Technological Approach for Cultural Heritage: Augmented Reality

Brogni A., Avizzano C.A., Evangelista C., Bergamasco M.
PERCRO
Scuola Superiore S.Anna
Pisa, Italy

Abstract

Augmented Reality systems allow the user to see a combination of a mixed scenario, generated by a computer, in which virtual objects are merged with the real environment. The calibration between the two frames, the real world and the virtual environment, and the real time tracking of the user are the most important problems for the AR application implementations. Augmented Reality systems are proposed as solutions in many application domains. In this paper we addressed the aspect related to the development of AR applications in the Cultural Heritage field. Possible future applications are described, including the use of haptic interfaces in AR systems, designed at PERCRO.

Keyword: Augmented Reality, Virtual Reality, Haptic, Cultural Heritage

1 Introduction

In the last few years we have witnessed a constant evolution in the relationship between the technical and cultural sciences. The work presented in this article describes an aspect of the state of the art of this relation and intends to propose new systems for a fuller enjoyment of works of art by trying to obtain the most of the new interaction technologies. Compared to the typical information systems, as museums, photographs, books or paintings, the computer has the possibility to present the information from another point of view: it is possible to consult very big databases, possessing thousands of photographs, and print them; there are three-dimensional models of buildings or archaeological works to look on a monitor, and by wearing a Head Mounted Display (HMD) we can be immersed in a Virtual reconstruction of an ancient world. Also the study of the Art works can exploit computer based systems, because it is possible to find new approaches on the work, and to integrate many studies together.

Many studies are presently addressing the Cultural Heritage field, where it is important have a good graphic quality in order to have a realistic visual representation of the digital images. Now computer performances can allow to develop interactive systems for the consultation of virtual environments, and it is possible now to look for other paradigms to show information.

2 Augmented Reality

2.1 The Augmented Reality Definition

One of the most powerful area in the Virtual Reality (VR) field is that related to the systems designed to augment the user's view of the real world by embedding additional visual information, graphics and text: this area of research is called Augmented Reality (AR). This is a combination of a virtual scene, generated by a computer, in which virtual objects are coherently integrated in order to complete the view of the real world. VR was defined as " a computer generated, interactive, three-dimensional environment in which a person is immersed " [3], then the user is totally immersed in the virtual environment and interacts with it with some kinds of interfaces. A typical device for a VR system is the HMD: this system is devoted to give a 3D graphical representation of the virtual scenery and, since it is immersive, separates the user from the real world. Every scene is virtual and generated by the computer by tracking the head of the user. On the contrary, in an Augmented Reality application the virtual images are merged with the real view of the user, and the two sources of images have to be coordinated very well in order to give a coherent superposition effect. Milgram [18] proposed a taxonomy to identify the relation between Augmented Reality, VR and Augmented Virtuality, which are different positions in the "mixed-reality" continuum.

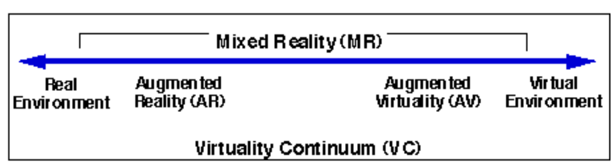

Figure 1: The Mixed Reality continuum defined by Milgram [18].

Figure 1 represents the schematic concept introduced by Milgram. Virtual Reality and Real World are the two ends of this continuum, and the Augmented Reality is on the side where the real world is predominant; virtual additions are used to complete the real scene.

To define this class of environments Milgram has formulated a taxonomy, with three dimensions:

- extent of world knowledge,

- reproduction fidelity,
- extent of presence metaphor.

The world knowledge is the first step to be performed in this kind of applications. AR is a difficult technology, because it needs to maintain an accurate registration of the two worlds, and the computer generated images must be aligned to the real one. This need imposes a preliminary calibration phase and a regular tracking of the two reference frames, the real world and the point of view of the camera, therefore of the viewer. In some applications it can be relatively easy, because the designers know everything of the real world but in some situations, for example outdoor, this knowledge could be difficult to be obtained.

The reproduction fidelity is "the quality with which the synthetising display is able to reproduce the actual or intended images of the objects being displayed" [18].The photorealistic rendering in a real-time system is the target of many studies; at present the computer capabilities are not so good to show virtual objects completely integrated in the real world: the task is to have a mixed reality, where the user does not perceive the real from the virtual added objects.

The "feeling as sensation of present" in a virtual scene is a very important property of a VR application: the movements and the use of some interfaces are possible only if the user "feels the space" and understands where all the virtual objects are located. The level of immersion in the mixed-reality highly depends on the display devices used. In AR application the presence metaphor is very good, because the user has a view of the real environment around where the virtual objects are placed.

In this operating system, a big problem is the right positioning of the 2D image plane of the virtual objects representation. Two factors must be considered in tracing a virtual object in the graphical plane: the occlusion and the collision detection which respect to the other real objects belonging to the real scenario. In VR applications the developers have to consider the z-buffer, to know the spatial depth of every point of the representation of an object, and to evaluate which graphic point must be traced from the camera perspective, but in AR is needed to know the real world before, to evaluate the correct position of both the elements (virtual and real) [22].

If the application allows to the user to move virtual objects in the real environment, collision detection capabilities have to be considered, to have a realistic behaviour in every situation. It is clear now how a correct world knowledge is important to have a good AR system and allow to the user a coherent immersion in the mixed-reality.

2.2 The AR System

The AR research is a confluence of many technological fields, in which there are electronics, computer science, mechanics and robotics. In a AR system the user is very sensitive to visual misalignments between the virtual world and the real one, therefore the first step is to track both the frames to define the relation between themes and merge the images in the right way [8].

The virtual world is generated by the computer, but for the real one there are many techniques used. In the first case a camera records the real world from the perspective of the user; video frames are analysed to know the object's position and identify the real objects in the environment [13] [14]. Another possibility is to track the camera with a 6DOF sensor [16], and to know in real time the camera position and orientation (see fig. 2).

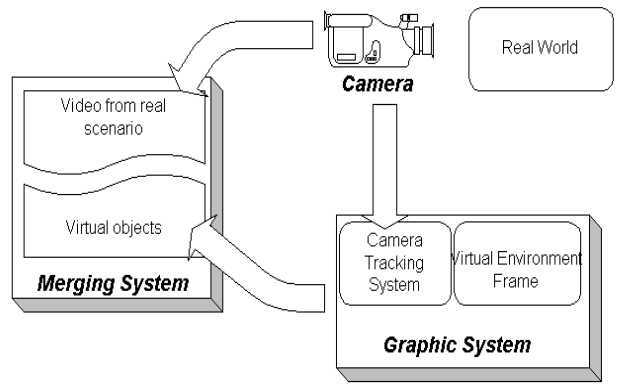

Figure 2: AR system with tracked camera.

The calibration of the reference frames must be very accurate, because all the system visualization depends from these values: an error could induce the system to trace the virtual objects with the wrong position or orientation.

Then the computer merges the images from the camera and the virtual environment, and the graphical display technology, for example a HMD, shows a mixed reality scene.

Another technique is the use of a different display, e.g. see-through glasses in which it is possible to control the opacity of the glass and to allow the wearer to look through having a direct vision of the real environment (see fig. 3). This system offers a perfect view of the real environment and to trace the virtual objects it is enough to track the head of the user. With this system it is possible to consider the occlusions between the real environment and the virtual one, but not with moving real objects because the computer has just a map of the positions of the real objects. The use of a camera is needed to define occlusions or collision detection with moving real objects, to analyse the scene, and to know in real time what change in the scenario where the user is moving: for example if he moves the hand, the system must consider the occlusions with virtual objects behind the hand [7].

The display device is a basic component of an AR application. The HMD is the most common display, also in other VR applications; this gives to the user a complete visual isolation from the environment around. At

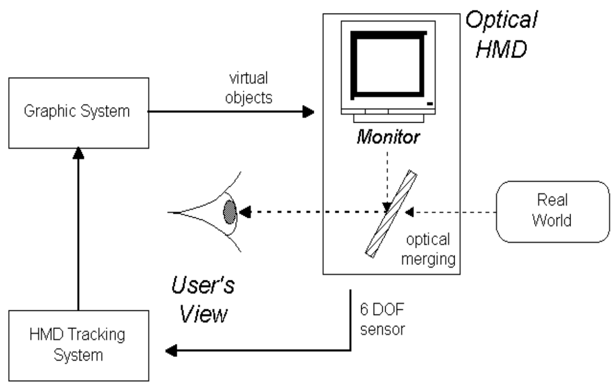

Figure 3: AR system using the optical see-through H-MD.

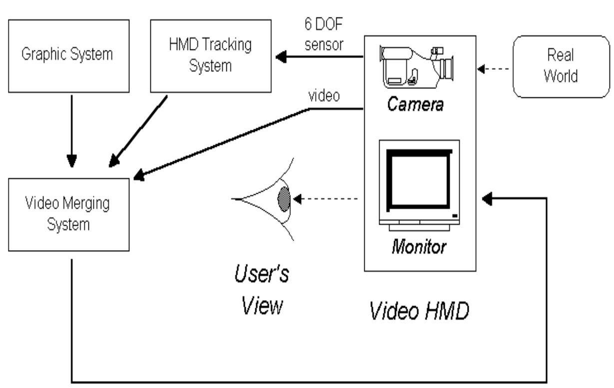

Figure 4: AR system using the video see-through HMD.

present for AR research two types of HMD are available, an optical see-through (see fig. 3) [5] and a video see-through (see fig. 4); the different choice defines the other components of the system, which can require a 6DOF sensor just for the HMD or also for the camera.

The latency is another crucial problem for the AR systems [11]. Each device has a delay in sending data to the computing, and this is a source of misregistration that must be reduced. The system needs time to evaluate the new graphic images, using the data from the camera tracking. This time could be long if the virtual environment is big or complex.

2.3 AR Applications

Augmented Reality systems are proposed as solutions in many domains, in which the possibility to have many different information at the same time is revealed very useful. The areas of development range from the military field, to the surgery aid and the robotic control.

Some military cockpits have been developed to give technical information about the fly, so the pilot can drive and fight without leaving his attention on the outside situation [17]. The helmet can visualize the enemy units in the battlefield, in a real situation or in a training case.

AR can assist the human operator in the telerobotic control. The image on the display is the same of the remote workspace in the robot workspace, and the operator has a three-dimensional view of the scene, therefore a better spatial control for the operation [19]. Milgram, Rastogi and Grodski have developed an augmented reality toolkit, for remote manipulation systems, to "gatering quantitative spatial information about a remotely viewed 3D worksite" [9], and this information are used off-line to evaluate the operation and transmit the new commands for the manipulator.

Boeing researches are developing an augmented reality system to equip the factory-floor workers with a AR display; the information about the repair or the hardware to be removed can be added on the real view of the operator, and he can use the repair equipment, without requiring to refer to a separate paper or electronic manual [20]. The wiring assembly for the Boeing aircraft is projected in the AR display, showing the right point where the real wire to be repaired is located.

One of the most important augmented reality applications refers to the medical field, where computer generated images are a very useful way for the diagnosis. The visualization of 3D volumes on an AR display aids to prepare the surgery and to assist during the operation. At the University of North Carolina, it has been developed an AR system to guide the needle biopsies in real-time [21]. The system merges a 3D graphic volume, obtained from ultrasound data, and the real images of the patient; also the probe is tracked in real-time for a correct reproduction of the action in progress.

The field of engineering design is coming to use the AR concept [2]. Ahlers presented a multi-user system to enable the users at remote sites to collaborate at the same design project; all the users can look the same virtual objects in the real design environment [1].

In the last years also entertainment and TV industries are using some AR applications, with the large business of virtual studios, in which actors work in a blue-painted stage (chroma-key method), but appeared positioned in a computer generated scene. Maybe this application is near to be an Augmented Virtuality system, because there is a dominance of virtual environment in the rendered scene. The chroma-key method works by using the chromaticity to have differentiation between the real and generated images, but it assumes that the real subjects are in front of the virtual scenario. Kanade [12] has developed the "Z-key method", that uses pixel by pixel depth information and is able to create a merged scene, according the global position relationship.

Some researchers are developing mobile augmented reality systems [10] for a wearable computer, with a headworn display, to merge graphic information with the outdoor environment. The big problem for this kind of applications is the great range of operating condition [4], and the fact that the user tracking can be made in a better way with an hybrid tracker, combining a rate gyros and a tilt orientation sensor.

3 Haptic Interfaces in AR Systems

The design and development of interface systems increased the possibility of total immersion of the user in a virtual environment. Not only the visual input but also other senses could help the user to interface with the computer generated world. The development of force and tactile feedback systems allows the human operator to feel realistic sensations moving and interacting in a VR environment.

Lederman and Klatzky have defined haptics as "a perceptual system that uses both cutaneous (including thermal) and kinaesthetic inputs to derive information about objects, their proprieties, and their spatial layout" [15]. Since in a VR system it is very important the rendering of the sensation of a physical interaction with the virtual objects, haptic interfaces have been designed in order to conduct a realistic interaction and, at the same time, to allow natural movements to the human operator. The impedance offered to the human hand by a force feedback system must reproduct the natural impedance "during the performance of a real grasping or manipulative operation" [6] (see fig. 5).

PERCRO at Scuola Superiore S.Anna, Pisa, Italy, has developed some force feedback systems to allow a natural mobility to human hand and arm (see fig. 6). Fundamental requirements for these systems are the portability and the wearability.

Haptic interfaces are useful also for AR applications, to give more inputs to the user than only the visual information about the contact with the virtual environment.

At PERCRO, we are developing a 3D User Grafic Interface to interact with the application from the virtual environment, and this method can be used in AR to have active information and representation systems:

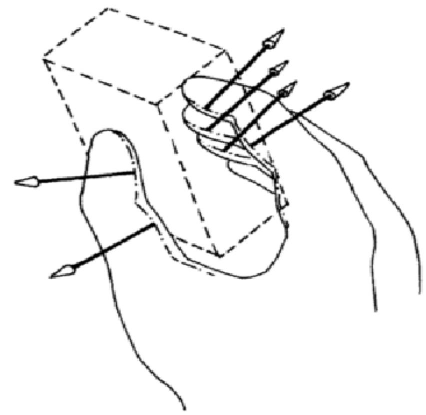

Figure 5: Force applied at the level of the fingers.

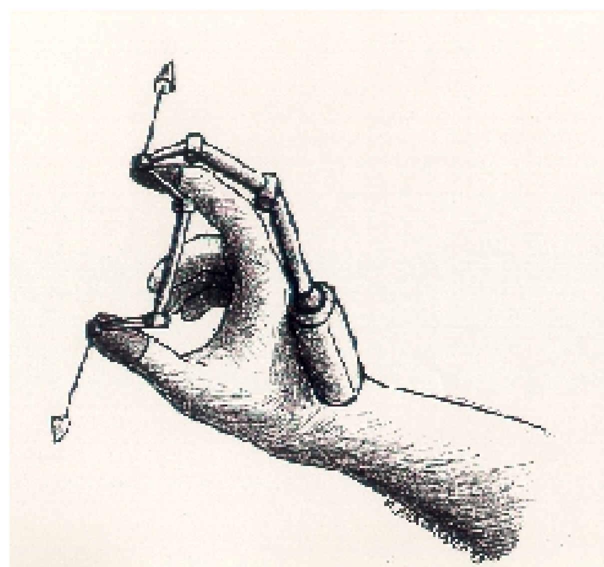

Figure 6: Haptic Interface under development in PERCRO at Scuola Superiore S.Anna, Pisa, Italy.

an haptic device can help the user to touch a virtual button, or move a virtual slide and change the view, change the kind of information he receives, and so on. It is possible to develop a system to give the possibility to move the virtual objects in the real environments, with a complete inertial and weight compensation.

4 Examples of AR applications in the field of Cultural Heritage

4.1 A New Approach to the Information

The advent of computer technologies allowed the redesign of several procedures, methods and applications in the field of Cultural Heritage.

The first area in which the information technology has modified the common way of work is on the data acquisition, which is changed by using electronics devices; the introduction of ultrasound systems, or X-ray, in the historical or archaeological analysis of ancient buildings or biological finds has helped the researchers to evaluate the data from another point of view. The computer can elaborate the data, showing images and performing 3D reconstructions, or it can help to find new relationship from a large amount of data. All these new types of information need an adequate display device. VR technologies helped in this last years to show 3D models of ancient place or objects to explore a lost world from an atypical perspective.

Also AR can be very useful to this purpose. At present the main use of the AR technology is to give a technological aid in many work situations. A medical surgeon can be driven in the operation, an assembling operator can consult the manual while working on the repair, therefore many other professional situations have attracted the interest of the AR researches.

All this fields have in common the feature that the consultation systems are used by those working in the same field, such as surgeons, pilots or control robot operators: they know the information and have just to consult them easily and in the same time when they are working. The field experts are the only beneficiaries of the applications.

In the Cultural Heritage field there is also another kind of consumer: the public, who frequent Museums to look the artefacts or see an archaeological site reconstruction in real dimensions. This kind of people do not know the subjects and the information system has to give the right data without long explanations, and in a easy and comprehensive manner.

VR is considered the one of the most promising technology to be introduced in this spreading field. There are many applications using HMD or CAVE systems to represent virtual reconstructions of Egyptian tombs or Roman buildings, and the consumer seems to appreciate this forms of representation, very intuitive and not complex.

At present, PERCRO has many collaborations in progress with different Cultural Entities, private or public, for the development of VR applications. We are working on immersive stations to visit 3D reconstructions of some pictures, using CAVE systems or HMD. However also new forms of communications are forseen: AR seems to offer new opportunities and new types of interactions with the users, and this can help us in our researches.

The Cultural heritage field can exploit the AR technology by finding a new way to provide the information and offering new consultation methods of archaeological or cultural sites or museums.

The idea is to involve the audience in the information world; it is important to offer the possibility to "verify the information", for example to evaluate if a reconstruction is faithfull or which parts are real and which are virtual; in AR systems it is possible to manage in real time images and texts, but also simplified 3D models to complete the real vision of the user.

The information system in a museum could be personalized on the visitor, who can choose which types of information wants and the correspondent level of the information complexity.

In large spaces, such as museums, palaces, or archaeological sites, a system for a personal guided visit could be developed with virtual path on the floor indicating the directions or the areas chooses to visit, with messages for new events and with all the other types of cultural information about the subjects.

The main problem with large spaces is the technology of tracking systems [4]. Hopefully the research in few years will develop more accurate sensor systems to allow to utilize some wearable computer for AR systems in large environments.

4.2 Possible Future Applications

Our research on haptic interfaces and VR have a good exploitation in AR systems. The user in fact can see the virtual object, relate it with the real world and have physical interaction with it by using some haptic devices.

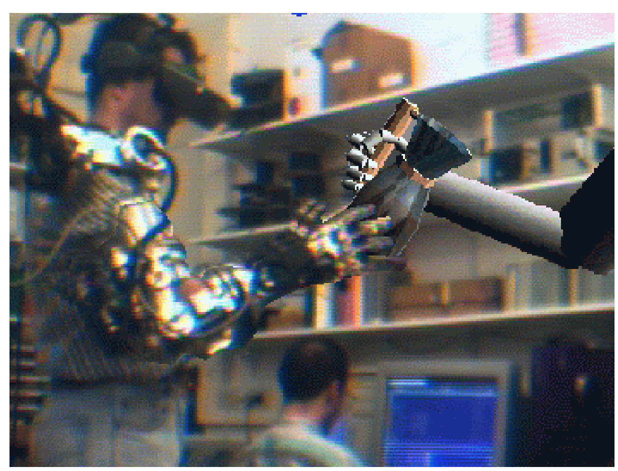

Figure 7: Example of AR-haptic system under development in PERCRO.

An application on large scale can be a city guide on a wearable computer, that offer tourist as well as historical information to the user. The system could have an interface to consult the database, and he could be able to touch some virtual subjects with an haptic device: for example for a sculpture positioned on the top of a church, it could be possible to have a reproduction in front of the user, looking that from any sides, feeling the surfaces or its weight.

The same system could be applied just in a fix station inside an historical place, and the virtual elements could be also the textual descriptions of the palaces, or an ancient reconstruction of the city view from that point. This application limits the problem of the wearable computer and of the tracking system, present in the city version.

The vision of a reconstruction is more interesting to see if the viewer has the exact perspective of the environment. It is interesting to see a 3D model on a monitor, but we loose the perception of the real dimensions, and also in a VR systems, as a CAVE, the actual rendering level does not give a realistic sensation; with an AR system the user can complete the real visual information, and have a totally integrated representation. In this systems we can show also only some aspects of the reconstructions, for example a roof, or a window no more directly available in a real visit.

We can also think to prepare many reconstructions of the same environment, in different ages, and the user could choose or change this consultation. In this way it will be possible to represent many buildings in the same place, but of different periods: often in the archaeological sites, or also in many old cities, like Pisa, there are many historical planes embending a modern buildings at the road level, with Roman buildings or medieval churches underneath. The problem for the fruition is very interesting and AR can help in this special situations.

PERCRO is studying an AR application to make visible a roman church, that is discovered under another later church, in the countryside of Pisa. The system will have a fixed station from which the visitor will have information about both churches and a double view of the environment: the reconstruction of the hidden church will be placed under the level, with the possibility to look the original construction, the actual state of the walls, or to move the model on the upper level, to see the old environment.

5 Conclusions

A general theory of the basic approach and technology to AR systems has been outlined. We described the work of art of the AR applications, in which it is missing the field of Cultural Heritage. We have explained our need to evolve from the VR to the AR. Also the experience in the haptic interfaces field can be useful for a more immersive system. The public is the consumer of AR application in Cultural Heritage: this means that new ways must be designed to offer the information by personalising the guides and developing wearable computers for a large spaces AR visit of the real environment.

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