

Mediators: Virtual Interfaces with Haptic Feedback

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Abstract. This paper presents an interface paradigm based on the concept of mediators: simple virtual entities that serve as interface to more complex environments. We present a prototype consisting of a Haptic Workstation™ with force-feedback on both arms and hands and an HMD. The system is used to manipulate virtual objects (mediators) that play the role of a virtual interface for driving a car situated in a remote and more complex virtual environment.

1 Introduction

This paper focuses on finding better paradigms to interact and control virtual and real devices. Our work is highly related to the teleoperation of robots. Direct manipulation through controls inspired on familiar physical devices such as joysticks and steering wheels seems to be the best way to control a vehicle and similar entities. The problem with physical interfaces is that they are expensive to implement, and difficult to reconfigure to match different user requirements and/or applications. Virtual entities (3D models) can solve the problem of reconfiguration and adaptation, but also have some drawbacks. The main disadvantage of an interface based on 3D models is the absence of physical feedback. "Feeling" a control tool is essential, otherwise the manipulation requires too much effort and becomes unprecise. Haptic technologies aim at solving this problem by enabling virtual objects to provide a tangible feedback to the user.

The central idea of this paper is the concept of **mediator**: the use of 3D models with haptic feedback as an intermediary for remote control of real/virtual entities. We believe mediators are a promising alternative for implementing adaptive and reconfigurable interfaces for teleoperation.

2 State of the Art

This overview of the state of the art deals with the three main areas of study that we are trying to make converge into mediators.

2.1 Teleoperation

Teleoperation systems are targeted to remotely drive robots working in places inaccessible to the human operator: nuclear plants, submarine or extraterrestrial spaces, etc. Interaction with the remote device -robot- is typically achieved through physical controls: joysticks, steering wheels. Video cameras mounted on the robot provide visual feedback. Latter work has improved the parametrization of the interface through the use of personal computers. The computer screen is used to display the visuals coming from the "robot's eyes" and to provide graphical representations of the acquired data. The control can be enhanced through 3D reconstructions of the remote environment [1]. Recent research has taken the interface out of the PC and embedded it in a handheld device [2]. The result is kind of a remote control where the interaction controls are rather virtual (GUI on the handheld's screen). A deeper overview on vehicle teleoperation interfaces is presented in [3].

2.2 Haptics and Virtual Reality

Virtual Reality (VR) has revealed itself as an excellent tool for teleoperation applications, and combined with haptic technologies, true telepresence systems can be foreseen, letting the user not only operate at distance, but feel as being physically in the remote site.

Most of the work on haptics consists on implementing tangible interfaces with some kind of haptic feedback. Snibbe et. al. [4] propose several haptic techniques conceived to mediate and enhance the user's control of different digital media (video, audio), reproducing some of the physical properties of traditional tools into haptic devices. A more detailed overview concerning haptic devices such as exoskeletons and stationary devices, gloves and wearable devices, locomotion interfaces and full body force feedback, etc. can be found in [5]. Haptic devices and Virtual Reality tend to be used together for implementing telepresence systems. An ambitious approach, taking the use of VR and haptics to the limit can be exemplified by the work of Nitzsche et. al. [6]. The authors propose an interface for extended workspaces that permits unrestricted locomotion while interacting with remote environments represented as VR worlds with haptic feedback.

2.3 Interaction with Virtual Environments

Teleoperation through Virtual Reality worlds (Virtual Environments) requires haptic feedback to improve user's precision and perception. One of the most difficult problems on VR concerns the interaction. Researchers try to find the best way to flatten the learning curve and maximizing comfort. Interaction techniques can be classified according to their range of use into Navigation, Selection and Manipulation.

The performance of the techniques based on the virtual hand **virtual hand metaphor** or virtual pointer metaphors **virtual pointer metaphor** depends on

the task on the accuracy of selection required by the application and in particular on the notion of profiling -adapting to user preferences.

In our prototype we used the virtual hand technique due to its naturalness. Moreover, the objects we are manipulating are simple enough to minimize problems derived from the required collision detection algorithms. We keep the directly manipulated objects simple and in small numbers, ensuring a real-time response. In order to ease the interaction we incorporate force-feedback at the level of the arms and fingers through the Haptic Workstation™ [7].

We could conclude haptic feedback can be used in combination with VR to create reconfigurable interfaces that make possible complex interactions, through an intermediate layer, the mediator interface.

3 Mediators: Convergence of teleoperation, Virtual Reality and haptic feedback

Free locomotion and full-body all-senses feedback is the holy grail of remote control applications. However, there are still several problems to solve before haptic and VR technologies can be as reliable and precise as a true telepresence application requires [8].

We believe an intermediate approach using mediators can give better results. A mediator can be defined as a virtual interface used to control a more complex environment. We position ourselves in the middle of the spectrum: half the way between direct manipulation of complex objects through haptic interfaces and remote control of semiautonomous entities through GUIs -be they embedded in mobile devices or implemented in PCs. We can build familiar interaction controls with the help of VR and enhance them with haptic feedback, making them cheaper to produce and easier to readapt.

For example, the European Project VIRTUAL [9] where our lab participated, exploits the whole spectrum of VR technologies. In a fully virtual environment, users interact with a virtual representation of a car. An exoskeleton allows "touching" virtual objects. The simulator showed it is difficult for the user to have the same feeling as in reality when touching the steering wheel, because the quality of the feedback response is neither optimal nor perfect -still far from the telepresence holy grail. Manipulating virtual objects with these peripherals is difficult.

However, human operators are still more confident with familiar physical interfaces such as handles, steering wheels, and so on. The drawback of physical interfaces is that they are difficult and expensive to adapt, parameterize and reuse.

We propose to use virtual interfaces that resemble the physical devices that have been traditionally used to control a vehicle, but simplifying them so that they can be used with rather coarse gestures. This approach differs from the one taken by the works cited before in the sense that our interface mimics the physical controls, but provides assistance to the user, so that we are directing -from a higher level- rather than directly driving. Our goal is to assist on the

operation, not on training. This requires incorporating some degree of autonomy -artificial intelligence- in the controlled device, e.g. space rovers.

The virtual interface is situated in the middle of the complex environment under control and the user, see figure 1. It plays the role of a mediator, an entity that interprets the unprecise gestures acquired by the haptic interface (trackers and other sensors) and communicates them to the remote environment.

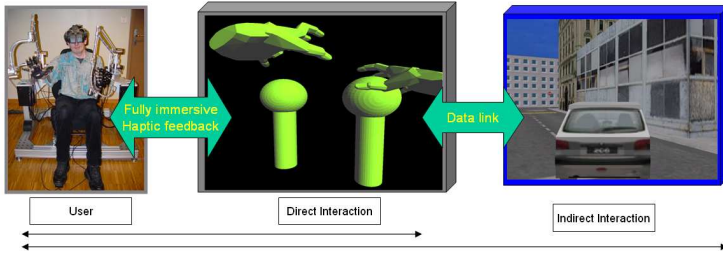


Fig. 1. Conceptual diagram of the mediator concept.

4 Test application: conducting a virtual car through a virtual interface

We chose to combine direct manipulation with indirect manipulation. The user acts indirectly on the world through the mediator. The -remote- controlled world, provides information that will allow the user to interact and take decisions. Using a virtual window rendering the remote world in this case. The mediator world communicates the information acquired from the controlled world and translates it into different stimuli: visual, acoustical, or force feedback. Therefore the concept of mediators allows for remote operation of objects situated in the controlled world. To illustrate this concept and proof its feasibility, we developed a test application to drive a car indirectly (instead of driving it with precise movements through a steering wheel, we just indicate the direction with a higher level interface).

The main system is composed of two PCs. One PC is dedicated for the "Mediator 3D World". It controls and communicates via network with the Haptic Workstation using the VHT API developed by Immersion and with a second PC which renders the "Controlled 3D world" (proprietary OpenGL viewer). The VHT API handles the virtual hands and collision between them and the 3D world. The goal of the application is to control or drive indirectly -by means of a mediator- a car in a city. For the purpose of this first prototype we limit the controls to four basic actions: move forwards, backwards, turn left or turn right. The mediator consists of a pair of 3D handles, see figure 2. The user

is immersed in a Virtual Environment through an HMD (FOV limited at 40); better to selected information) where he can manipulate the virtual handles using the virtual hand metaphor -receiving force-feedback through the Haptic Workstation- and view the car inside the city. See figure 2.

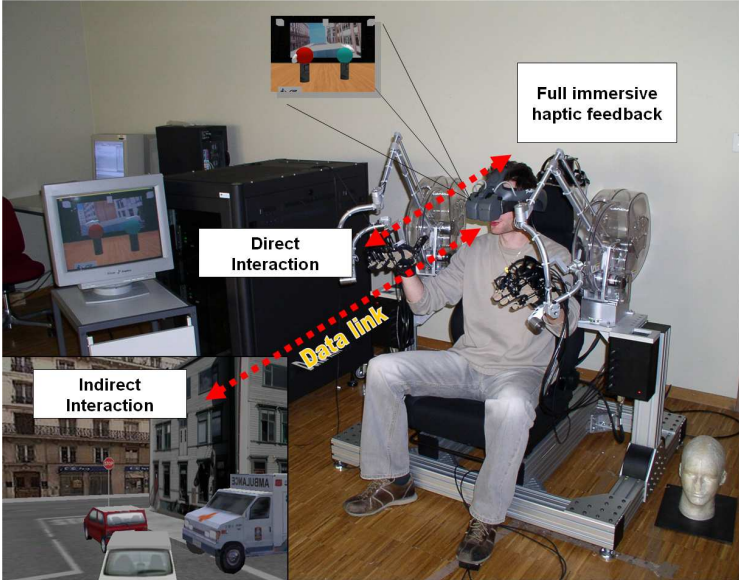


Fig. 2. System architecture and snapshots.

The user wears an HMD and a pair of data gloves while sitting inside the Haptic Workstation (HapticW) that provides upper body force-feedback. A 22-sensor Cyber Glove is used for interacting with a limited number of 3D objects representing physical interfaces in the "mediator 3D world". The Cyber Force systems apply ground-referenced forces to each of the fingers and wrists. The user can grasp the different devices of the control interface and interact with them. The car in the "controlled 3D world" executes the order. Free motion of the handle is constrained through the HapticW's arms, making the user feel that the handle truly reacts as a physical object would do.

5 Discussion and further work

Our prototype can be compared to the project VIRTUAL [9]. There the user had to drive the car in a realistic way using virtual objects. Manipulation of such controls was rather difficult. Moreover, the goal in such project was to train users for using real vehicles, our approach is to use technology for assisting in the conduction/operation of remote vehicles. With the use of mediators we

have implemented a computer-aided layer. The user is in fact manipulating the car in an indirect way in contrast with direct manipulation. We uncharge the user from the responsibilities of low-level control -changing wheels, precise motion of the steering wheel- and provide a simple way to input commands when fast decision-making is required: control of the direction to follow. We take advantage of haptic-feedback to provide a close-to-physical-world experience. We have proposed the concept of mediators as virtual intermediaries that provide simple interfaces with haptic feedback for controlling remote environments. The prototype we have presented shows the feasibility of implementing and using mediators. Informal evaluation shows the virtual interface with haptic feedback is almost as functional as a physical interface. The mediators as virtual interfaces have the great advantage of being fully parameterizable. They can be adapted to the user preferences, skills and application requirements. Further work includes defining a framework for the design and configuration of general purpose mediators. The ultimate goal is a VR system where the user can build and fine-tune his personal interface for teleoperation in virtual or real worlds.

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