

Tactual Exploration in Cultural Heritage

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Abstract

In this paper we propose a potential solution to overcome a common restriction for museum visitors: the tactual exploration of works of art. The sculptures are experienced as synthetic virtual 3D models retrievable from a data-base. The interaction between the human perceiver and the simulated sculpture is based on the development of haptic interfaces exploiting both force and tactile feedback. A portable non-contact laser scanner has been used to obtain the real geometry of the sculpture and generate the haptic model. Tactual exploration could represent an important means for fully appreciating the features of archaeological finds.

Keyword: Cultural Heritage, Haptic Interface, Touch, Exploration, Virtual Reality

Introduction

It is usually not allowed to touch works of art, which means significant restrictions for museum visitors and for researchers who work in the archaeological field. The Museum of Pure Form (IST-2000-29580-PURE-FORM) is an European research project coordinated by PERCRO, that indicates a potential solution to these constraints. In fact, the PURE-FORM Project aims at allowing the tactual exploration of virtual 3D copies of works of art. Within the project, that started in September 2001 and will go on for three years, experts on technology, computer software and perception will develop a so-called haptic display in cooperation with art museums experts.

Haptic displays are systems devised to exert a controlled force on operator's hand, capable of creating a perception of touch with a virtual object, by artificially conveying tactile-force stimuli to the operator. A selection of sculptures will be digitally scanned for realizing virtual 3D copies of them

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that will be available to touch in a user-friendly way, either with the statues in direct sight or together with visual representations of them.

In the framework of the PURE-FORM project is foreseen also the creation of the 3D virtual library of the digitised sculptures that will be accessible through the Web at all museums having the necessary equipment. This network will allow studying, by the sense of touch, many finds placed in different museums and could permit for example comparative tests among them. Moreover, the complete device with the force feedback and the virtual environment will enhance the experience of the statues for all the people, but it is of potential interest also for visually impaired people. In fact, the tactile exploration could be the right way to offer to the blind people the possibility to enjoy of the art, and to verify all the verbal description used for their studies. The PURE FORM project is just the first step to verify the possibility of the use of the tactile and force feedback in the Cultural Heritage field, to develop systems for an interactive network of platforms, which could offer a new interaction paradigm with the art.

The Ways of Art Fruition in the Museum New Potentiality

Nowadays, in many important national and international museums, most of the information relating to the works of art on display is available on paper or anyway in writing, on panels, notices, leaflets and catalogues. Traditional museums are mainly conceived as places for preserving works of art, and for this reason, they represent artificial areas, or rather "non-areas", where the preserved object loses its original symbolic meaning because it has been isolated from its context of reference. In fact, by visiting an archaeological museum and looking at fragments and pieces of sculpture and buildings, the visitor is normally asking for where that fragment was found, what building it was part of and what sort of landscape surrounded. Furthermore, by taking into account that the finds extracted from one only place are often spread among museums all over the world, it could evaluate the complexity of the cognitive reconstruction process imposed to the visitor. A great part of the traditional art historical and archaeological museums uses panels for presenting information on the history and origins of the exposed art objects. Sometimes, there are adapted rooms for showing films that try to immerse the visitor more deeply in the original cultural environment of the preserved art's work [1] [2].

By integrating multi-media technology with the traditional concept of the museum, the virtual museum recreates the "surroundings" which the objects were part of. This allows the visitor to experience a genuine immer-

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sion in time and space by means of various sensory channels [3]. It must be taken into consideration that, in the traditional museum the sequence of displayed works follows a pre-established meaning according to museological and museographical rules, where the user is the passive receiver of a transfer of knowledge while in the virtual museum the information technology permit to eliminate these constraints, by giving the visitor the chance to directly interact with the art's works , freely accompanying the visitor in the exploration, and along the path of knowledge according to visitor's personal criteria (cultural education, curiosity etc.) [4]. A considerable added value is represented by the experiences in complete absence of the physical objects and by the data sharing through networks, that allow to make the cultural heritage available in a worldwide scale [5].

In the case of the system that will be developed during the PURE- FORM project, it is opportune to emphasize that the digitalization of the work, besides supplying visual support to the haptic perception, permits greater accesses to the work of art because it provides the selected work with further textual and graphical information relating to the author, the original location, the history and so on. In addition, in the case of a damaged work, it will be possible to supply further evidence combining two digital 3D models, each representing the original status of the work and the current one. This new system could allow also the interaction with works of different sizes by the introduction of suitable scale factors . In this way it will be possible, for example, to explore and interact with the scalemodel of the Sphinx in all its parts, or with the statues of the Abu-Simbel temple and so on. It is evident that the PURE-FORM concept could be potentially applied in various ways in the Egyptology field, including the diagnostic in the restoration area.

Virtual Reality and Art Fruition

The field of Computer Graphic (CG) and Virtual Environment (VE) mediated artistic applications is a novel emerging sector of research. Some museums and universities around the world have started digitalizing their collections in recent times. Digital copies of art collections range from simple pictures to complex 3D images, which can be scalable and can be viewed from different points of view. Many museums have recently developed a strong interest in technology since they are faced with the challenge of designing appealing exhibitions, handling large volumes of visitors, and conserving precious artwork. They look at technology as a possible partner to help achieve a balance between leisure and learning, as well as to help them be more effective in conveying story and meaning [6].

Until now, the haptic perception has been yet applied. In fact, every art piece that has been digitalized can be viewed with generic instruments, like a

browser, or using customized software. However the only sense that is used is that of sight, limiting the user's capabilities. The sense of touch is extremely important for anyone who is interested in fully grasping the essence of any 3D form of art. While it wouldn't be reasonable to let anyone touch statues exposed in a gallery, for obvious safety reasons, it can be argued that sight only cannot be enough for someone to fully appreciate every aspect of a 3D art piece that stands in front of them. Surely the perception that an artist shaping an object has of it is very different from the one of a person simply staring at it from a certain distance.

Haptic Interface

Haptic Interfaces (HI) are robotic systems which allow a user to interact with virtual objects using the sense of touch. This is accomplished exerting a force feedback on the user. The design and development of interface systems increased the possibility of a complete immersion of the user in the Virtual Environments (VE). The development of force and tactile feedback systems allows the human operator to feel realistic sensations moving and interacting in a VR environment.

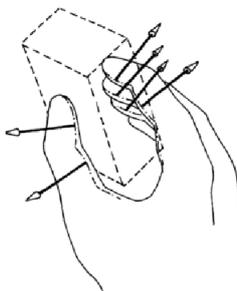


Figure 1: *Force applied at the level of the fingers*

Lederman and Klatzky have defined haptic as "a perceptual system that uses both cutaneous (including thermal) and kinaesthetic inputs to derive information about objects, their properties, and their spatial layout" [7]. Since in a VR system it has been very important a rendering of the sensation of physical interaction with the virtual objects, haptic interfaces have been designed in order to conduct a realistic interaction and, at the same time and to allow natural movements to the human operator. The inertia offered to the human hand by a force feedback system must replicate the natural inertia "during the performance of a real grasping or manipulative operation" [8] (see fig. 1).



Figure 2: *Haptic Interface developed by PERCRO at Scuola Superiore S. Anna, Pisa, Italy*

PERCRO has developed some force feedback systems that allow a natural mobility to human hand and arm (see fig. 2). Fundamental requirements for these systems are the portability and the wearability.

The PURE-FORM Project

The Objective

The Museum of Pure Form (MPF) was introduced by M. Bergamasco in [9]. Its goal is to radically change the way normal users perceive sculptures, statues or more in general any type of 3D artworks. The concept of "The Museum of Pure Form" gathers both the interaction procedure and the physical site where the interaction occurs, being these two mediated by the virtual presence of 3D simulated sculptures. In the Museum of Pure Form it is in fact assumed that sculptures are not physically present as solid 3D entities; on the contrary only synthetic virtual 3D models of the sculpture can be retrieved from a specific data-base (local or shared with other Museum located worldwide). Although the 3D model of the sculpture can be represented and graphically rendered to an external audience on large screen, the approach followed in the Museum of Pure Form refers only to haptic perception, i.e. the capability of perceiving 3D object features (such as shape, hardness, temperature, etc.) by exploiting kinesthetic and cutaneous stimuli. In particular the aim of the visit to the Museum of Pure Form is that of extracting a direct

perception of the sculpture's shape only by haptics.

The proposed interaction methodology between the human perceiver (from now on, indicated as the "observer") and the simulated sculpture is based on the development of haptic interfaces exploiting both force and tactile feedback on the hand of the observer (see fig. 3).



Figure 3: *The Concept of the Museum of Pure Form*

The Museum of Pure Form Layout

The Museum of Pure Form system will be located inside real museums, in close contact with the real art pieces that can be perceived by the users. This will allow anyone visiting the museum to interact with a selected art piece standing in front of them and not with a digital model represented on a computer screen, thus making the overall effect more immersive and, therefore, realistic. The Haptic Interface that will be used in the MPF will be specifically designed, controlled and integrated for accomplishing this task, allowing a higher order of haptic realism. The innovative aspects of this system are multiple. First of all, the overall system allows a new and highly innovative form of interaction between visitors and information. Thus, the MPF itself is a novel system that enables a whole new set of services.

Innovative technical aspects are used in order to make the overall system realistic and user-friendly: the design of force-feedback HIs, the usage in CAVE structure and new haptic rendering techniques applied to sculptures. Two different realizations of Museum of Pure Form systems are currently being developed at PERCRO, Pisa, Italy.

The first realization will be a gallery-like environment, containing a set of digital representations of selected sculptures, will be recreated virtually. Users will be able to navigate through such environment, select a specific sculpture to be examined and interact with. The overall VE will be visually

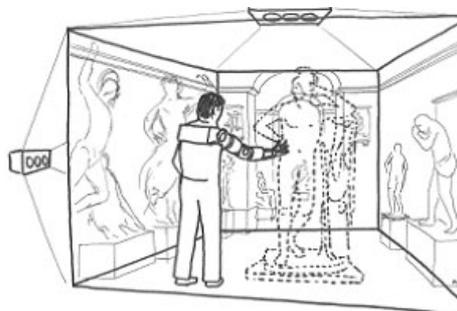


Figure 4: *The Museum of Pure Form inside a CAVE*

reproduced inside a CAVE system, which is a multi-person, room-sized, high-resolution, 3D video and audio environment (see fig. 4). The interaction with the selected sculpture will be obtained through the visual channel, using the CAVE system, and the haptic channel, using a HI similar to the one proposed for system.

The second realization will be a reduced version, placed inside a real museum, with real sculptures standing around it. Anyone visiting the museum will be able to normally observe the displayed art collection and to interact with a digital model of a selected sculpture with a desktop haptic interface. This system will be highly user-friendly and will be located in a normal non-expert environment. Therefore its use will be accessible to any standard visitor of a museum.

The main system is intended to fully recreate a museum environment and is physically located away from the real art pieces. A key issue that applies to both, however, is that both systems will be used in order to allow users to navigate through the collection of a network of museums, participating to the project. In this case, clearly, the GUI (Graphic User's Interface) alone accounts for the visual feedback. Such computer network will allow the tele-perception of digital copies of sculptures belonging to museums located in geographically different places. Different museums will therefore be allowed to share visual and haptic copies of their art works, thus creating a common European library of sculptures.

The overall structure of the MPF consist in 3D digital models of sculptures, located in different museums, that can be uploaded by the VR system. The HI tracks the user's arm and hand positions and sends such information to the VR system. According to the position of the avatar (graphical replication of the user inside the VE) and of the position of the art piece, the contacts forces between the two are computed by the collision detection algorithms. These are based on the haptic model of the avatar and of the

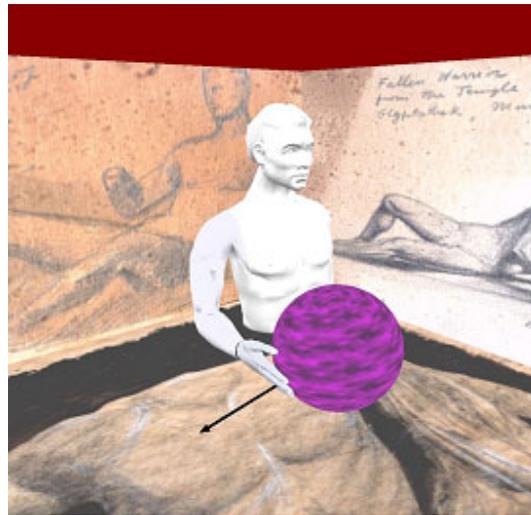


Figure 5: *The Avatar in the Virtual Environment is touching a virtual sphere art piece.*

The Current Status of the Project

The Haptic Environment

The core systems reproducing the feeling of touch within the MPF are two haptic devices. They will be capable of exerting forces synthesized in the digital environment on the user fingers. Two types of HI are under development: an external (desktop like) device and an exoskeleton like device [10]. The presence of an anthropomorphic exoskeleton HI, to be worn on the operator arm (Figure 7), is required in a CAVE-like full immersive visual system in order to avoid interference problems between the visual rendering component and the links of the HI.

A portable HI for the hand with six degrees of freedom is currently being developed at PERCRO. This HI will be mounted on the terminal link of the exoskeleton and desktop like HIs and will provide the operator with the contact point forces on the thumb and index (see fig. 2 and 4). The whole HI system will be capable of tracking the arm movements of the operator and of providing a force feedback on his hand in order to simulate the surface perception.

With the aim of exploring the basic issues of shape recognition by haptic feedback, an experimental set-up has been realized at PERCRO, based on the force feedback arm exoskeleton (see fig. 5). In the Virtual Environment a full-body avatar of the operator is represented as it is shown in following figures, while the contact forces are displayed as solid arrows. The operator

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Figure 6: The digitalization of the “The Prophet” by Giovanni Pisano at OPAE museum in Pisa

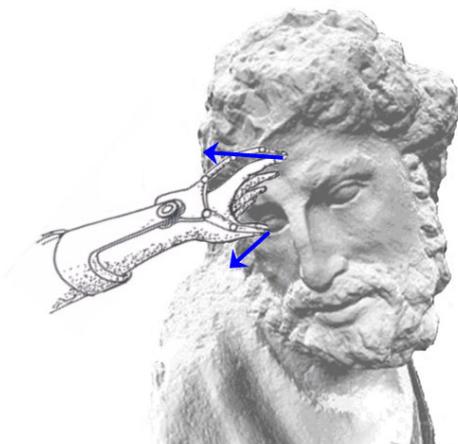


Figure 7: The concept of the Museum of Pure Form shown with the digitalized version of

can observe the movements of his arm on a wide screen, on which the Virtual Environment is projected. Several objects with different geometrical shapes have been represented, such as a sphere, a wall, a cube and polyhedral objects. The operator can move freely his arm in the space, without feeling the weight of the exoskeleton, since gravity and friction forces are compensated by the action of motors.

3D Models

The paradigm of this interaction with novel forms of art was introduced for the first time by [9] and is represented in Figure 7. The 3D digital model shown in the figure, was digitally acquired by means of a 3 dimensional laser scanner on May 2002 at the Museum of the "Opera della Primaziale Pisana". It is the plaster copy of an existing sculpture, exposed in the past on the front face of the Baptistery in Pisa. A portable non-contact laser scanner has been used, mounted on an articulated robotic arm. The system is moved around the sculpture to acquire data, without touching it in any way. A probe is used to create datum points and planes on the floor or on the plinths, etc. This helps in the process of moving round the object and recombining images from different viewpoints. After the acquisition of the real geometry of the sculpture, a haptic model is being generated on the basis of geometric information.

Some preliminary experiments on the model in figure 7 have been currently carried out, demonstrating the flexibility of the developed integrated graphics/control software to different needs. The research on the perceptual issues, from a psychological point of view, are currently carried out in collaboration with Uppsala University experts.

Conclusion

By taking into account that, many archaeological sites are often difficultly reachable in reason of their geographical location, and moreover the perishable status of many ancient objects constitutes a limit to their examination by touch, because it would expose them to the risk of damage, it is usually unallowable to touch archaeological finds. Nevertheless, it is evident that the tactual exploration could represent an important mean for fully appreciating the features of also archaeological finds, as ancient works of art. The PURE-FORM project proposes a novel technological mean that could be naturally extended in the field of the archeological finds. In fact, it could offer the researcher the chance of carrying out his studies and investigations on a virtual exact reconstruction of the archeological find, rather than on the real one. It is worth to notice that the high resolution achievable nowadays by 3D scanners makes possible to obtain accurate models of object surfaces.

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This virtual reconstruction will allow either to analyze the original techniques adopted for manufacturing the pieces or to detect eroded features, i.e. hieroglyphics, in a more intuitive way or to evaluate the original functionality of virtually restored models of the same pieces.

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