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ScienceDirect

Procedia Computer Science 100 (2016) 832 – 839

Procedia Computer Science

Conference on ENTERprise Information Systems / International Conference on Project MANagement / Conference on Health and Social Care Information Systems and Technologies, CENTERIS / ProjMAN / HCist 2016, October 5-7, 2016

Proposal of a Tangible User Interface to Enhance Accessibility in Geological Exhibitions and the Experience of Museum Visitors

Roberto Ivo Fernandes Vaz[a], Paula Odete Fernandes[b,]*, Ana Cecília Rocha Veiga[a]

[a]Federal University of Minas Gerais, R. Paraíba, 697, Belo Horizonte, 30130 140, Brazil
[b]Polytechnic Institute of Bragança, Campus Sta. Apolónia, 5300 253 Bragança, Portugal
UNIAG - Portugal, NECE (UBI) - Portugal

Abstract

Currently, the museums use different interactive technologies to communicate their exhibitions; however, it turns out that in most cases, information is not accessible to all members of the public. In this paper we present the design of a tangible user interface to enhance accessibility in geological exhibitions, specifically for the case of visitors with visual impairments, and we also present the study's results about how to improve the experience of those who visit museums, using this tangible media technology as an exhibitor for samples. The results showed that the interaction with the interface pleased the visitors and that it has application space within geological exhibitions.

Peer-review under responsibility of the organizing committee of CENTERIS 2016

Keywords: Technology in museums; Experience of the visit; Tangible user interfaces; Accessibility ; Participatory design; Tangible media.

1. Introduction

Once a technological research project is held in a museum, it is crucial to understand the role of these spaces in contemporary, defined as "a non-profit, permanent institution in the service of society and its development, open to

* Corresponding author. Tel.: +351 273303103; fax: +351 273313050.
E-mail address: pof@ipb.pt

Peer-review under responsibility of the organizing committee of CENTERIS 2016
doi:10.1016/j.procs.2016.09.232

the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment"[1]. So, as institutions are increasingly interested in providing outstanding informal learning experiences, there has been an effort to meet the visitor's needs, by, for example, providing new experiences of interaction and contact with the exhibits through the adaptation of innovative technology to communicate and encourage a visit to these spaces[2].

In some cases, these technological resources are seen as essential for facilitating the reproduction of stories and intangible processes; in other instances, they contribute to expand information about what cannot be exposed, giving access to digital replicas and reconstructions[3].

Among the technological means adopted to enhance the experience of people visiting museums, we can refer the interactive kiosks and multi-touch surfaces[4], interactive projections[5], human-machine interfaces (as Kinect) to track visitors' movements[6], mobile guides – which most recently use smart phones and tablets to convey the exhibition[7] – and augmented reality to discover new information, that can use Quick Response Code (QR Code) or Near Field Communication (NFC) tags, embedded in the museum exhibits and space[6,8]. However, if we pay attention to the visual impairment reality, it appears that, although innovative and highly sophisticated, these solutions don't provide neither the access, nor the effective understanding of the exhibitions[9], therefore becoming irrelevant to these public members.

According to Classen[10], in most cases, the artefacts in museums can only be looked at, ignoring one of the major human senses that allow interaction with the world: the touch. The possibility of being able to establish physical contact with the exhibits has the advantage of complementing some sensory aspects that vision cannot grasp by itself, such as weight, texture, shape, materials and hardness of the objects[10,11]. To fix this gap and increase accessibility in exhibitions, it is important that technology is used as a mean and not as an end, where, ideally, the collection elements should be combined with digital content, providing a useful experience and facilitating the convenient communication of the various museum themes[12].

In this article we discuss the design development process, implementation, and evaluation of the visitors' experience and interaction with a functional prototype of an accessible exhibitor, based on four geological samples belonging to the collection of MM Gerdau - Mines and Metal Museum, located in Belo Horizonte, Brazil. This project is an integral part of the new digital media communication and human-computer interaction areas, during which development was intended that the interaction with the tangible user interface would happen with the direct handling of the four samples, so that visitors could physically manipulate them in order to obtain information concerning to them.

2. Tangible user interfaces: from genesis to adaptability in museum exhibitions

2.1. Brief history of tangible user interfaces

The establishment and acceptance of the notion of tangible user interfaces were not immediate. The beginnings of this concept dates back to 1993, when the publication of "Back to the Real World", which warned that the digital environment of computers and augmented reality did not constitute natural habitats for humans, so it was evident the need to develop practices that allow a more balance interaction between the real world and the virtual one, in which the physical dimensions were enriched by digital elements[13].

Two years passed, and in 1995, Fitzmaurice, Ishii and Buxton introduced the term "Graspable User Interface", where tangible blocks – "bricks" – were used to manipulate digital objects, making it possible, among other actions, to control the position of the digital material and make use of both hands simultaneously. These authors emphasize the difference between input systems multiplexed in time and space, in which, for the first case, is given the example of the computer mouse that allows the user to control several virtual actions, one at a time. In turn, the space-multiplexed input has a specific transducer associated to each function, which occupies its own space and allows any of these points to be accessible at any time to the user, and to be handled simultaneously; this provided a new way of human-computer interaction[14].

After this, Ishii and Ullmer proposed the conceptual model of TUI – "Tangible User Interfaces" – as a combination of the architecture of ubiquitous computing system with the conceptual model of augmented reality and physical computing, turning the world into an interface. To this end, there are three key concepts: "coupling of bits and atoms" to the allocation of digital data to tangible objects, which gain expression when they come into contact with the “interactive surfaces” – solid interfaces adapted to the coexistence of both worlds. Finally, the “ambient media” includes elements that discretely allow influence human perception, including changes in sound, light and air movement. The authors’ work focused mainly on embedding physical environment with computational elements, as a way to increase it’s expression[15]. With this, tangible objects simultaneously allow the representation and manipulation of digital content, opening space to the inclusion of this concept in many aspects of daily life, in which they have proved to be effective, such as in the educational and learning areas, new scenarios of information visualization, problem solving and planning, entertainment and games, music and performances, social communication[13], amongst others, and for museums’ exhibitions communication, which constitutes our main focus.

2.2. Examples of tangible user interfaces in museum exhibitions

Scientific studies using TUI for communication and interaction in museums are scarce, when compared with other fields of these solutions application, but if we think about blind people, it comes immediately to mind the importance of touch in the context of a museum visit. Nevertheless, it is possible to identify some examples: the National Palace Museum, located in Taiwan, hosted the exhibition “Harmony and Integrity: The Yongzheng Emperor and His Times” where, by manipulating six representations of the Emperor wearing different costumes, three scenarios were presented in the interface, showing images of the artefacts belonging to his reign[16].

Based on the concept that contact with art should combine the processes to see, discover, stimulate and excite, making use of imagination and sensitivity to experience and interpret the exhibition, the Museum Lab was inaugurated in 2006, as a collaboration between the Louvre Museum and Dai Nippon Printing. The exhibition “Diplomacy and Sèvres Porcelain, Prestige and the French art of living in the 18th century” included an interface dedicated to the exploration of the artefacts using TUI. Visitors were provided with a set of physical miniatures of some of the objects in exhibition which, when placed in a specific area, allowed to visualize a three-dimensional virtual representation of the objects[17]. Also at the Louvre DNP Museum-Lab, the exhibition “El niño azul, Goya and Spanish Painting in the Louvre”, had a space dedicated to understanding the factors related to painting, through a TUI named “The painting, a material object”. Visitors could handle eight physical elements that allowed to virtually act in the different layers of the work, in order to get to know the various stages of its creation and the alterations in the original work caused by weather, humidity, heat and light exposure[18]. During the presentation “A Masterpiece of Ancient Greece: a World of Men, Gods and Heroes”, visitors interacted with a TUI handling a copy of the statue “Heracles Resting” to observe images of artefacts from ancient Greece, projected on an interactive map on which the representations were displayed in greater detail on a screen[19].

In the Musée d’Histoire Naturelle, France, visitors can discover the collection of minerals by manipulating tangible disks on a surface, which represent atoms. Each one of these is associated to geological samples made of that particle, and it is possible to combine various elements. A vertical screen shows images and textual information about the rocks[20].

“Belongings” is the name of a TUI to explore the intangible cultural heritage and the belongings as a cultural knowledge, using replicas of unearthed Musqueam objects, as well as other elements used by the community nowadays. During the exhibition, as a collaboration between three institutions in Vancouver, visitors could learn about ancient knowledge, culture and technology, by interacting with the material objects[21].

To conclude the examples of TUI in museums exhibitions, we also point out the SynFlo exhibit, a project developed for The Tech Museum Of Innovation, that utilises physical objects with integrated displays and laboratory objects, with which visitors can interact to explore bio-design activity: when manipulating real lab items, it is possible to add virtual plasmid or toxins to the previous gene selected and observe the results of these reactions in the active tangible tokens[22].

3. Prototype concept, interaction design study and implementation

In this section we will explore the concept of the tangible user interface, interaction design study and the prototype development and implementation, as well as expose the methodology adopted during these phases.

3.1. Concept and interaction design study

The development of the functional prototype of an exhibitor was based on four geological samples – fossilized wood, aquamarine, muscovite and flint – belonging to the collection of MM Gerdau. It was intended that the interaction with the interface would happen with the direct handling of the four samples, so that visitors could physically manipulate them to obtain information about them.

Taking as supporting elements for the study of interaction design the definition pointed by Goodman, Stolterman and Wakkary – discipline that aims to specify the digital behaviours in response to human or machine stimuli[23] – and the primary purpose referred by Norman – to develop usable interactive products, i.e. which are capable of providing rich and pleasant experiences of use at the same time, while being simple and effective to use[24] – we elaborated the interaction model to be implemented, bearing in mind some of the aspects pointed out on usability principles for a good conceptual model, and, therefore, a good interaction experience[24,25]. During interaction design study we followed a methodology of participatory design, which relied on the collaboration of various professionals of geosciences, education, communication design and some Museum visitors.

For the communication of the four geological samples, it was intended to present graphical and sound information along with the handling. The inclusion of sound was intended to provide blind visitors with the same information graphically available to other visitors, visually capable, making these contents accessible for people with special needs. For that, the voiceovers included a detailed description about the shapes, textures and roughness of the samples, for an easy identification – these contents were elaborated by the geosciences Museum coordinator.

Regarding the system's consistency, it was defined that the act of lifting a sample would identify an interest in knowing more about it, while the movement of putting the sample down would determine the lack of intention to access such contents. From the adoption of this interaction language, we expected to achieve a good visibility and a feeling of instinctive mapping, where each action was associated with the initiation of a specific event. There was also the need to clearly delineate the area corresponding to each sample – named "constraints" – in order to provide the visitors with a clear recognition of where the interaction with the interface leads to results. In order to achieve this, we projected a saver disposed on the surface, where four regions have dimensions and shapes similar to those presented in the four geological samples, as shown in Fig. 1, where the four geological samples are arranged on the interface, illuminated with white colour and delimited by black areas – that were not traversed by the light.

Fig. 1. View of the four geological samples arranged on the interface.

Additionally, we intended to provide some feedback to indicate the success of the actions taken by visitors, when handling the physical elements of the system, in order to facilitate the return of items to the interface. Since the samples of MM Gerdau had different colours, we concluded that providing visual feedback could be advantageous in this case, in order to show the immediate effects of the actions taken. Each time a geological element was lifted, the light in the correspondent area was similar to the colour presented by the sample, while when all the samples were arranged on the surface of the interface, the light was white – the sum of all the colours.

In addition to knowing information regarding only one of the four specimens of the collection, each time, we designed the possibility to allow users to find out the differences between two samples, simultaneously. So, whenever two elements were handled at the same time, the graphical and sound content were related to both geological samples, presenting a comparison by themes they had in common.

3.2. Prototype development and implementation

After the technical viability study for the realization of the designed interaction model, we created the scheme of the implemented system architecture, which is shown in Fig. 2. The "User Interface" block refers to the physical structure of the display, where four force sensitive resistors and four bright actuators, LEDs RGB –Light-Emitting

Diode Red, Green and Blue – were arranged. These elements were connected to the Arduino Leonardo microcontroller, who ran the program code previously stored. This was connected to the computer, where, according to the transmitted data, the Processing software presented the multimedia data corresponding to the action, as projected images and sound information. To do so, a projector and two speakers were connected to the computer.

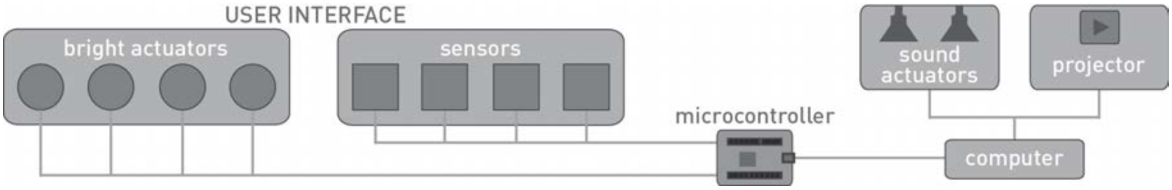

Fig. 2. Scheme of the implemented system architecture.

For the production of the audio content, there was a public call during which 15 volunteers showed up for the recording of a text model, and amongst them, we selected the volunteer who then made 10 recordings, 4 with individual information and 6 with comparative themes.

Fig. 3 presents three photographs of the prototype in operation in the main exhibition space of MM Gerdau. In it is possible to observe an overview of the installation in the leftmost image (a). On the centre (b), a visitor is handling two geological samples and learning about comparisons of both. On the picture on the right (c), the projector is placed behind the exhibitor, which is responsible for conveying graphical content. In the same picture, it is possible to observe four areas under the surface, where the four bright actuators were placed and, below these, an area reserved for safeguarding of the samples when the interface was disconnected. The computer and the speakers were placed within the cabinet, behind the projector. For the design and construction of the prototype, collaborative working sessions took place inside and outside MM Gerdau, with the Museum development team and potential users of the interface.

a

Fig. 3. (a) prototype installation in MM Gerdau; (b) a visitor interacting with the interface; (c) implemented system architecture details.

4. Evaluation of the interaction with the prototype and visitors experience

During the evaluation of the prototype we were concerned about measuring some pragmatic and hedonic qualities of the interaction with the interface and, on the other hand, trying to understand how visitors consider that their experience during the museum visit can be enhanced by using this type of TUI, particularly in terms of multimedia content, the number of geological samples to provide and new ways of experiencing the exhibition.

As a research instrument for data collection we used two different kinds of questionnaires, one for “common” visitors (without special needs) and another one with specific questions directed to blind visitors. Both were made available in MM Gerdau Museum space between April 10th and August 28th 2015, both in paper form and online, according to people preferences – this was because some visitants didn’t feel comfortable answering the questions using the tablet. Note that people without special needs answered the questionnaires by themselves, while for the case of blind visitors, the questionnaires were read in loud voice and the answers registered in accordingly.

A total of 138 responses were collected, of which 9 were from blind visitors, 17 from internal employees of the museum and the remaining from spontaneous visitors who visited MM Gerdau during that time. All of the data was processed using simple descriptive analysis and will be presented below, in four sub-sections: sample characterization, interaction aspects with the interface, considerations about how to improve the multimedia contents and the experience within the exhibition.

4.1. Sample characterisation

As shown in Table 1, the majority of the 138 visitors involved in the study – 43.5% – said they were between 15 and 25 years old and 28.3% between 26 and 35 years. According to the results presented in Table 2, it is concluded that the sample is almost homogeneous, i.e., 52.2% of the visitors were female and 47.8% male.

Table 1. Non-blind and blind visitor's age.

Visitor's age	< 15	15-25	26-35	36-45	46-55	56-65	> 66
Non-blind	2	60	39	13	5	9	1
Blind	-	-	1	1	2	4	1

Table 2. Gender of respondents.

Visitor's gender	Female	Male
Non-blind	68	61
Blind	4	5

When asked if they already had the opportunity to handle collection samples on other museum before, 72.5% of total visitors said no, but if we look to the case of blind visitors, only 2 said that have had this opportunity before, so 77.8% visited museums but didn't have access to any exhibit.

4.2. Considerations about some aspects of the interaction with the interface

It was our purpose to assess the sample considerations regarding the pragmatic and hedonic aspects of the interaction with the interface and ascertain whether the interface was interesting from the standpoint of providing contact with information on samples, by using the sense of touch.

For this, we based our questions according to AttrakDiff[26] instrument of measurement by using three items whose poles are opposite adjectives (simple – complicated, pleasant – unpleasant and motivating – discouraging), in which each set of adjective items were ordered according to a scale of intensity, in a 5-point Likert scale.

According with the results included in Table 3, we conclude that 87.7% of total visitors consider interaction as simple instead of complicated, 89.9% classifies it as pleasant and 73.9% think is more motivating than discouraging. Notice that about 18.8% of respondents pointed the 4th point of the scale when asked about the motivation – discourage dichotomy (between very positive and average) and 6.5% indicated that the interaction with the exhibitor is not motivating but is not discouraging also (3rd point of the Likert scale). Looking only to the 9 blind visitor's answers concerning the pragmatic and hedonic aspects of the interaction with the interface, we notice that interaction was classified by the totality as simple, pleasant and motivating.

Table 3. Visitor's considerations regarding the pragmatic and hedonic aspects of the interaction with the interface

Scale to measure considerations		5th point	4th point	3rd point	2nd point	1st point	
Non-blind	Simple	112	9	5	2	1	Complicated
Blind		9	-	-	-	-	
Non-blind	Pleasant	115	9	4	-	1	Unpleasant
Blind		9	-	-	-	-	
Non-blind	Motivating	93	26	9	-	1	Discouraging
Blind		9	-	-	-	-	

To try to increase the accessibility in the future, blind visitors were questioned about their preferences when starting an interaction with the system, and 88.9% think that the exhibitor should inform through audio to pick up one or more geological samples, whereas 11.1% consider that this information should be provided in Braille.

When asked if it would be interesting to have a tactile mapping to identify where the objects are displayed on the interface, 88.9% agree completely and 11.1% disagree completely – this last value is related to one blind visitor.

4.3. Considerations about the multimedia contents presented and how to improve them

Since the educational contents are presented in a multimedia format, provided in the form of images, text and audio, it was important to understand what the visitors thought about them. Aspects regarding graphical content were only answered by non-blind people, while the data concerning to the voiceovers took into account all visitors' opinions. To the visual contents evaluation, people were asked to measure it through an identical scale used during the considerations about the interaction with the interface, but, in this case, using four items with opposite adjectives: appealing – monotonous, indispensable – dispensable, more images – more text, with animation – without animation.

Regarding graphics content design, 46.5% of the sample under study indicated the design was average – point 3 of the measuring scale – 19.3% considered it appealing and 17.8% marked it in the point 4 of the range, between appealing and average. We'd like to clarify that the images projection was made on an historical, dark coloured wall, and permanent interventions were not allowed on it, so the colours and brightness of the images presented were greatly altered. Regarding the need of these contents, 51.9% of the non-blind sample answered that they are indispensable, 20.9% consider them indifferent and 20.2% placed their opinion on the 4th scale point, between indispensable and average. The format of the information in images or text was also an evaluation item: 44.2% indicated that there must be a balance between both, 30.2% said they prefer only images and 23.3% of respondents think that images should be prioritized instead of text (point 4 of the measurement scale). Following this, when asked about the dynamics of the visual information, 48.1% of visitors indicated a preference for animations, 23.3% want a balance between animations and static images and 21.7% stated that there must be animation sometimes (represented in the scale by point 4).

To study the visitors' considerations about audio contents, they were asked to measure interest, duration and speed of the voiceovers in three items with opposite adjectives: interesting – uninteresting, long – short and fast – slow. It was observed that 76.8% of respondents pointed to interesting content, 13% classified them between interesting and average and 8.7% by an average evaluation. In turn, 58% of visitants set the duration as optimal, while 12.3% indicated that they were long and 26,1% between optimal and long (4th point of the Likert scale). With respect to the speech speed, 76.8% considered it ideal, 5.8% referred to it as fast and 14.5% between optimal and fast. Another question was about the audio presentation: 72.5% of the sample preferred to hear the educational contents out loud and 27.5% said they should be presented with headphones.

4.4. Other considerations about how to improve the experience of MM Gerdau Museum visitors

As ways to improve the visitors' experience during the exhibition, we were interested in knowing what they think about the number of samples provided and how people feel about a new way of experiencing the visit.

When asked if the number of geological samples provided was enough, 55.1% of the visitors said yes and 44.9% answered no – it is important to note that all the blind visitors consider the quantity unsatisfactory. For those who think the exhibition must have more geological samples to interact with (62 visitors), we calculated the average of suggested numbers and it should be about 15 geological samples.

In order to study the members' considerations about the interest in moving through the exhibition blindfolded, as a new scenario of experiencing the exhibition, we registered 63 answers from non-blind visitors, measured in a 5-point Likert scale of intensity (from tedious to amazing). According to data, 63.5% of the visitors have a very positive opinion describing the ideas as amazing, 6.3% indicated that it would be between amazing and indifferent (point 4 of the measuring scale), 14.3% consider it tedious and 12.7% showed their indifference about it.

5. Conclusions and Future Research

In this paper we explored the design and the visitors' interaction with an accessible TUI to the exhibition and communication of four geological samples of MM Gerdau, and how it can be used to enhance their visit experience.

The data collected from 138 study participants – mainly aged between 15 and 35 years old and a relatively homogeneous sex distribution – showed that for the massive majority, this was the first opportunity to handle collection samples in a museum. Both blind and non-blind visitors reported hedonic and pragmatic aspects of the interaction as very positive, and it was possible to conclude that all blind visitors felt good using this interface.

Regarding the aspects to be taken into account to improve the visitors' experience, we should review the graphic design content, giving priority to images instead of text, but the voiceovers and their presentation proved to be ideal.

The study also concluded that more than half of the visitors would like to find a larger number of geological samples available for interaction, and the proposal to move through the exhibition with a blindfold was well received.

In general, it found out that the interaction with the interface pleased the visitors and, based on the results, it is possible to conclude that this system based on TUI for the communication of geological collection has an application space within MM Gerdau.

Acknowledgements

We would like to thank: MM Gerdau' technology, museography and education teams, Soraia Vasconcelos, Leonardo Miranda, LavGRAFT, DRI UFMG, State Public Library Luiz de Bessa and São Rafael Institute.

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