and virtual avatars. Visitors could also interact with virtual versions of the tapestries using gesture-based and gaze-based communication. Our work goes in the direction of NUIs, towards a more active and engaging involvement of visitors.

2. Gesture-Based Interaction

Interacting with computers through gestures and body movements has now become an almost frequent practice [3], and also museums and exhibitions can exploit gesture communication (both explicit and implicit [4]) to create more engaging experiences for visitors. To be really effective, explicit gestures should be as intuitive and comfortable as possible, so as to maximize the quality of the user experience.

2.1. Related Work

One of the first uses of gesture-based interfaces in the cultural heritage context was a finger tracking method proposed by Malerczyk [5]. The release of Microsoft Kinect in 2010 significantly increased the number of this kind of applications. For example, the combination of Kinect and RFID sensors was adopted by Cafaro et al. [6] to track and identify visitors in a museum. In the same year, an augmented reality application was developed which exploited the Kinect to allow users to gesturally manipulate 3D models of archaeological pieces from the Museo Regional de Huajuapan [7]. A Kinect-based application allowing visitors to perform a gesture interaction with virtual copies of historical relics was installed at the K2R International Expo in Rome, Italy [8]. Yoshida et al. [9] created an immersive environment, to teach paleontology to children. A similar approach was used by Soga [10] to allow visitors to “walk” through a 3D representation of the Shogo-in Temple.

2.2. Gesture Interaction at the Battle of Pavia Exhibition

For the Battle of Pavia Exhibition, we exploited the Microsoft Kinect sensor to allow visitors to control the computer through hand gestures (Figure 1). The system consisted of a personal computer, a 24” full HD monitor, and a Kinect v1 sensor. In its “slideshow stand-by mode”, the program repeatedly displayed, in sequence, the seven tapestries. As soon as a visitor was detected in front of the device, the “interaction mode” could be started by simply holding a hand out, with the palm facing the sensor. By moving the screen cursor with the hand, visitors could select the tapestries and surf them. Besides tapestries, it was also possible to explore the map of the battle area. Visitors could select one of the seven tapestries or the map of the location of the battle in the screen shown in Figure 2.

By virtually “pushing” one of the eight rectangular areas in Figure 2, the corresponding enlarged version of the tapestry or of the map was displayed. Since pictures were big and only partially visible, the visitor could scroll them by clenching the fist and moving the hand in the four directions.

3. Gaze-Based Interaction

Human gaze can be exploited as an input channel to control the computer and other digital appliances. Eye input is the result of an eye tracking process carried out by eye trackers, i.e., devices that can detect the user’s gaze direction [11].
Basically, an eye tracker finds where the user is looking at and records the related gaze coordinates. Eye movements occur as sequences of saccades (lasting less than 100 ms) and fairly steady fixation periods (with durations normally between 100 and 600 ms). Eye tracking has been applied in a variety of contexts, from advertising (e.g., [12]) to accessibility (e.g., [13]) and biometrics (e.g., [14]). Among others, Milekic [15] provides an overview of gaze-based interaction and its potential applications in the context of museums and exhibitions.

In the Battle of Pavia Exhibition, we exploited eye tracking to allow visitors to expand and shrink high-resolution pictures of the tapestries. In addition, it was possible to scroll the images and see contextual descriptions displayed when specific characters or elements were observed. All these actions were performed without using the mouse or keyboard, but simply by means of gaze input. After the interaction with the virtual tapestries, visitors could also watch their “gaze replays” and download their “gazeplots”.

3.1. Related Work
There are few examples of previous works in which eye tracking has been exploited within museums or exhibitions.

Buquet et al. [16] describe one of the first cases in which visitors’ gaze behavior was assessed in a museum, specifically at the Cité des Sciences et l’Industrie de la Villette in Paris, in September 1986. Wooding et al. [17] employed an eye tracker in the “Telling Time” exhibition at the National Gallery of London, from 18th October 2000 to 14th January 2001. Mobile eye tracking was experimented by Wessel et al. [18] through a wearable device similar to glasses. Museum Guide 2.0 was an experimental project developed by Toyama et al. [19] as a virtual museum guide. Eghbal-Azar and Widlok [20] studied the use of a mobile eye tracker in two German exhibitions. More recently, Calandra et al. [21] employed E.Y.E C.U., an eye tracker to be placed below an artwork and tested in a museum of Naples (Italy).

3.2. Eye Tracking at the Battle of Pavia Exhibition
The eye tracking system for the Battle of Pavia Exhibition was developed to be robust and autonomous, as the interaction had to occur without any intervention from museum operators.

The employed eye tracking device was the ‘Eye Tribe’ (theeyetribe.com, company acquired by Facebook-Oculus in December 2016), a very cheap tool providing an accuracy of about 0.5 to 1 degrees and working at a 30 Hz sampling rate. The eye tracker was positioned below a 24” Full HD screen (Figure 3). Unlike other eye tracking implementations, no further input tool was provided. The interaction could occur in Italian or English, and initial instructions were delivered both textually and through audio messages. Three eye tracking workstations were available at the exhibition (Figure 4). Gaze data was automatically synchronized with a remote server through an FTP module.

Figure 1. A visitor browsing a tapestry with his hand.
Figure 2. Screen for tapestry or battle map selection.
Figure 3. A visitor interacting with the eye tracking system.

Figure 4. The three eye tracking workstations at the exhibition.

After a short initial calibration procedure, a Tutorial module allowed visitors to undergo a brief interactive training procedure explaining how to browse tapestries by means of the eyes (Figure 5). A zoomed-in tapestry image could be scrolled in the four directions by simply looking at the four screen edges. A visual menu composed of four “control icons” was displayed whenever a screen point was fixated for two seconds (Figure 5). Zooming operations (in and out) were performed by fixating the ‘plus’ or ‘minus’ lens icons of the menu for two seconds. Three zooming levels were available, which enabled visitors to closely observe the details of tapestries. To display another tapestry, the visitor had simply to look at the upper icon (the one with six squares). Each tapestry picture also contained four “sensitive areas”, corresponding to “notable elements” (mainly characters). Sensitive areas were highlighted by means of a semi-transparent yellow rectangle as soon as the visitor’s gaze was perceived on them. Immediately after that, a small rectangle containing a brief description of the watched element appeared. Looking at the ‘Stop’ control icon in the visual menu caused the interaction with the system to end. Visitors could then watch their own “gaze replay”, i.e., an animation where gradually expanding circles represent fixations and straight lines between fixations indicate saccades. The gazeplot (Figure 6) that visitors could download at the end of the interaction (through the code they were provided with) is a graphical representation that shows the position of fixations (depicted with circles with areas proportional to their durations).

Compared to previously developed eye tracking solutions for museums and exhibitions, the implemented system allows a much more complex interaction, purely based on gaze input.
4. 3D Characters and Objects from the Tapestries

3D printing is a practical way to create copies of artworks that cannot be displayed directly, for example because they are not easily available, manageable, or accessible [22]. These 3D reconstructions can be also useful for partially sighted or blind people, who cannot enjoy the visual appearance of the treasures cultural heritage offers.

At the Battle of Pavia Exhibition, several 3D reconstructions of characters and items from the tapestries’ scenes were on display. The models were created by the students of the Computer Vision course of the Master’s degree in Computer Engineering of the University of Pavia using the CINEMA 4D and Mixamo Fuse Character Creator software tools. Figure 7 shows the 3D printing of five characters.

5. Virtual Avatars

Avatars are often exploited in historical exhibitions to provide computer-generated experiences in which visitors can play virtual roles. For example, the TOURBOT project [23] was one of the first works going in this direction.

In the Battle of Pavia Exhibition, some characters mimicked the visitor’s facial expressions and head movements, in real-time (Figure 8). The application was developed by means of the facial capture and animation technologies provided by Mixamo Face Plus.

Figure 7. Some character models (bottom) and their 3D printings (top) made with a ProJet 460Plus (color) printer. Figure 8. A user interacting with the avatar.

6. Tactile Images

The possibility to touch artworks or their reconstructions is very important for blind and partially sighted visitors of museums and exhibitions. Tactile images are 3D transpositions of pictures so that they can be read and interpreted by touch.

6.1. Related Work

Giving to visually-impaired people the possibility to visit museums and appreciate artworks is a complex task. Typical solutions involve the use of audio devices, which provide descriptions of the objects on display (e.g., [24]). However, also haptic interfaces have been deeply studied [25]. These implementations require technologies such as 3D scanning and modeling, sometimes combined with \textit{ad hoc} devices. However, haptic interfaces are not directly applicable to two-dimensional artworks, such as paintings. In this case, it is necessary to create \textit{tactile images}, sort of 3D representations of the original creations. Typical solutions can be summarized as variations of two main approaches: tactile diagrams, where only the main edges in the painting’s elements are exploited [26], and bas-reliefs [27]. In the last years, the availability of relatively cheap 3D printing technology has definitively increased the interest in this field. Carfagni et al. [28] compared four different transformation methods from the original 2D artwork to its tactile representation. Furferi et al. [29] proposed a systematic
method for semi-automatic generation of 2.5D models from paintings. Albertazzi et al. [30] tested for the existence of cross-modal visual and tactile associations in abstract art.

6.2. Tactile Images at the Battle of Pavia Exhibition
The Battle of Pavia Exhibition proposed tactile versions of the seven tapestries for partially sighted and blind visitors (Figures 9 and 10). The tapestry images were digitized, simplified, adapted, reconstructed as three-dimensional models, and printed in 3D so that they could be read through fingertips.

Figure 9. Tactile images at the Battle of Pavia Exhibition.

Figure 10. A tactile tapestry.

The tapestry modeling process for 3D printing was developed in several phases, namely: (1) A segmentation process was performed using the DoG filter to extract relevant parts [31]; (2) The extracted contours were then selected based on their relevance for proper scene comprehension. Segments could be either “full” (i.e., represented as high-relief areas) or “empty” (i.e., implemented as low reliefs). The CINEMA 4D software was used to process tapestries and create 3D models with three depth levels; (3) In each segment, a Braille alphabet letter (repeated in a regular pattern) was used to indicate the specific character or element — a Braille legend described such associations; (4) Finally, the tactile images were printed with a ProJet 460Plus full color 3D printer. Compared to other solutions, this kind of tactile images are much more informative.

7. Conclusions
In this paper, we have described the technological solutions we have implemented for the exhibition “1525–2015. Pavia, la Battaglia, il Futuro. Niente fu come prima” (“1525-2015. Pavia, the Battle, the Future. Nothing was the same again”) held at the Visconti Castle of Pavia (Italy) from 14th June to 29th November 2015.

Our main goal was to study, also from a practical point of view, the opportunities offered by digital media for museums and exhibitions, in order to develop approaches, procedures, and tools that can maximize their benefits in such settings.

Although museums and exhibits increasingly exploit novel technologies, such as Natural User Interfaces, their number is still very low. It is only by promoting the use of new technologies in cultural settings that it will be possible to really assess their value, both as a way to create more engaging experiences for visitors and to provide disabled people (especially those who are visually and motion impaired) with alternative manners to access art.

As digital humanities point out, digital tools applied to the study of humanities foster collaborative and transdisciplinary research activities, enlarging the way of knowledge dissemination, and enriching the production of applications and techniques for cultural heritage.
The “Battle of Pavia” Exhibition can be considered a successful event, and the number of visitors went beyond expectations. The solutions proposed included gesture communication by means of the Kinect sensor (one workstation), gaze-based interaction (three workstations), 3D full-color element reconstruction and printing (six characters, a cannon, and two prints of the city of Pavia), a virtual avatar (one workstation), and seven full-color tactile images.

Our research goes in the direction shown by Natural User Interfaces, with the purpose to involve visitors more effectively and create positive experiences, also in relation to accessibility. To the best of our knowledge, no previous single art exhibition has been characterized by so high a number of multimedia and multimodal solutions.

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