Cultural Heritage Interactive Dissemination through Natural Interaction

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ABSTRACT
Virtual Heritage is widely used in education, enhancing the learning process by motivation and by providing a natural experience. New ways for the user to explore cultural heritage virtual environments represent dynamic research areas, being based on the latest technologies, such as mobile, wearable or ubiquitous interfaces. We have designed SNAIP, a distributed system based on natural interaction, for exploring a virtual heritage environment populated with interactive agents.

Author Keywords
Natural interaction; virtual heritage; interactive virtual environment; cultural heritage dissemination; virtual reality; human computer interaction; distributed systems; interactive experience; cultural immersion

ACM Classification Keywords
H.5.m. Miscellaneous. H.5.1. Multimedia Information Systems. D.4.7; H.1.2; I.5.5.

General Terms
Human Factors; Design; Measurement.

INTRODUCTION
Cultural Heritage is an essential expression of the wealth and diversity of human cultures. It is a collection-driven domain that is based on institutions such as museums, art galleries, special collections, and historical archives [3]. The main activities for maintaining the cultural heritage are documentation, interpretation, restoration, dissemination and sustainability [2]. New technologies are vital not only to enrich the cultural experience, but also for the sustainability of the cultural heritage [1, 2].

Virtual Heritage is a combination between Cultural Heritage and a computer-based interactive technology, which helps to reproduce ancient cultures by simulating a realistic environment that the user can immerse into, learn and understand. Virtual Heritage is widely used in education, enhancing the learning process by motivation through providing a natural experience. It facilitates the understanding of certain events, ancient cultures and historical elements benefitting both students and researchers alike[4].

In this paper, we propose a system for reproducing a glimpse of an ancient culture by implementing methods of visualization, navigation and interaction. The created virtual culture is enacted by the virtual agents that interact with each other, with the user, and with interactive virtual objects. The navigation through the environment is carried out in the "point of view" (POV) manner, usually by walking on the ground. Another manner of navigation is by flying, in order to enable moving on the vertical axis. Everything inside the environment is designed to be as self-explanatory as possible.

The most natural and sustainable way to learn about any foreign or ancient culture is through a consistent story. Viewing an archaeological excavation, photos of drawings or a list of facts, in general, may not be enough to recreate a full model of a given culture. The answer may be an interactive story, or a lot of generated stories based on the same facts [15] allowing each user to become an active part in the plot evolution [16]. The role of the virtual, believable and evolving agent is to create a slightly different story each time, by making use of previous interactions and the biographical agent's memory [17].

In order to provide a deeper understanding of any society, we need to give the user a possibility to melt into a simulacrum of this culture. To create users the impression that they are surrounded by authentic characters, we use believable, human-like agents. For attaining a high degree of credibility these culture carriers should possess specific knowledge and behavior [6].

The way in which people learn about ancient cultures is shaped by methods that rely on studying the results of archeological excavations and available written sources that produce text descriptions, drawings, and various mock-ups of artifacts and scenes associated with a given culture.

Culture is traditionally connected to the environment, the materials and the objects used and created by a population and culture carriers that possess culture specific knowledge and behavior [6]. The most popular techniques that can reproduce ancient cultures are films and Virtual Reality [5]. Creating a 3D Virtual Culture is considered the most affordable, dynamic and interactive option for integrating together the environment, the artifacts and knowledge associated with a culture. The obtained virtual environment is reflecting the actual physical environment, where a culture is situated and enacted by virtual agents.

Populating the 3D Virtual Culture with virtual agents that behave similarly to the ancient citizens could bring the heritage preservation to a new level. Usually, virtual agents are able to interact with the environment, among them, and with the user himself by human-like manifestations. Intelligent agents can absorb relevant knowledge and become the knowledge carriers. This fact can ensure the desired realism level of the Virtual Culture [5, 6].

New ways of exploring cultural heritage virtual environments represent dynamic research areas being based on the latest technologies such as mobile, wearable or ubiquitous interfaces. Exploration, navigation and interaction metaphors still need to be further developed [10], whether the user accesses cutting edge technology such as Myo [9] or LeapMotion devices [11].

Storytelling in museum environments is currently transitioning from traditional media types such as printed visuals and clips, to more immersive and interactive forms of knowledge dissemination [20]. The amount and types of virtual heritage elements is continually increasing with the development in technology, therefore innovative organizing structures and the design of interfaces for accessing information represent a top priority in the field [21].

Cultural heritage data is becoming more available over the web, and research is carried out in designing user friendly and minimalistic information visualization styles according to user targeting group and developing efficient browsing methods [22]. Furthermore, web and mobile platforms are now able to render artifacts in detail and new methods of interactive exploration are developed for natural and touch interfaces [19].

Our contribution is organized as follows. After presenting the general concept of virtual heritage and showing the state of the art in technology serving this purpose, we introduce our vision and SNAIP, the application that we developed. We explain in detail the navigation and interaction metaphors that we designed. Then, we present the architecture of our hardware and software components. Further, we present the results of the usability tests that we have performed on our system. Last, the conclusion summarizes our main achievements and presents directions for our future work.

SNAIP - THE SYSTEM FOR SMART NAVIGATION AND INTERACTION

We designed the SNAIP system for both navigation and interaction having a high degree of affordance as our goal. The quality of being self-explanatory of the objects, the entities and the environment through shape and action is conveying this level of affordance that the user can enjoy as a natural interaction experience.

For exploration and interaction with the virtual replicas of the artifacts, we provide a solution based on the visitor's mobile phone. In this regard, at the beginning of the museum visit, the visitor will install an application free of charge, which will allow interactive exploration of a virtual replica through an intuitive and user-friendly interface (Figure 1). In our vision, the exploration consists of navigation and non-interactive observation of artifacts. Once selection and interactive observation are involved, we consider that the user experiments with the artifacts, so an interaction metaphor shift occurs.

Navigation

The user can navigate through the environment in a POV manner, by using the touchscreen on the mobile phone and watching the effect on a tablet (Figure 1).

Figure 1 - Smartphone based user navigation in a cultural virtual environment.

There are several commands implemented on the smartphone that acts as an input device (Figure 2). By performing a first touch, a virtual joystick is initialized, having the shape of a circle. Then according to which direction the user drags their finger, a walking direction is set, which is updated every time there is a change in the input. Speed is set according to how much the finger is dragged inside the circle. By rotating the input device while walking, we rotate the camera inside a cone of 90 degrees, as we would normally rotate our heads for only a certain amount of distance while walking.

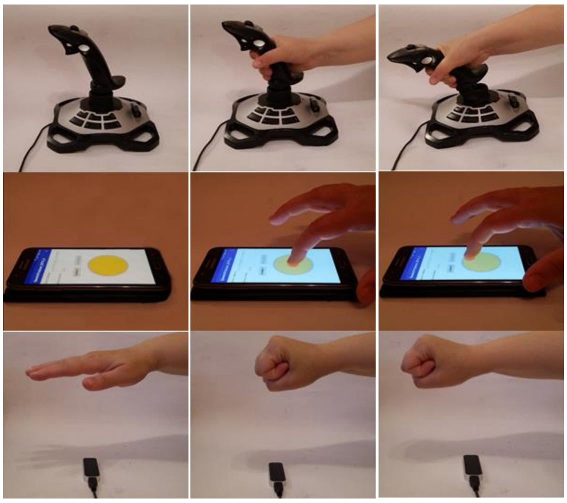

Figure 2 - Navigation joystick-like metaphors (prepared (a), activated (b) and in use (c)) applied for mobile phone and LeapMotion devices.

Interaction

We have applied a metaphor proposed in [7] that allows the user to switch back and forth between the navigation and the interaction mode, using natural gestures. During navigation, when we enter the aura of an object, the navigation metaphor becomes an interaction metaphor. Also, by clicking objects inside the preview available on our touch input device on the smartphone, we can select objects and interact with them accordingly, by rotating the device and examining them from every angle on the output screen.

There are different degrees of interaction present inside the virtual environment. Agents are aware of the presence of each other, of the user, and of the objects existing inside the environment. This is demonstrated at a basic level through the fact that agents try to avoid collision. Furthermore, agents sense the presence of the user and try to introduce him to the elements of the environment by performing an action to demonstrate the use of an object (Figure 3).

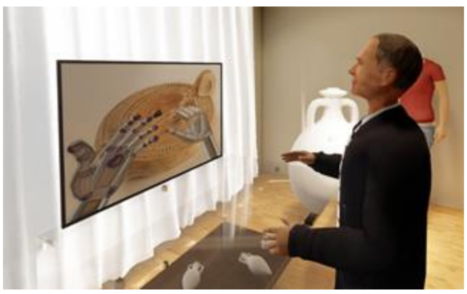

Figure 3 - User interacting with virtual artifacts by the mean of a LeapMotion device.

This way, we manage to overcome the limitation of the visitor's access to national cultural heritage based on the "Do not touch the exhibits!" rule and to give the public the opportunity to discover, explore and experience, in a personal way, the existing artifacts through their in-vitro replicas.

ARCHITECTURE

We chose a distributed architecture for our system, composed of several input and output devices connected to a server (see Figure 4). Every device is either an input device, an output device, or acts as both. This kind of architecture makes it easier to implement other types of multimodal interaction in the future.

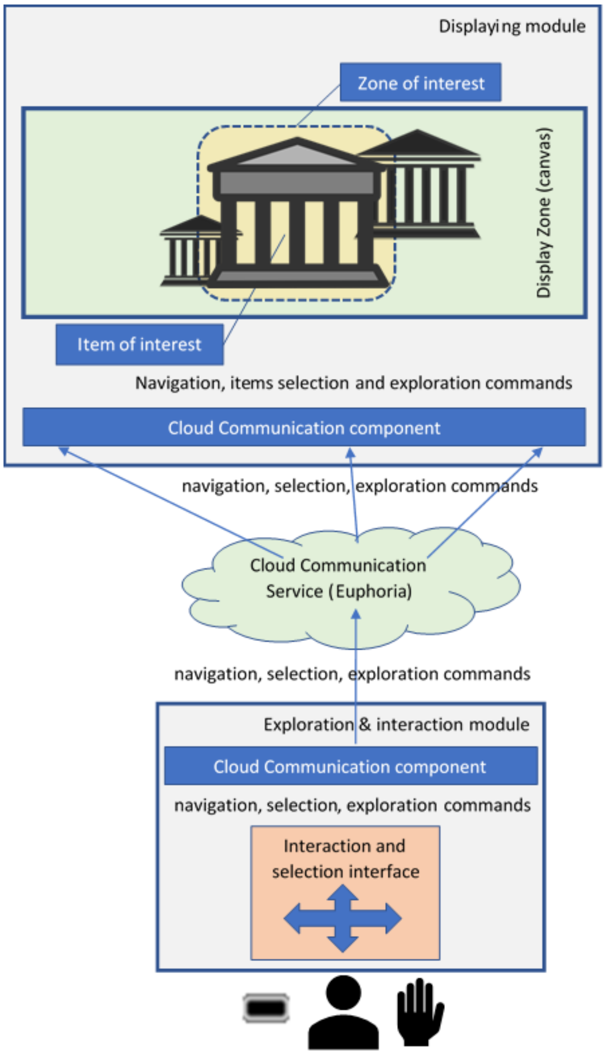

Figure 4 - System general architecture.

Hardware

Our system is composed of input and output devices that connect to the web server in the cloud. First of all, everything inside the dynamic environment is visible on an output device which can be a tablet, a TV set, a video projector, or any other type of device that can access the web server through a browser.

The input device is any Android smartphone that meets the requirements above version 19, so that the app can be downloaded and run properly. This device also acts as an output device because, besides the virtual joystick, there is a preview available for navigation and interaction purposes.

Another input device is LeapMotion, which scans the hands with IR light and interprets specific hand gestures and the position of the hands in space. Both the smartphone and LeapMotion are used for navigation and interaction, each having another metaphor of intention communication.

Software

The system involves several different applications. First of all, we have the Euphoria server that helps manage connections and communication between devices [8]. This server is based on Node.js alongside functional libraries, and it is a JavaScript server that has an event driven architecture. The server runs in the cloud and accepts connections through WebSocket protocol.

The output device connects to this server and a webpage displaying a virtual environment is opened. The heritage site is modeled with the help of the three.js JavaScript graphics library. Virtual elements are controlled through parameters sent over the server communication line by one of the input devices.

The smartphone input device sends the following parameters. First, the joystick detects the angle of touch and amplitude of drag. The accelerometer sensor is also able to send data about the X and Y rotation axis of the phone. These data are all interpreted according to a navigation or interaction scenario metaphor.

LeapMotion input device sends parameters of gesture and position in space. All interactions and navigation possibilities of the smartphone are also mapped for this type of input device. Direction and amplitude are measured from a point in which a specific gesture is made, and hand orientation gives X and Y axis rotation.

USABILITY TESTS

In order to evaluate the usability of our system, we start from the following hypothesis concerning natural gesture-based interaction using common devices:

A user is more willing to try new modes of operability with a known device, rather than trying a new device specially designed for these modes.

We measure usability with respect to its definition, as highlighted in [13,14], "the extent to which a system, product or service can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use".

To this end, we performed an experiment that involved 18 users (8 males and 10 females), sampled from students and faculty members of the Faculty of Economic Studies, Ovidius University, Constanta.

The environment used in testing our system was configured based on virtual replica obtained in the TOMIS project [12], a virtual reconstruction of the Greek colony named Tomis. The users were let to freely navigate and interactively observe objects inside the virtual environment.

With respect to the user profile, we were interested in their previous experience using a mobile device for spatial orientation and navigation, respectively a LeapMotion device for the same purpose. 55% of the users never used the phone for a similar purpose as the one presented with our system, and 83% of users never used LeapMotion for any purpose.

The experiment was carried out in 3 stages: first, we presented the system to the users; second, we asked the users to test it for 10 minutes (each variant, phone and LeapMotion); and finally, we asked them to fill in a questionnaire, in order to evaluate the system with respect to navigation and interaction. In the questionnaire we focused on topics like ease of usage, image quality, and application's responsiveness. The users were asked to select answers on a Likert scale with values from 1 to 5 [14], with 1 meaning complete disagreement with the statement, and 5 meaning complete agreement with the given statement.

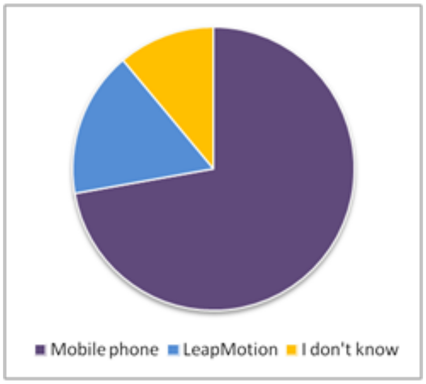

Figure 5. The distribution of answers to the question "Which of the ways of interaction offered by our system seems more appropriate?"

The system is considered intuitive and easy to use by all users (100% of answers of 4 and 5 to items Q1 and Q2 concerning ease of handling and understanding respectively), with the spatial orientation offered by the system good (39% of the users) and very good (61% of the users). The users' preferred manner of interaction is presented in Figure 5.

The quality of the *interaction* by means of the mobile phone, respectively the LeapMotion device, was positively appreciated by the users, with the mobile phone being maximally appreciated by 14 (77.78%) of the users (see Figure 6). The scores for the quality of the navigation are depicted in Figure 7. The results are consistent, and the mobile phone is preferred for navigation: in the navigation scenario, 88.89% of the user graded the mobile phone for navigation with 5.

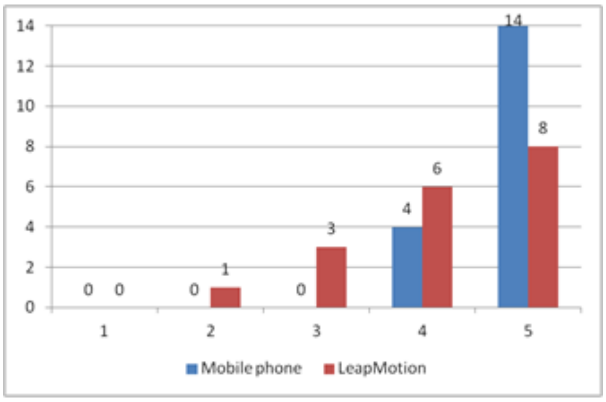

Figure 6. Evaluation of the interaction.

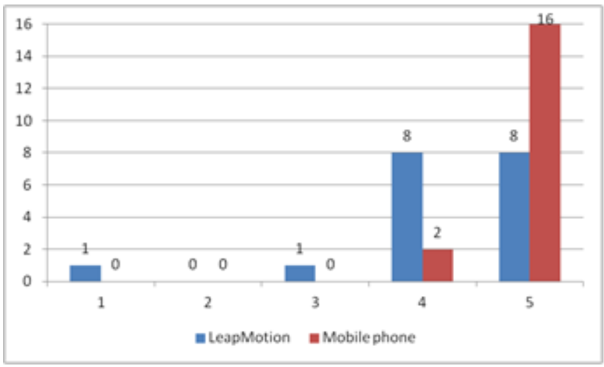

Figure 7. Evaluation of the navigation.

The questionnaire contained two open questions, where users were asked to provide personal input in the form of depicting positive and/or negative features of the system. Among the positive features, we received as feedback: "interesting to use your phone for another type of communication", "I think the phone is in the advantage because of the user being familiar with it. Touching the phone gives you a sense of security in the gesture".

On the negative side, one of the opinions was "The disadvantage of the phone is the lack of hands-free interaction", and "LeapMotion has a limited action area while the phone has no such limitation", with someone concluding that "I would prefer to keep the phone in one hand and work with LeapMotion with the other hand in a combined interaction metaphor."

To sum up, we consider the impressions that were gathered from the users as favorable (see Figures 6 and 7). The system will be further developed, and future usability studies will build upon the current results.

CONCLUSION

Our application serves the purpose of culture dissemination through exploration by natural interaction of the virtual environment. Artifacts are engulfed in their normal circumstances and can be manipulated. The expressiveness of the site is enhanced by virtual agents that resemble citizens of that time. The user is cognitively immersed both through the realism of the scene and through the feedback of their natural interaction with the environment.

Further work will be done in implementing new ways of using the system and updating the realism of virtual agents. One direction of interest is implementing a multi-user option for collaborative exploration of the environment by allowing several users to connect simultaneously, each having their own input device, display and avatar. Another interesting option would be recording people's actions inside the environment and re-enacting them with the help of virtual agents.

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