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Interaction with Replicas of Small Pieces: Using Complementary Technologies to Maximize Visitors' Experience

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Abstract

Current technologies for digitizing artifacts allow us to create compelling virtual installations, in which visitors learn about them through playing and exploring virtual proxies. However, different technologies enhance certain types of information and preclude other usages. In this paper, we show how one can create complementary installations in order to enhance the use of available information of small artifacts. Our case study is a set of small gold artifacts at the Gold Museum in Bogota, Colombia. We collected from each piece high-resolution 3D scans at different levels of detail, high resolution images, sound, text, and contextual images. With this information, we created a traditional multimedia installation for the computer room at the Museum, a web site for remote visitors through the Internet, and finally a novel haptic and stereo display interface that allows visitors to touch, observe in stereo, locate themselves inside the Museum, and hear the sound of an artifact when it is struck with a virtual stylus. In this paper, we show how one can develop these experiences and how they complement each other. We will also present an early evaluation of their strengths and weaknesses.

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1. Introduction

Pre-Hispanic civilizations in Colombia such as the Muisca, the Tairona, or the Sinu produced rich adornments, musical instruments, and working tools in which they showed their expert knowledge of goldsmithing and handcrafting. The Gold Museum in Bogota is the institution responsible for preserving, researching, and exhibiting a very impressive collection of 33.000 artifacts made of gold, together with 20.000 other artifacts of stone, pottery, wood, and textiles that are also representative pieces of Colombian's historical heritage.

Objects from pre-Hispanic societies are displayed in different rooms according to their technological, sociological, symbolic and religious aspects. Some of the artifacts are small, and although these artifacts can be easily enclosed and displayed in any available space, they can be difficult to see by visitors. For example, their size can preclude several visitors to see them at once, details can be difficult to observe to the naked eye, and their original purpose and characteristics could be missed by the casual observer.

Many of these beautiful artifacts deserve a closer look with the vast possibilities of digital imaging. Virtual proxies do not replace the originals, but provide other experiences and information helping the visitors to look at them more closely, to better understand its usage and meaning, and to give to the visitor a personal experience that will transform

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their visit into a personal memory. For example, the golden jaguar from the Tolima culture looks imposing by itself at the exhibition, but having the possibility to virtually touch it, to turn it upside-down, or even feel its weight is a memory-making experience that goes far beyond an artifact behind a glass window.

This paper presents a collaborative effort between the Gold Museum in Bogota and some local and international universities for exploring new ways to experience real artifacts through a virtual proxy. Our goal is to show in the best possible way different types of information about those artifacts that will create a personal experience. In order to do so, we have developed several installations giving to the visitor complementary experiences. By considering characteristics of each technology and how each type of information fits into such technologies, we managed to maximize visitor's experience and its use of the information. Of special interest is the use of novel technologies in public exhibitions, such as stereo displays and haptic devices[†]. Although these technologies have existed for quite a while and have been used in many fields, its use in a Museum setting is still limited due to costs and reliability. Nevertheless, a proof-of-concept installation was developed allowing visitor to experience the power of these technologies.

This paper is divided as follows. Section 2, we review the related work. Then, in Section 3, we describe our development in terms of the artifacts selected, the digitizing technologies used, the display and interactive technologies used, and how one can maximized visitor's experience using a multi-modal interface. We will also describe the complementary installations that are open to the public, which include a web site, a multimedia experience at the Museum and a multi- modal experience that allows visitors to touch, hear and observe in stereo some of the artifacts. Section 5 describes an early evaluation processes to determine how successful we achieved our goals. We will then conclude and mention future directions of our work.

2. Related Work

There have been several virtual heritage applications that have incorporated haptics in their interface development. In the CREATE project, Christou et al. [CAL*06] shows an installation that uses a CAVE environment, a tracker, and two large haptic devices to create a realistic experience of manipulating artifacts from ancient Greece. Tecchia et al. [TRF*07] presents a multi-modal exhibition with high-end haptics and stereo display, as well as a virtual gallery on the Internet with a selection of sculptures from several Museums involved in the project. A sophisticated haptic device is used in Bergamasco et al. [BFB02] in order to explore the shape of Museum artifacts, specially sculptures. Although these devices promise to create a very real haptic experience, it is probably too costly for most Museums. Laycock et al. [LLD06] presents a system in which a simple haptic device (Phantom Omni) has been integrated to a high-quality pre-rendered environment, mostly for navigation.

In terms of usage, Bergamasco et al. [BFB02] describes two systems, one in front of a physical artifact and one in a virtual setup. In the first one, visitors are positioned in front of a sculpture where a haptic device allows them to feel its shape. An extra display shows more information, such as the current point of contact. In the second system, visitors are in a CAVE-like environment in which they can see in stereo a virtual replica of an artifact, and interact with it. Christou et al. [CAL*06] presents also a CAVE-like scenario for the exploration of large scale archeological sites. Tecchia et al. [TRF*07] uses a virtual setup similar to the second system presented in Bergamasco et al. [BFB02]. Brewster [Bre01] describes an exhibition in the Hunterian Museum at Glasgow University targeted to partially blind or blind visitors, in which it is possible to feel the edges and differences in height in some carefully selected artifacts using a haptic mouse. Mclaughlin et al. [MSS*00] developed a system for collaborative, remote haptic exploration of artifacts, based on heterogeneous setups composed of a Phantom and cybergrasp devices. Petridis et al. [PPW06] presents a multi-modal system that uses some novel devices, such as a Space-Mouse and artifact replicas manufactured by a 3D printer.

In terms of usability studies, Burke et al. [BPG*06] have shown that additional modalities to visual feedback such as touch and sound improve performance. Butler et al. [BN08] suggest that visitors might expend more time looking at an exhibition when their interface involve haptic devices. Asano et al. [AIMF05] suggest high expectations on exhibition planners and visitors about haptic enabled displays of artifacts in remote museums.

Finally, there have been more advanced systems to capture more of the physical characteristics of an artifact, such as the work by Pai et al. [PDJ*01] who measures mechanical properties at different positions, or by Corbett et al. [CvdDLH07] who measures sound. Although we are not using all these complex apparatus, our work is inspired by Pai and Corbett as we try to measure more than just one modality per artifact.

3. Development

In order to maximize visitor's experience, we took numerous considerations into account such as the digitizing technologies available, and the end-user display and interactive technologies available before designing our three systems. As for operative constraints, we had just six months for development, we were also asked to minimize the disturbance to

[†] A haptic device simulates the sense of touching objects through force feedback.

the Museum's environment as they were moving during the time of the project. This implied that we only had a week to digitize the 12 artifacts. In addition to operational constrains, we also had budget constraints that limited our options in hardware setups, in other words, we left out the possibility of developing custom technologies.

In terms of final system implementation, we took into consideration the following design constraints:

- The 3D model resolution, or the number of polygons that a 3D model could have, should allow high refresh rates (min. 10 Hz) in our interactive environment.
- The 3D model had to be textured, in order to improve the visual appearance of the virtual artifacts without having to increase the polygon count. There are three options for adding texture to a 3D model: automatic texturing, manual texturing, or artificial texturing. We considered all three.
- The image resolution, both for documentation and for interacting with visitors, should be the maximum possible.
- Interactive frame rate should be of at least 10Hz, in order to assure compelling interactive experiences.

Because of budget limitations, we reused as much as possible existing equipment and software from the developing team, and we used just low or middle range technologies so our solution could be easily deployed at reasonable cost for future museum work.

The following subsections describe the artifacts we selected, the digitizing process, the interactive technologies we used, and the way we maximized userÂt's experience.

3.1. The Artifacts

Our first task was to select a limited set (12) of representative artifacts to be digitized. We decided to limit the size of the artifacts between 1 and 17cm to guarantee that we could digitize them using the available 3D scanners. We also decided to digitize artifacts with a variety of materials, functionality, and cultures. Figure 1 shows the selected artifacts which are described as follows:

Figure 1: *Selected Pieces for this Project.*

- A woman that was modeled in bee's wax and then cast in gold, then decorated with hammered pendants to enhance the shining power of the metal, considered the vital power of the sun.
- A Tolima pendant in the form of a jaguar mixed with insect features and powers (between 1 and 700 A.C.)
- A stone bell from the Tairona culture (between 900 A.C and 1600 A.C.)
- A bell from the Nariño region (between 600 A.C and 1600 A.C.)
- A gold based jaguar from the Calima culture, used as a lime container for the coca ceremony (between 200 B.C and 1300 A.C.)
- A small object in the form of a skull from the Tumaco culture, made of gold and platinum (between 700 B.C. to 350 A.C.)
- A disc from the Urabá region, which was probably used as decoration for a stick used in the sacred consumption of coca leaves
- From the swampy area in the north of the country and the Sinu culture, a golden heron that was used as decoration of a chiefly staff (between 200 B.C. to 1600 A.C.)
- A gold based cover for a snail shell, which was probably used as a trumpet for ceremonies (between 200 B.C and 1300 A.C.)
- A ceramic vase from the Cauca region, probably for holding sacred liquids (between 150 B.C and 900 A.C.)
- A ceremonial raft from the Muisca culture, one of the masterpieces of the Museum (between 600 A.C and 1600 A.C.)
- A small rattle

3.2. Digitizing Technologies

We used different digitizing technologies, in order to assure we had enough data for our planned interactive experiences and for future research work. In the following list, we characterize each technology by a name, a set of attributes of the data we gathered, and the operations we could do with them.

- A Faro/Kéon digitizing arm, that allowed us to capture data at high resolution (50 micron) with no texture. The digitizing errors created by the fact that the artifacts were made of gold were very fast to clean as it is easy to control integration time vs laser power and to take views away from specular reflections. The usable data set was very large and was reduced by a polygon compression software to meet the requirement of each application. Because the sensor do not provide texture with the 3D data a post-processing is necessary to add high-resolution texture to the model. During this project some technical issues delayed this integration and some artifacts were manually textured.
- A Minolta 3D laser scanner, which captures data at medium resolution (0.1 mm) with real textures, although data cleaning time was much longer than the Faro system

as it is not possible to control as well lighting and sensor orientation. Also many of the artifacts were at the limit of the sensor resolution and field of view making modeling and view integration hard.

- A NextEngine a low cost 3D laser scanner, which captures models at low resolution (1 mm) with real textures, although cleaning time was longer than the previous two as there is no real control of the views or laser power..
- High resolution pictures. We made two sets of pictures, one with markers to facilitate texture registration, and one with black background. Finding the camera position for automatic texture registration in the first set is still under development, while cleaning artifacts from the second set of pictures does not take too much time. Each picture was taken at the highest resolution of our cameras (13M), and camera parameters (focal length, aperture, etc..) were manually fixed.
- High quality sound from selected pieces. Our purpose was to give a general idea about how an artifact may sound when struck with a stylus, so this information was ready to be used without modification as captured from a directional microphone.
- Complementary text and images, related to each artifact's origin, location at the Museum, and description. This information was provided by experts at the Museum.

All 3D scanning devices we used had problems with the shininess of gold artifacts, although the Faro arm allowed us to tweak important parameters, as it was mentioned. We were forced to use a special powder in order to reduce reflectance, after a careful analysis of the Museum's curators of both the components of such powder and its effects on the pieces. For this reason also we could not use the texture information we gathered from the Minolta and the NextEngine devices, since pieces were covered by powder. We are working on the automatic integration of high resolution pictures to 3D scans, although for the purpose of this project we manually stitched pictures to selected pieces, due to time restrictions.

3.3. Display and Interactive Technologies

We took into consideration many commercial technologies, their characteristics, and their possibilities to develop the new interfaces for visitors to observe replicas of small artifacts. This analysis was guided by the goals and constraints defined by the museum application, the type of information we gathered, and the possibilities that each technology provides. The technologies we considered and their characteristics are the following:

- Active stereo displays: They allowed us to see models in 3D. It requires shutter glasses and a controlled light space.
- Auto-stereoscopic displays: They do not require glasses in order to show 3D models, although the quality of the image is usually lower than the one obtained from active stereo displays. They are ideal for museum applications as they do not require extra glasses.
- Standard monitors: They can show all types of information, although 3D information does not look as good as in active stereo displays. However, images and text look better than in 3D displays.
- Sensable's Phantom Omni: Of all possible haptic devices we studied, this one has the best price-feedback quality ratio.
- Novint's Falcon: This new haptic device has similar characteristics to the Phantom, and it is the most competitive in terms of price.

We ruled out projector based passive stereo solutions due to space limitations at the Museum. Due to development time restrictions, we only considered rapid prototyping software technologies that could support our hardware, such as Quicktime VR, Flash, RapidForm, X3D, and H3D.

Finally, all these elements could be mounted and presented to visitors in different formats. As we will describe in Section 4.3, we chose in our multi-modal installation a format that directs visitors' senses and interaction towards one common virtual space.

3.4. Maximizing Visitors Experience

In order to maximize visitors experience, we selected information that can be optimally used with each display technology. The data sets used are the following:

- From the scanned geometry, we decided to use the Faro's data, since it is the most complete and faster to process than the other sources.
- We also used high resolution pictures with black background, sounds bites, and text for the final installation.
- For stereo display, we used active stereo technology, due its output quality and ease of use. However, in the case of picture and text, we used standard monitors.
- For haptics, we decided to use a Phantom Omni, again because of its output quality and its low cost.

There was no display capable of showing all our data with the highest quality possible at one time. For this reason, we needed at least two complementary installations, one for showing mainly 3D content and the other one for images and text.

This process also involved certain compromises. Since the Faro's data did not include textures and we had not completed the automatic texturing process yet, we had to rely on hand texturing and fake coloring to finalize the virtual artifact models. In the case of smooth gold pieces it was possible to create a compelling material that looks good, such as the color for the bell in Figure 2.

In the case of shapes with complex textures, it was necessary to manually stitch the photography of the artifacts as textures on its 3D version. Also, due to limitations in the

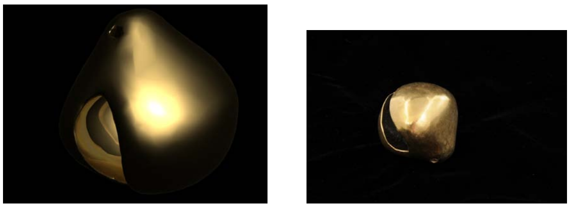

Figure 2: ***Comparison between a bell's replica with faked material and a picture.***

interaction with the haptic device, it was necessary to reduce the number of polygons in the shapes captured with the Faro, and therefore the resolution of textures was also limited. Although this process is common in the game industry, it has two main problems we would like to overcome in the future: textures may not perfectly blend due to perspective distortions, and low polygon shapes and standard rendering techniques may show artifacts not present in real life objects, such as the apparent cracks of the ceramic in Figure 3.

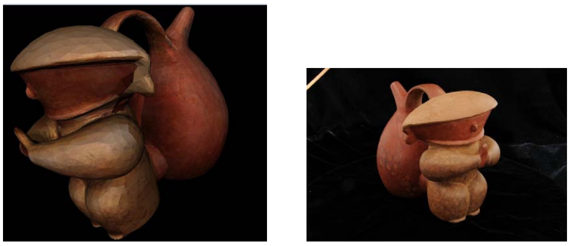

Figure 3: ***A model of a ceramic for interaction and its picture.***

4. Installations

Complementary installations were developed in order to maximize visitors experience with the captured data. In order to facilitate interaction with high quality images, we created both a web site and a multimedia installations. In order to allow visitors to interact with 3D content, we created also a multi-modal installation. Details are shown in the following subsections.

4.1. Web Environment

The web environment is both the basic interactive environment with all captured information and the place for contextual information about this project. A catalogue of six virtual reproductions (Figure 4) allow users to observe each piece in detail and hear their sound when it get struck with a virtual stylus.

Once a virtual artifact is selected it is possible explore its meaning and its origin using the text information, see it from all sides with our Quicktime VR viewer, see it in 3D with a

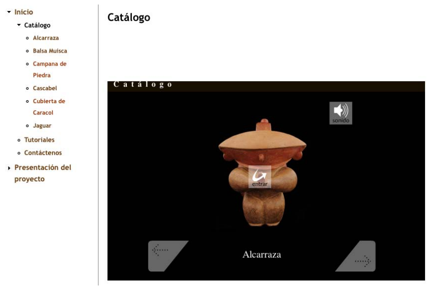

Figure 4: *Web Catalogue.*

X3D viewer, or see detailed pictures with two Flash-based tools. It is also possible to see the piece's location in the Museum, and the region of the country were it was discovered. One can see at Figure 5 a sample display page.

Figure 5: *Details about a Piece in the Catalogue.*

This exhibition allows us to maximize remote visitors' experience with pictures and textual information. A total of 36 high resolution pictures allow visitors to observe all around each artifact, and admire its details. The X3D-based reproduction allows exploration from any point of view, and see better an artifact's shape.

The web site presents also information about the development process of the project. Videos show the main elements in development. Public documents and credits to people and institutions are also included. This site is available at http://imagine.uniandes.edu.co/MuseoOro.

4.2. Multimedia Environment

In order to take advantage of a computer room inside the Museum, we developed a multimedia presentation based on the information on the Web. In general, it has the same functionality than the web site, although it is designed to be used in full-screen mode with a rugged track-ball with a button as interface. Figure 6 shows the detailed view and the magnifying glass view of such an interface. The detailed view is based on high resolution pictures and the view depends on the distance from the mouse pointer to the center of the screen. The magnifying glass view changes the pointer for a circle that shows an enlarged zone in its context.

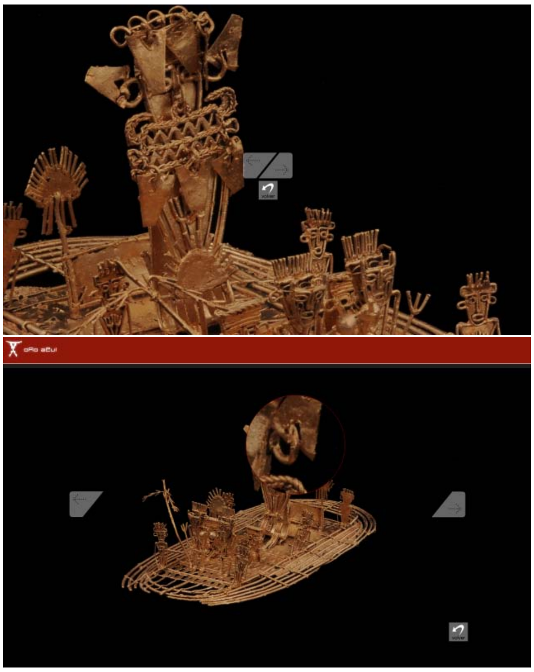

Figure 6: ***Detailed View and the Magnifying Glass View.***

4.3. Multimodal Environment

We took advantage of commercial hardware in order to offer visitors at the Museum a unique experience, in which they can touch, hear, and see in stereo six selected pieces. It consists of a stereo display, a haptic device (Phantom Omni), and consumer-level speakers, all mounted in a way that co-locates haptic manipulation with stereo visualization. Figure 7 shows a user interacting with in our current setup. The aluminum frame allows to co-locate the stereo image with the space for haptic manipulation, so users see and touch the virtual artifact in the same space.

We chose H3D [Sen09] as the main software technology for this setup, due to its support for several haptic devices, its high level language approach for development, its fast learning curve, and due to its roots in an open standard for 3D content such as X3D. However, in order to keep interactive rates in the final application, we had to reduce the number of polygons in our models. We compensated this lack of detail by adding textures to some models that needed them, such as the gold jaguar and the ceramic vase. The lack of detail in the 3D models is compensated by tools in the other installations, such as the detailed view and the magnifying glass view in both the multimedia and the web site.

Figure 8 shows the entry screen. It shows small translucent versions of each floor of the Museum with the selected

Figure 7: *The Haptic Installation of the Blue Gold Project.*

one in red, a big copy of the current floor, and a set of door-like widgets with the virtual replicas that could be visited. The small green cylinder with a sphere in its tip represents the haptic pencil. By moving such a pencil and touching virtual objects, visitors can change the current floor, so they can see which other objects are available in this virtual exhibition, or they can push one door to see details of a particular object. Haptic feedback is active in all virtual objects.

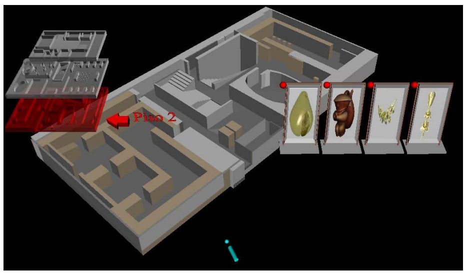

Figure 8: *Entry Screen on the Haptic Installation.*

Once a visitor enter a door, the system shows a screen such as the one illustrated at Figure 9, that permits observation of an artifact from any point of view. The sticky white semi-sphere on the left is a widget for rotating the artifact. This widget allows us to avoid different states in the interface that could appear with the use of buttons in more common techniques such as dragging, so we keep the interface manipulation as simple as possible. In this level visitors can touch the artifact and feel its surface and shape. Some selected artifacts can also play sound when hit with a virtual stylus. On the top, we represent as doors the current option (darker gray in its background) and available experiences: weighing and cleaning.

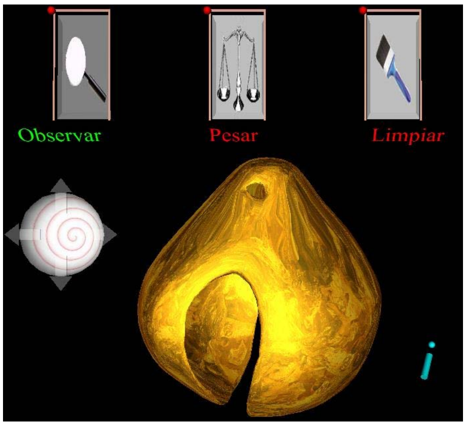

Figure 9: *Observing an Object in the Haptic Installation.*

Weighing shows the current object in one side of a simple scale. By pressing the other side with the haptic pencil, it is possible for visitors to feel a relative weight of the artifact. Finally, the cleaning mode shows the artifact with some dirt. Visitors can clean the artifact by touching it with the haptic pencil. Figure 10 shows these two modes.

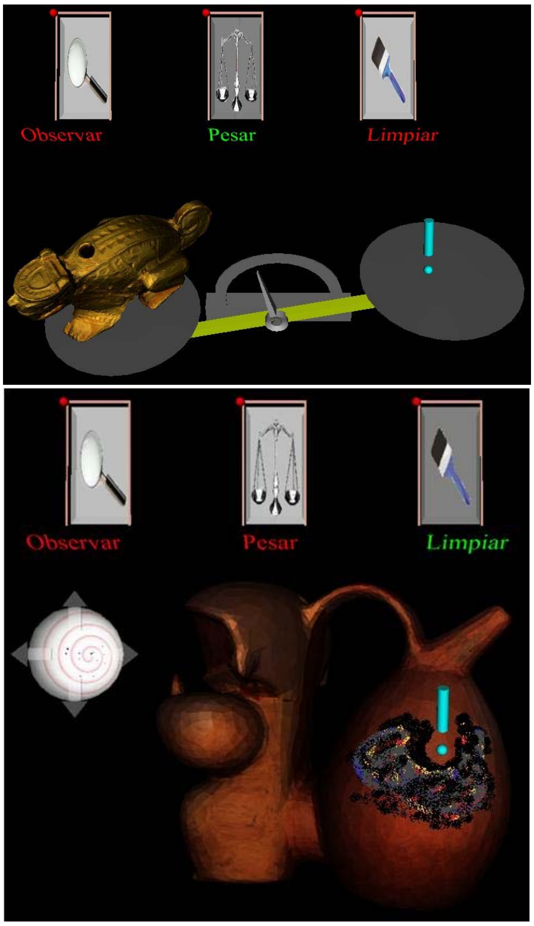

Figure 10: *Weighing and cleaning an artifact.*

5. Initial Evaluations

Of particular interest in this section is the set of evaluations we performed to evaluate the multi-modal installation. We developed our system in a iterative way, with user studies at the end of each cycle.

First, we evaluated our first multi-modal prototype with a group of computer graphics experts from our labs. We showed all functionality to these selected experts and asked them to give us their feedback on the system as well as to fill a detailed questionnaire based on [Shn98, p.136]. In general, they liked the interface and they pointed out some improvements, although some comments were directed to richer functionality, which could be useful for experts but too complicated for casual visitors.

Our second prototype was evaluated by 121 people both at a conference and by student volunteers at our labs. We performed a between subjects study in order to study the differences of the following interface technologies: an active stereo display with shutter glasses and a Phantom in co-location, an auto-stereoscopic display with an inter-ocular distance of 0.01m and a Phantom in a normal position, and finally a similar setup but with an inter-ocular distance of 0.02m. Although a Kruskal-Wallis analysis on the data did not give us significant results about the differences between the conditions, comments imply that subjects found our weighing interface very informative but our rotating widget not very intuitive.

Finally, for our third design, we improved the visualization of our application and we opened our exhibition at the Museum. A guide person at the museum shows to visitors the basic operation of the interface, which are allowed to see by themselves one more artifact. Approximately 1000 visitors came to see the system in a month so far, from kids in elementary schools to casual elders. From sporadic observations, we have found that the guide in this exhibition is extremely valuable, since casual visitors prefer not to interact with haptic technologies, since it seems it is unknown to them and they seem frightened to break it. Our guide motivates casual visitors to see more about this exhibition, and explains the basics, although sometimes guides the experience too much. Once visitors understand the interface, they are willing to explore one virtual artifact, and sometimes more than one. Kids are even motivated to queue several times to see all artifacts in the exhibition, We have also found limitations on the haptic device we are using, and certain fragility of both the device and the software were observed. Our guide also helps us by asking visitors to revise the way they use the haptic device, or by rebooting the system if necessary.

6. Conclusion and Future Work

We have presented a scheme that allows visitors to interact with replicas of small artifacts at the Bogota's Gold Museum by using complementary installations, where each installation enhances certain type of content information on the artifact. The ability to digitize artifacts but to also present this material in various forms is key for a successful museum exhibit. The new haptic-stereo display has proven so far that by co-locating object observation with the ability to touch or hear is indeed compelling and capable of creating a personal experience with the artifact.

In the future, we want to conduct more studies in the integration of complementary installations with the real pieces at the Gold Museum, and how each one feeds from others. We also plan to create more compelling and interactive experiences, probably based on games, such as [DGREG07]. Although it was not a main concern in this development, we also plan to consider security of our information such as in the work by [KTL*04].

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