The "Bubble" Technique: Interacting with Large Virtual Environments Using Haptic Devices with Limited Workspace

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Abstract

The "Bubble" technique 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.

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.

1. Introduction and previous work

Haptic interfaces were shown to greatly enhance interaction with Virtual Environments (VE) [5]. Using such interfaces enables to touch, grasp and feel physical properties of virtual objects. However, in the case of grounded interfaces such as the VIRTUOSE force feedback arm [2], these devices allow a haptic interaction only inside their limited physical workspace. Therefore, the user can not reach and interact with virtual objects located outside this workspace easily.

Some software solutions have already been proposed as interaction techniques to address this issue. A first technique is based on the concept of *clutching* [2], 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. A second technique consists in amplifying the user's motion, i.e. defining a *scaling* factor between the haptic workspace and the VE [1]. However, a high amplification of the movements may sometimes exacerbate fine control and precision tasks.

In this paper, we propose a novel interaction technique to provide a natural way to reach and touch virtual objects in a VE larger than the workspace of the haptic device.

2. Description of the "Bubble" technique

To overcome the mismatch between the workspace of the haptic device and the size of the VE, we got inspired by the hybrid position/rate control described in some previous tele-operation studies [4]. 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 [4]. We adapted this approach, using the following adjustments.

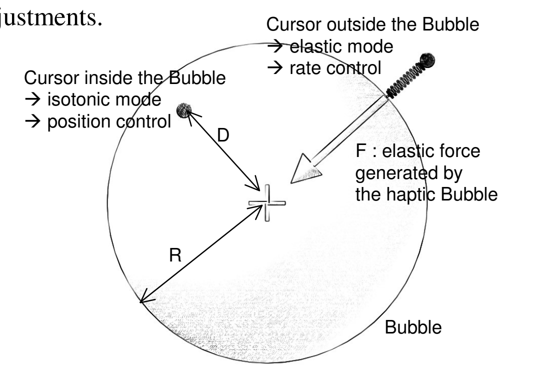

Figure 1. Control modes of the "Bubble" technique

A spherical bounding volume is defined around the neutral position of the haptic device (see Figure 1). The control mode of the manipulated object (here: the

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cursor) is switched when it crosses the surface of the bounding volume. When the cursor is located inside, its motion is position-controlled (direct mapping of the user's motion onto the cursor's motion). When the cursor is outside, it is rate-controlled, and it may reach any location of the VE very quickly.

Unlike previous implementations of hybrid position/rate control in tele-operation, we chose here to display the spherical bounding volume both visually and haptically in the VE. This double display ensures a consistency between the visual and haptic spaces.

The visual display of the bounding volume consists in a semi-transparent sphere, looking like a "bubble" (see Figure 2). The semi-transparency of the bubble improves the perception of the bubble position relatively to its surroundings [3].

The haptic display of the bubble is achieved by applying an elastic radial force as the cursor crosses the surface and goes outside the bubble (see Figure 1). The user can thus "feel" and slide on the inner surface of the bubble. The reaction force is computed using Equation (1), where k is a constant stiffness, D is the distance between the endpoint of the haptic device and the centre of the bubble, R is the radius of the bubble, and $\vec{r}$ is the normalized radial vector pointing outside the bubble (in our implementation k=200 N/m and R=10 cm).

$$\vec{F} = -k \cdot (D - R) \cdot \vec{r} \qquad (1)$$

In the rate control mode, the velocity ($\vec{V}$) of the cursor is computed using Equation (2). A non-linear control law was implemented to enable small and precise motions of the cursor as well as the ability to move the cursor in a very fast way. In our implementation, K was set to 0.03 $N^{-3}.s^{-1}$. The haptic display (elastic force) of the bounding volume is expected to improve the rate control, by simulating the use of an elastic device [6].

$$\vec{V} = K \cdot F^3 \cdot \vec{r} = K' \cdot (D - R)^3 \cdot \vec{r} \qquad (2)$$

When in rate control, the visual model of the bubble moves with the same velocity as the cursor. This preserves the relative position of the cursor relatively to the surface of the bubble, and gives the impression that the bubble is actually following the cursor.

In one implementation of the Bubble technique called **BubbleCam**, we propose to attach the camera used to render the VE to the centre of the bubble. This "camera metaphor" [3] gives the impression that the objects of the VE are moving, instead of the cursor and the bubble. With the BubbleCam technique, the user may also navigate in the VE, in addition to the haptic exploration of objects. A first advantage is that the point of view is always focused on the main zone of interest (i.e. inside the bubble: the zone of haptic interaction). The camera-metaphor also enables the use of our technique when having a visual display smaller than the size of the database of the VE (e.g. when displaying a whole car at scale 1 on a Workbench). Last, attaching the point of view to the bubble can improve the co-location of the haptic and visual spaces.

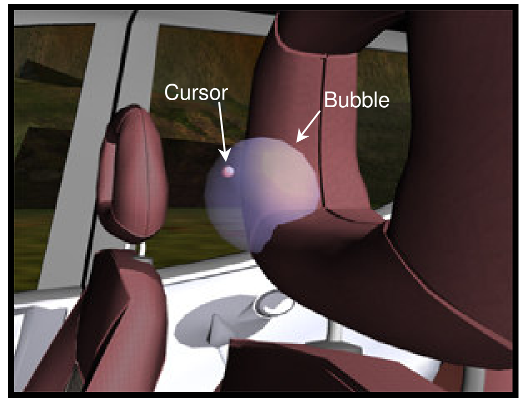

Figure 2. Visual display of the bubble in the VE.

3. Conclusion and future work

We have presented a novel interaction technique called the "Bubble" technique based on a hybrid position/rate control. This technique is useful to interact with a large VE using a haptic device with a limited workspace. The Bubble technique was presented to the Haption Company [2] and it was much appreciated. It will be available in the next release of the VIRTUOSE API [2] (the commercial haptic programming interface of Haption).

Future work will mainly consist in evaluating the Bubble technique, compared with other interaction techniques dedicated to the provision of force-feedback in large virtual environments.

4. References

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