

# Mixing Telerobotics and Virtual Reality for improving immersion in artwork perception

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**Abstract.** This paper aims at presenting a framework to achieve a higher degree of telepresence in environments rich of artistic content using mobile robots. We develop a platform which allows a more immersive and natural interaction between an operator and a remote environment; we make use of a multi-robot system as the mean to physically explore such environment and we adopt virtual reality as an interface to abstract it. The visitor is thus able to exploit the virtual environment both for keeping the sense of direction and for accessing a high-resolution content, while the immersion is achieved through the robot sensors. This study represents a starting point for overcoming the limits of the current use of virtual technology associated with artistic content. Long-term results of such study can be applied to tele-didactics, remote tele-visits for impaired users and active man-machine cooperation for efficient tele-surveillance.

## 1 Introduction

Robots are entities being used more and more to both extend the human senses and to perform particular tasks involving repetition, manipulation, precision. Particularly in the first case, the wide range of sensors available today allows a robot to collect several kind of environmental data (images and sound at almost any spectral band, temperature, pressure...). Depending on the application, such data can be internally processed for achieving complete autonomy [1, 2] or, in case a human intervention is required, the observed data can be analyzed off-line (robots for medical imaging, [3]) or in real time (robots for surgical manipulations such as the da Vinci Surgical System by Intuitive Surgical Inc., or [4]). An interesting characteristic of robots with real-time access is to be remotely managed by operators (Teleoperation), thus leading to the concept of *Telerobotics* [5, 6] anytime it is impossible or undesirable for the user to be where the robot is: this is the case when unaccessible or dangerous sites are to be explored, to avoid life threatening situations for humans (subterranean, submarine or space sites, buildings with excessive temperature or concentration of gas).

However, any teleoperation task is as much effective as an acceptable degree of immersion is achieved: if not, operators have distorted perception of distant world, potentially compromising the task with artifacts, such as the well know

tunneling effect [7]. Research has focused in making Teleoperation evolve into Telepresence [8, 9], where the user feels the distant environment as it would be local, up to Telexistence [10], where the user is no more aware of the local environment and he is entirely projected in the distant location. For this projection to be feasible, immersion is the key feature. One way to achieve a high degree of immersion is Virtual Reality [11–13]. Virtual Reality (VR) is used in a variety of disciplines and applications: its main advantage consists in providing immersive solutions to a given Human-Machine Interface (HMI): the use of 3D vision can be coupled with multi-dimensional audio and tactile or haptic feedback, thus fully exploiting the available external human senses. The relatively easy access to such interaction tool (generally no specific hardware/software knowledge are required), the possibility of integrating physics laws in the virtual model of objects and the interesting properties of abstracting reality make VR the optimal form of exploring imaginary or distant worlds. A proof is represented by the design of highly interactive computer games, involving more and more a VR-like interface and by VR-based simulation tools used for training in various professional fields (production, medical, military [14]). Collaborative teleoperation is also possible [15] thanks to this framework, because through VR more users can interact with the remote robots and between them. With VR the door for immersive exploration are open: a typical scenario in which a thorough, continuous, detailed, immersive exploration is needed is represented by places rich of artistic content, such as rooms of any size where walls, possibly hosting paintings, ceiling and floor are the target of the user attention. Furthermore, such space can be enriched by sculptures or other objects which make the immersion more necessary, as their perception through still pictures risks to be most of the time "flat". In this work we propose a VR-based approach to achieve Telexistence using mobile robots to explore a distant place which is rich in artistic content. The reminder of this paper is organized as follows: Section 2 details the common features between VR and art, while Section 3 analyzes the currently use art and Robotics. In 4 we present our general scheme for mixing Telerobotics and VR. Finally, discussion and future work are stated in Section 5.

## 2 Virtual Reality and Art

The connection between art and Virtual Reality is evident: VR is an evolution of computer graphics, which is a discipline strongly relying on images. In turns, images are one of the fundamental languages of art [16]. Well-designed interfaces can thus efficiently "trick" the user's senses and convey a visual 3D sensation

Virtual museums are a very useful way to convey artistic content to remote users over the internet. Examples are Visita 3D of the Galleria degli Uffizi <sup>1</sup>, where a certain degree of immersion is provided by a 360 degrees reconstruction from several pictures. This technique shows two main drawbacks: first, the observation considers a single viewpoint, thus preventing a realistic sensation of

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<sup>1</sup> Visita 3D, Galleria degli Uffizi, <http://www.polomuseale.firenze.it/musei/uffizi/filmati.asp>

movement; second, objects are distorted when they reach the interface borders, thus making this immersion implicitly limited. A more precise idea of the user location inside a museum can be given by adding a 2D map of the room currently visited, as in <sup>2</sup> Another approach consists in creating a purely virtual environment, as made in <sup>3</sup>: immersion is somewhat given by pre-loaded movements the user can choose while navigating from one room to another or across floors (an elevator can be simulated); this ensures a nice sensation of movement, but little faithfulness to reality. Some fixed views of the artistic content are an efficient approach to paintings galleries: in <sup>4</sup> simple pictures from a single viewpoint illustrate a number of artworks the user can click on, thus accessing higher resolution pictures. This approach gives no movement sensation, but conveys a strong and detailed content of the artwork. Recently the Museo del Prado (Madrid, Spain) made ultra-high resolution pictures (up to 14 Gpixels) freely available over the Internet through Google Earth <sup>TM</sup>. To the best of our knowledge, the more complete compromise between immersion and detail is represented by the *Musée du Louvre* <sup>5</sup>, which reconstructs real environment with textures and allows users both to freely navigate and to zoom on higher resolution artworks. The freedom of movement helps the user to locate himself in the virtual room. We point out that the perception of the artwork depends also on the enclosure containing the artwork: very often the enclosure *is* an artwork itself. Furthermore, in the last years the digital representations have become a form of art themselves [17, 18]: the so-called *Net.Art* is thus a new way to make Virtual Reality a potential artwork together with an immersive mean of access.

By stating the problem from the standpoint of immersion in a distant world where the artwork is located, the following means of access can be available: pictures (at various resolutions), a whole website, a pure virtual model of the world, a webcam. We believe that the degree of immersion is related much more to a realistic sense of movement and direction rather than the quality of the representation: in fact, a low-res webcam, possibly panned and tilted by the user, offers much more sense of *being there* rather than a very well equipped website, because the piece of information is unique in the moment the user experience it. *Real movement* and *synchronization* are thus the major drawbacks in the state-of-the-art systems which prevent a true remote user immersion. We believe, as we will see in section 4, that Telerobotics can overcome such drawbacks.

### 3 Robotics and Art

Robots have been successfully used in the past years as a link between humans and art. A first kind of use are robot-guides: in [19, 20] prototypes of robots interact with users, each with a good level of autonomy (obstacle avoidance, path

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<sup>2</sup> Van Gogh's Van Goghs, Virtual Tour, National Gallery of art, <http://www.nga.gov/exhibitions/vgwel.htm>

<sup>3</sup> Museo Virtuale di Architettura, Regione Campania et al, <http://www.muva.it>

<sup>4</sup> Galleria Virtuale, Carlo Frisardi, <http://www.cromosema.it/arte/>

<sup>5</sup> Musée du Louvre en 3 dimensions, Musée du Louvre, <http://www.louvre.fr>

planning, simultaneous localization and mapping). Research is also focusing on how such robots can gesture similarly to humans [21], either in an autonomous way or remotely guided by an operator [22]. Recently, some products are available on the market [23]. A second, more challenging kind of use are robot-explorers of artistic sites: the problem of perceiving art through an interface is clearly more difficult to face: some researchers [24, 25], within the framework of the Minerva and Rino projects, have added to their robots a web-based interface which informs the user on the robot's current position, all by providing instant pictures of the robot camera. Other studies [26] implied visitors who could pilot a small rover in a small environment, but relying on the fact that the operator could both see the interface and the real scene. Perceiving a remote exhibition is undoubtedly a challenge: if the problem is effectively solved, then artistic resources would be available to millions of people, connecting through a highly scalable system. In this paper we focus on the second kind of robots, even if we are aware that every explorer robot must have an impact on the public possibly visiting a museum or an exhibition. Though effective solutions have been proposed, there seem to be no research involving a deep immersion of the operator while performing his/her exploration task.

## 4 Mixing Telerobotics and VR

We point out that the VR-oriented approach used in the *Musée du Louvre* is still limited, because the virtual environment lacks any natural light conditions. Another interesting point is that the user is always alone in exploring such virtual worlds. The technologic effort to make an exploration more immersive should also take into account such human factors: should navigation compromise with details when dealing with immersion? We believe this is the case. Does the precise observation of an artwork need the same precise observation during motion? Up to a certain degree, no. We propose a platform able to convey realistic sensation of visiting a room rich of artistic content, while demanding the task of a more precise exploration to a virtual reality-based tool.

### 4.1 Deployment of the ViRAT platform

We are developing a multi-purposes platform, namely ViRAT (Virtual Reality for Advanced Teleoperation [27][28]), the role of which is to allow several users to control in real time and in a collaborative and efficient way groups of heterogeneous robots from different manufacturers, including mobile robots built in IIT. Virtual Reality, through a Collaborative Virtual Environment (CVE), is used to abstract robots in a general way, from individual and simple robots to groups of complex and heterogeneous ones. Robots virtually represented within the interface of ViRAT are thus the avatars of real robots, with a shared state and an updated position in the virtual world. The advantage of a VR-based approach offers in fact a total control on the interfaces and the representations depending



**Fig. 1.** A robot, controlled by distant users, is *visiting* the museum like other *traditional* visitors.

on users, tasks and robots. Innovative, user-oriented interfaces can then be studied using such platform, while inter-sensory metaphors can be researched and designed.

We deployed our platform according to the particularities of this application and the museum needs. Those particularities mainly deal with high-definition textures to acquire for building the virtual environment, and new interfaces that are integrated into the platform. In this first deployment, consisting in a prototype which is used to test and adapt interfaces, we only had to install two wheeled robots with embedded cameras that we have developed internally (a more complete description of those robots can be found in [29]), and a set of cameras accessible from outside through the internet (those cameras are used to track the robot, in order to match virtual robots' locations and real robots' locations). We modeled the 3D scene of the part of the museum where the robots are planned to evolve. The platform uses a peer-to-peer architecture, where the VR environment and the control routines are installed both at the teleoperator side and in the remote artistic place of interest, while the latter hosts the tracking cameras. The teleoperator thus uses the internet to connect to the distant computer, robots and cameras. Once the system is ready, he/she can interact with the robots and visit the museum, virtually or really.

## 4.2 Usage of Telerobotics and VR for artwork perception

As previously underlined, existing works with VR offer the ability to virtually visit a distant museum, but suffer from the lacks of a complete set of sensory feedback: first, users are generally alone in the VR environment, and second, the degree and sensation of immersion is highly variable. The success of 3D games like *second life* comes from the ability to really *feel* the virtual world as a real world, where we can have numerous interactions, in particular in meeting other *real* people. This sensation is active at the cognitive level, since the interface would be the same if the avatars were not driven by humans. Moreover, when a place is physically visited, a certain atmosphere and ambience is felt, which is in fact fundamental in our perception, memory and, thus, feeling. Visiting a very calm temple with people moving delicately, or visiting a noisy and very active market would be totally different without those feedbacks. The kind and degree of immersion is a direct consequence of these aspects. Thus, *populating* the VR environment is one of the first main needs, especially with real humans *behind* those virtual entities. Secondly, even if such VR immersion gives a good sensation of presence, so of a visit, we're not really visiting the reality. Moreover, virtual characters of *second life* do not really mirror their users: the reasons for this mismatch are sociologic and behind the scope of this paper; however a fully immersive environment would, on the contrary, create a bijection between the *reality* and the *virtuality*. This is what we intend to do and believe being more effective. Seeing virtual entities in the VR environment and knowing that behind those entities a very similar real world is represented, directly increases the feeling of really visiting, being in a place. This is especially confirmed when the operator can anytime switch between virtual world and real world.

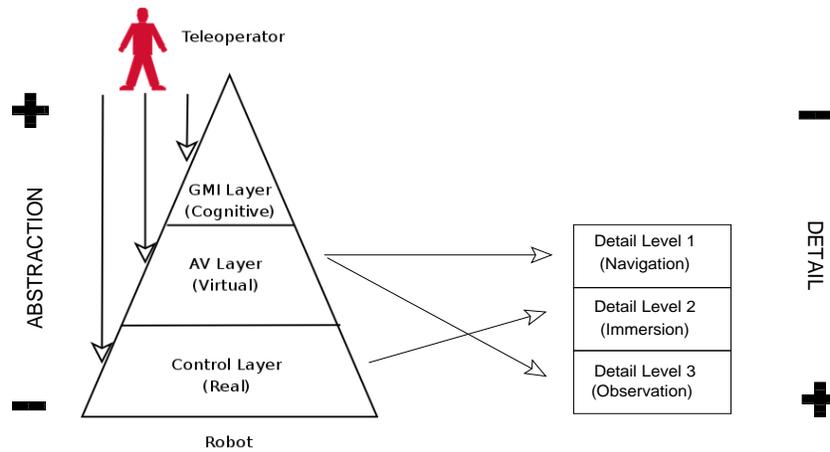


Fig. 2. Different levels of abstraction mapped into different levels of detail.

Following those comments, the proposed system mixes VR and Reality in the same application. Figure 2 represents this mix, and its usage.

On the left part, the degrees of immersion are represented, while on the right part, the level of details are depicted. Our approach is to split the degrees of immersion in three layers[28]: Group Management Interface (GMI), Augmented Virtuality (AV) and Control, in order of decreasing abstraction capability:

- First, the GMI layer, gives the ability to control several robots. This level could be used by distant visitors, but in the actual design it's mainly used by people from the museum to take a global view on robots when needed, and to supervise what distant visitors are doing in the real museum.
- Second, the AV layer -*Augmented Virtuality*- allows the user to freely navigate in the VR environment. It is called *Augmented Virtuality* because it includes high-definition textures, coming from real high-definition photos of the artworks (e.g. paintings). This level offers different levels of interactions: precise control of the virtual robot and its camera (so as a consequence, the real robot will move in the same way), ability to define targets that the robot will reach autonomously, ability to fly through the 3D camera in the museum, etc.
- Third, the Control layer. At this level, teleoperators can control directly the robot wheels or camera. Users can directly watch the environment as if they were located at the robot's location. This level is the *reality* level, the users are immersed in the real distant world where they can directly act.



**Fig. 3.** Detail Level 1 is purely virtual: it is the equivalent of the real environment and it includes the robot avatar.

On another hand, on the right part of the figure 2, the level of details represent the precision the users perceive of the environment:

- Detail Level 1 mainly represents an overview of the site and robots for navigation. Figure 3 shows the bijection between virtual and real, thus the use



**Fig. 4.** Detail Level 3 (high detail) is purely virtual, with high-resolution pictures as textures. This one is used in the scene of Figure 3

that a distant visitor can make of the virtual world as an abstraction of the real world.

- Detail Level 2 represents the reality, seen through the robots' cameras. At this level of detail, users are limited by the reality, such as obstacles and cameras' limitations. But they are physically immersed in the real distant world.
- Detail Level 3 is used when distant visitors want to see very fine details of the art-paintings for example, or any art-objects that have been digitized in high-definition. We can see in figure 4 a high-definition texture, that a user can observe in the virtual world when he/she wants to focus the attention on parts of the art-painting of the figure 3, that could not be accessible with the controlled robots because of technical limitations (limited dimensions of the robots, limited resolution of the on-board camera system).

When distant visitors want to have an overview of the site, and want to easily move inside, or on the opposite when they want to make a very precise observation of one art-painting for example, they use the Detail Levels 1 and 3, in the Virtual Environment. With this AV level, they can have the feeling of visiting a populated museum, as they can see other distant visitors represented by other virtual robots, but they do not have to fit with real problems like for example occlusions of the art-painting they want to see in details due to the crowd, or displacement problems due to the same reasons.

On another hand, when visitors want to feel themselves more present in the real museum, they can use the Detail level 2. This is the point where we mix Telerobotics with Virtual Reality in order to improve the immersion feeling. In

Figure 5, a robot observing one art-painting is depicted. This implies that a first distant visitor is currently observing through the robot's camera the *real* environment, and in particular the *real* art-painting rather than observing it in the virtual world in high-definition. Moreover, this picture corresponds to the field of view of another robot's camera: it means that a second distant visitor is actually observing the first distant visitor in front of the painting. We offer here the ability for the visitors to be *physically* present in the distant world with this Telepresence system, and to evolve like if they were really present. As a consequence, they can see the real museum and art-work, but also other visitors, local or distant, as we can see in figure 1.



**Fig. 5.** Detail Level 2 is purely real. A user is observing, through his robot and its camera, an art-painting. This screenshot comes from a robot observing another robot, thus from a user able to observe another user.

## 5 Discussion

In this paper we offered a platform to achieve exploration of artistic art sites with a high degree of immersion. This could be further enhanced by the use of stereo audio system, able to capture the remote sound. Further work is ongoing to develop this aspect. Part of our future research is to establish quantitative methods to evaluate the degree of immersion, which would represent the validation of our concept. Specifically, minimal information about a remote environment accessible in real-time may be enough to achieve a relatively high degree, while consistent information about the artworks may not require real-time constraints: in other words, where exactly the need of synchrony between the real and virtual world is located is still to be clarified. While studying the reactions of the remote operators relative to the robot use, at the same time we intend to study the ways such robots can be integrated among the ordinary visitors inside museums: specifically, would an effective telepresence motivate a past user to physically visit an artistic site? Furthermore, we intend to investigate whether the presence of a robot within the public can possibly infer some ludic aspects which would in turn make the visit more interesting for everybody. The acceptability of the system must be addressed, first of all concerning the motion planning of our explorers, then concerning the kind and size of our robots. We are aware that the more security constraints are respected, the more the acceptability is likely to increase. The accessibility of such a system can be addressed: it is important to clarify if such platform can be used by everybody or only by selected groups of people, such as schools, art and architecture university. Apart from the observation of artworks, it is within the scope of our work to find its possible direct application in active video-surveillance system when the museum is closed: in this case the operator would be a guardian, and robots would help him/her to keep much more than two eyes, which would be moving and not (almost) still as currently deployed camera systems are.

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