How to Go Beyond the Frontiers of Haptic Interaction?

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Abstract
This paper discusses the issue of using haptic devices with limited workspaces in large immersive virtual environments. In other words, we try to answer to the following question: how to go beyond the physical limitations of the force-feedback device and reach distant virtual objects that are located outside the mechanical workspace of the device?
We describe in this paper two interaction techniques that were both designed to cope with this issue: the Bubble technique for translation motions, and the Haptic Hybrid Rotations for rotation motions. These two interaction techniques use a hybrid position/rate control of the objects. The force-feedback of the device is used to simulate the use of an elastic device when in the rate-control mode. These two techniques were evaluated in several experiments that showed both their efficient usability and positive acceptance during assembly or painting tasks.

Keywords: haptic devices, physical limitations, interaction techniques, force-feedback, hybrid position-rate control, Bubble technique, Haptic Hybrid Rotations

1 Introduction

Haptic interfaces enable users to touch, grasp and feel physical properties of virtual objects. Nevertheless, in the case of grounded interfaces such as the VIRTUOSE force feedback arm [3], these devices allow a haptic interaction only inside a given limited workspace. Therefore, the user can not reach and interact with virtual objects located outside this workspace easily.
We describe two novel interaction techniques for providing a natural way to grasp and manipulate virtual objects over a VE larger than the device's workspace: the Bubble technique [8] [9] and the Haptic Hybrid Rotations [10]. The two techniques are based on a hybrid position/rate control that allows moving the haptic workspace wherever in the VE. Position control is used around the central position of the device for fine positioning, while rate control is used at the boundaries of the device, for coarse positioning. The haptic workspace is visually and haptically delimited. These techniques allow for accurate haptic interaction over a large VE.

2 Related Work

Some software solutions have already been proposed as interaction techniques to overcome the mismatch between the device workspace and the size of the VE. A first technique is based on the concept of *clutching* [3, 4], which allows the user to perform movements in a series of grab-release cycles. When the user reaches an uncomfortable posture with the interface, he/she may press a 'declutch' button to freeze the virtual cursor/object in the VE. Then he/she can move the haptic device to a more comfortable position, and then release the 'clutch' button to unfreeze the virtual cursor. To reduce the need for clutching, a second technique consists in amplifying the user's motion, i.e. defining a *scaling* factor between the haptic workspace and the VE [2]. This scaling factor corresponds to the use of a Control/Display ratio much smaller than 1, which may exacerbate fine control. Another technique that relies on an hybrid *position/rate control* has been proposed in several robotics and teleoperation studies [5]. Position control is used around the central position of the device for fine positioning, while rate control is used at the boundaries of the device, for coarse positioning. Automatic switching between position and rate control has also been used in non haptics contexts. For instance, it is used in the "Stretch-GoGo" technique developed by Bowman and Hodges to enable users to reach and manipulate remote objects [1] in large VEs: the space around the user is divided into three concentric regions. When the user stretches his/her hand out in the outermost region, the virtual arm begins to grow at a constant speed. When brought back into the innermost region, it retracts. In the middle region the arm length remains the same.

3 Bubble Technique

The "Bubble" technique [8] [9] is a novel interaction technique to interact with large Virtual Environments (VE) using a haptic device with a limited workspace. It is based on a hybrid position/rate control which enables both accurate interaction and coarse positioning in a large VE (see Figure 1). The haptic workspace is displayed visually using a semi-transparent sphere (looking like a bubble) that surrounds the manipulated cursor. When the cursor is located inside the bubble, its motion is position-controlled. When the cursor is outside, it is rate-controlled. The user may also "feel" the inner surface of the bubble, since the spherical workspace is "haptically" displayed by applying an elastic force-feedback when crossing the surface of the bubble.

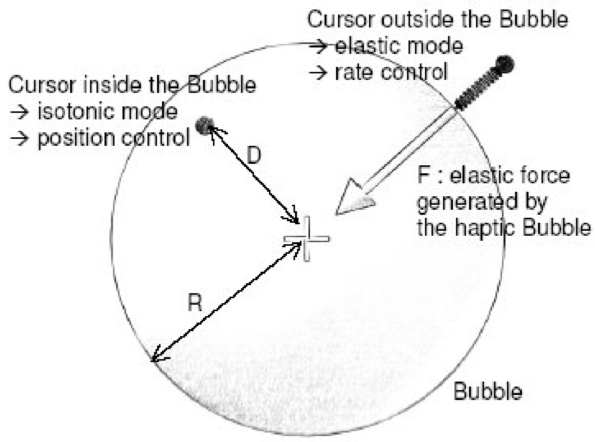

Fig. 1 - Concept of the Bubble technique

We have conducted an experiment to evaluate the Bubble technique and compare it with two other classical candidates aiming at interacting with large virtual environments using haptic devices with limited workspace: the Scaling technique and the Clutching technique. In this experiment, participants were asked to paint a virtual model as fast and as precisely as possible inside a CAVE, using a “desktop” haptic device. Our results showed that the Bubble technique enabled both the quickest and the most precise paintings. It was also the most appreciated technique.

Fig. 2 - Bubble technique: Experimental Set-Up

4 The Haptic Hybrid Rotations

As an extension of the Bubble technique, we have developed a new interaction technique called Haptic Hybrid Rotations [10] aiming at overcoming the physical angular limitations of force-feedback devices when manipulating virtual objects in rotation.

This technique is also based on a hybrid control of the object manipulated with the device. When approaching the angular mechanical stops of the device, the control mode switches again from angular position-control to rate-control. The force-feedback of the device is used to simulate the use of an elastic device in the rate-control mode.

Regarding the roll component, we chose to bind this degree of freedom with two imaginary angular springs constraining the device between two given orientations (see Figure 3). When the device operates between these two angular springs, the roll of the manipulated object is position-controlled; beyond the springs, it is rate-controlled. Regarding yaw and pitch, the space contained between the mechanical stops would be bounded by a prismatic conic-like shape. For simplification and usability purpose, we chose to approximate this shape to a cone. When the device operates inside the cone, yaw and pitch are position-controlled; outside the cone, they are rate-controlled. We propose to display the cone and the roll angular springs both haptically and visually. This choice was made to ensure a consistency between the visual and haptic spaces. In addition to the haptic display, the cone and the roll limits are displayed visually as well. An avatar of the device is also displayed to provide the user with hints regarding its orientation.

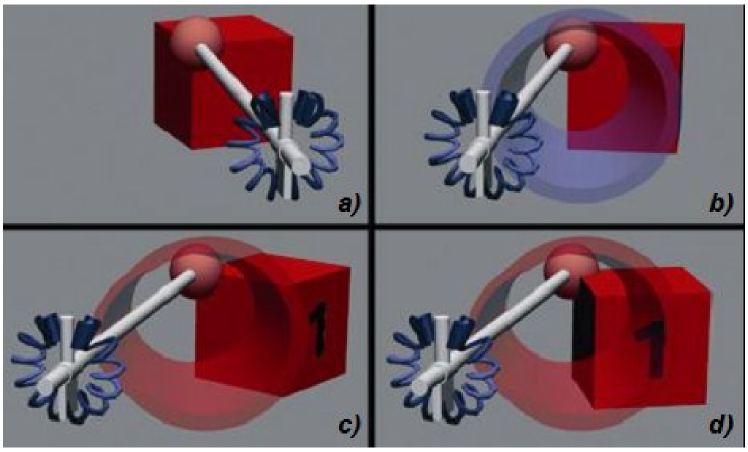

Fig. 3 - The Haptic Hybrid Rotations technique

To evaluate the performance of haptic hybrid rotations, we have conducted an experiment that consisted in building a pyramid made of several cubic bricks (Fig. 4) using a given interaction technique chosen among three different candidates (haptic hybrid rotations vs. classical scaling or clutching). Participants were asked to perform the task as precisely as possible. The performance of participants was recorded in terms of task completion time and quality of the final pyramid. Our results showed that haptic hybrid rotations were both the fastest and the most appreciated technique for the proposed experiment.

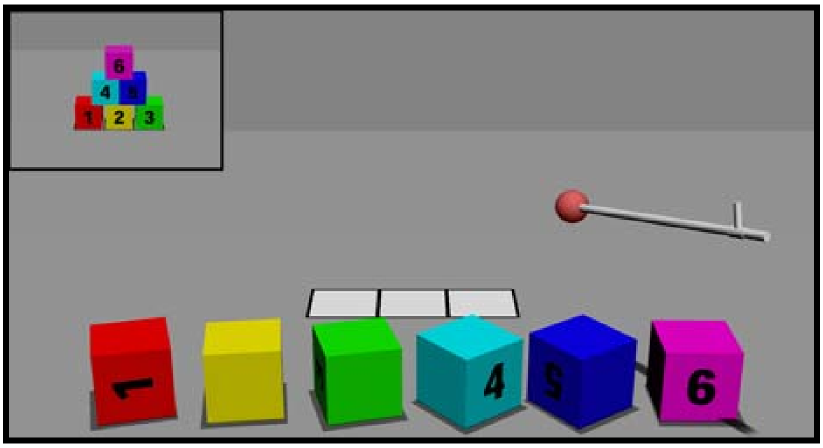

Fig. 4 - Visual display of the test application.

5 Conclusion

We have described two interaction techniques called the Bubble technique and the Haptic Hybrid Rotations designed to provide a natural way to reach and touch virtual objects in a VE larger than the workspace of the haptic device. These techniques are based on a hybrid position/rate control which allows for both accurate haptic interaction and over a large VE. The techniques were presented to the haptic devices manufacturer Haption [3] and will be available in the next release of the haptic programming interface VIRTUOSE API.

6 References

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