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Original article

Enhancing user engagement through the user centric design of a mid-air gesture-based interface for the navigation of virtual-tours in cultural heritage expositions

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ARTICLE INFO

Article history:
Received 8 November 2017
Accepted 19 February 2018
Available online xxx

Keywords:
Natural user interface
Virtual tour
User-centric approach
Gesture vocabulary design

ABSTRACT

One of the most effective strategies that can be adopted to make successful cultural heritage expositions consists in attracting the visitors' attention and improving their enjoyment/engagement. A mid-air gesture-based Natural User Interface was designed, through the user-centric approach, for the navigation of virtual tours in cultural heritage exhibitions. In detail, the proposed interface was developed to "visit" Murgia, a karst zone lying within Puglia, very famous for its fortified farms, dolines, sinkholes, and caves. Including an "immersive" gesture-based interface was demonstrated to improve the user's experience thus giving her/him the sensation of "exploring" in a seamless manner the wonderful and rather adventurous sites of Murgia. User tests aimed at comparing the implemented interface with a conventional mouse-controlled one confirmed the capability of the proposed interface to enhance the user engagement/enjoyment and to make "more" natural/real, the virtual environment.

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1. Introduction

The cultural heritage of a country represents a priceless patrimony not only for its inhabitants, to understand and explain the origin of customs and traditions but also for the touristic industry to attract visitors from abroad. Promotion of cultural, artistic, and environmental goods represents a crucial importance issue for a country as most of the touristic industry and hence, of the general economy, depends on how the financial resources are allocated for this scope. The use of new technologies, as well as novel interaction paradigms, were recognized to be one of the key-points to approach the mass audience and hence to adequately promote and present cultural heritage [1]. Among the technologies recently utilized to this purpose, Virtual Reality (VR) plays a role of predominant relevance [1–3]. By allowing the user to interact with the virtual world in an immersive environment, VR represents one of the most appealing and effective ways to improve the users' engagement and attract their attention on specific cultural heritage subjects.

It is a moral duty to share and spread the patrimony of a country among people and over time, but it is also a moral duty to preserve sites of interest and artworks although their large scale accessibility makes this task very difficult to accomplish. VR allows to replace the real visit with the exploration of reconstructed historical places and virtual museums [4], by means of virtual tours (i.e., immersive 360-degree panoramas [5]) and the manipulation of digital artifacts. Consequently, VR can provide both the preservation of these sites and the access of general public, and add all the potentialities related to the multiple virtual experiences, in terms of interaction and immersion [6].

Natural User Interfaces (NUI) that are at the basis of VR-based exhibitions – such as virtual tours or virtual museums [7] – are the object of the study of a large number of researchers throughout the world. For instance, the usability of gesture interfaces in virtual reality environments was investigated by Cabral et al. [8]. Navigation and selection techniques in virtual environments by means of gestures were studied by Dam et al. [9]. Fanini et al. [10] developed an engaging and shared gesture-based interface for visiting museums and exploring the treasures contained. Three principal approaches are followed in the design of interfaces: (i) user-centric, (ii) iterative and (iii) centrist analytical. The first approach utilizes an elicitation procedure where the user is asked to propose possible gestures to execute specific commands/referents. Interface

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inputs are then designed on the basis of the gesture proposals. Iterative and centrist analytical approaches design interfaces by basing upon technological constraints and/or the experience of experts in the specific application field. However, the user-centric approach represents the standard methodology in NUIs design [11,12] as it allows pursuing two important objectives: (i) lowering the cognitive load and (ii) improving the user experience.

Touristic/cultural events are no longer simply places devoted to the exhibition of products, customs, and flyers of a specific country but a privileged place to make culture accessible to the largest mass audience. In such exhibitions, VR technologies can be conveniently utilized to ‘immerse’ the user in virtual tours reproducing the typical environment of a country thus letting him feel as physically present in ‘that’ place that can be thousands and thousands of miles away. In a previous study [13], a multisensory system was proposed where a 20-foot container was utilized to host visitors giving them visual, climatic and olfactory stimuli. In this study, we further developed this system by designing and implementing a gesture-based interface for the navigation of virtual tours on a display wall (the display was hypothesized to be fixed on one of four walls of the container) and investigating the capability of such an interface to enhance the engagement/enjoyment of user’s experience. In detail, this interface was developed to “visit” Murgia, a karst topographic plateau of rectangular shape lying within Puglia, very famous for its fortified farms and for being the seat of transhumance practice in animal husbandry. A number of studies utilized gesture-based interactions with display walls [3,14,15], but their application scenario is quite different from the navigation of virtual tours. Indeed, scenes in virtual tours almost consist of spherical panoramas that users can explore by using a zooming function, changing gaze direction or selecting active items. Other studies [16,17], also reported in the literature, utilize VR technologies to carry out virtual tours but do not implement gesture-based interfaces.

2. Research aim

From the review of the state of the art, it appears that no specific studies are reported in the literature focused on the design, the implementation and the validation of gesture-based interfaces for the navigation of virtual tours in cultural heritage exhibitions. In detail, no studies are available that adopt the user-centric gesture-elicitation procedure for the definition of the vocabulary of gestures capable of guaranteeing the users’ engagement/enjoyment. Our hypothesis is that including an “immersive” gesture-based interface improves the user’s experience thus giving her/him the sensation of “exploring” in a seamless manner the wonderful and rather adventurous sites of Murgia.

Therefore, the aims of this work are:

- to describe the application of such an elicitation procedure to the design process of a mid-air gesture-based NUI;
- to test the developed NUI and evaluate its effectiveness in improving the engagement and the enjoyment of users with respect to the classical mouse-controlled interface.

3. The gesture vocabulary design

The gesture vocabulary, i.e., the set of gestures utilized by the user to interact with the interface, has to be straightforward and intuitive in such a way that the resulting NUI satisfies the general requirements of the low cognitive load and the low physical fatigue [18]. The design process of the vocabulary was structured into three principal phases:

- the “Interface requirements definition” phase. In this phase, the set of commands that are the most suited to the specific scenario/application are defined. Three aspects must be considered in this phase: (i) the specific tasks that have to be performed, (ii) the environment/context where tasks must be accomplished, and (iii) the set of commands required to perform the tasks;
- the “Gesture elicitation” phase. Spontaneous gestures the users would intuitively use to trigger the interface commands are proposed and collected. The agreement analysis then follows;
- the “Vocabulary definition” phase. The gesture proposals, collected in the previous phase, are ranked according to their guessability. The vocabulary of gestures will include, for each command, the most intuitive gesture among those proposed for that command.

Hereafter, the following definitions will be utilized in the present article:

- referents: interface commands, in this study five referents were hypothesized to be necessary to conduct and control a virtual tour (see next Section 3.1);
- gesture proposals: gestures proposed by the participants during the elicitation phase as interacting metaphors to “execute” a given referent;
- vocabulary: a combination of different gestures devoted, each, to “execute” a given referent.

3.1. Interface requirements definition

The following five interface commands were hypothesized to be strictly necessary to properly conduct and control a virtual tour on a wall display:

- move the pointer on the screen;
- zoom-in;
- zoom-out;
- change gaze direction (i.e., the solid angle of the spherical panorama visualized on the display);
- select items.

The context/environment where the virtual tour was hypothesized to take place is a container with an average space of 8 m² available for users. Containers are “portable” installations that can be easily transported to the location where cultural/touristic events are organized and properly equipped with all the devices required for a virtual tour. Following the hypothesis that the container can host up to 4 visitors simultaneously, the proposed virtual exhibition system was designed to switch the control among users according to a defined policy. Users were hypothesized to be not familiar with gesture-based interfaces which were, therefore, designed as intuitive as possible.

3.2. Gestures elicitation procedure

In order to conduct the gesture elicitation process, a population of 29 participants (average age 21.3 years, SD = 3.11) was first recruited, including 18 males and 11 females, all right-handed. All of them were students in Mechanical and Computer Engineering: five participants declared to use an Xbox Kinect for recreational purposes regularly; nine utilized the device a few times; fifteen never used it.

Before performing the elicitation, a preliminary investigation was carried out to evaluate the users’ preferences on the two control modes that are available in the software suite *krpano* [19] utilized to implement the virtual tour. In detail, this suite includes

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