Interaction Techniques for Object Selection/Manipulation in Non-Immersive Virtual Environments with Force Feedback

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Abstract

The interaction techniques (ITs) that are used for object selection/manipulation are very important for easier and faster user interaction with objects in virtual environment (VE). Although research in this area is very intensive, few works are interested in possibility to combine these techniques with force feedback. In this paper we present short review of ITs for immersive VE. We discuss the possibilities to apply these ITs in non-immersive virtual environment with force feedback. We also show advantages and disadvantages of force feedback in VE and we try to adapt the methods to provide with better interaction.

Keywords: 3D interaction techniques, 3D user interface, virtual environment, selection and manipulation techniques, haptics, force feedback, PHANT*o*M

1 Introduction

To perform selection and manipulation in virtual reality is not easy, because we are restricted to our arms reach. It means that we are able to select and manipulate objects that are within notably limited area in the neighbourhood to the user. Hence to realize these operations it is necessary to use interaction techniques that would allow us to accomplish given type of interaction better and faster.

In the last five years, the research of interaction techniques for object selection and manipulation for immersive VE was very progressive. But we have not found any work which tried to combine these techniques with force feedback and use it in VE applications. Adding force feedback enables users to feel the object shape and its other properties such as hardness, lubricity or weight of the object.

In this paper we deal with selection/manipulation techniques enhanced with force feedback. We especially study their properties i.e. advantages and disadvantages which occur in the presence of haptics. With respect to the features they show, we adapt them to achieve the improvement of their properties.

For realization of force feedback we have used PHANT*o*M 1.0 device. This device provides single 3DOF force feedback applied at space point in limited space.

2 Previous work

The research of interaction techniques and their modifications was focused to immersive virtual reality (VR), and later also to augmented VR. Several studies [2, 5] compared individual techniques one to another. These studies allow the user to choose appropriate technique for given type of interaction. Unfortunately, only a few of them dealt with haptic interaction in VE.

That was the reason why we chose to evaluate the interaction techniques with haptics as described bellow.

3 Interaction techniques

VE Interaction techniques extend user's workspace for object manipulation within virtual scene and they enable to select the object situated out of our physical reach. Important requirement for these methods is that they must be easy to use and learn.

The taxonomy of interaction techniques for manipulation was published by Poupyrev et al [5]. Using this taxonomy we study the usage of haptics within *egocentric* ITs, especially techniques based on *virtual hand* and *virtual pointer* metaphor.

3.1 The taxonomy of manipulation techniques

The taxonomy [5] (Figure 1) divides current manipulation techniques for VE according to their basic interaction metaphors.

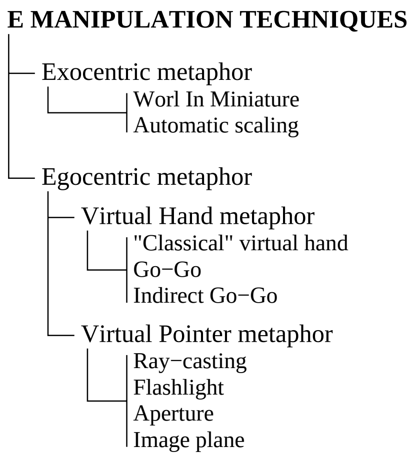

Figure 1: Classification of VE manipulation techniques depending on their underlying metaphor. Reproduced from [5].

The techniques are divided into *exocentric* and *egocentric* group. Exocentric techniques are also known as God's eye viewpoint, where user interacts with a scene from outside. An example is World In Miniature (WIM) technique [6].

On the contrary, with egocentric techniques the user is situated and interacts inside VE space shared by user and objects. These techniques are subdivided according to the metaphor they employ - either virtual hand metaphor (the user selects or manipulates the object using a virtual representation of a hand) or virtual pointer metaphor (where user interacts by pointing).

3.2 Egocentric techniques for selection and manipulation

In this section we describe the techniques that we used, other techniques are mentioned only briefly.

3.2.1 Virtual hand metaphor

With methods based on virtual hand metaphor it is possible to select the object in the case of intersection between the object and a cursor (in our experiment, the cursor follows the position of end point of PHANT*o*M's arm). These methods are subdivided to classical virtual hand technique and techniques that extend arm length in some manner.

The virtual hand technique uses direct linear mapping of physical cursor motion to motion of his virtual representation, mostly in 1:1 correspondence. It means, that selection and manipulation is realized in the same way as in the real world.

On the contrary, techniques extending arm length use either non-linear mapping or arm length is modified by some signal. The Go-Go and Fast Go-Go interaction techniques use non-linear mapping. The Go-Go technique [4] defines a local region around the user to distance D (Figure 2). While the physical cursor

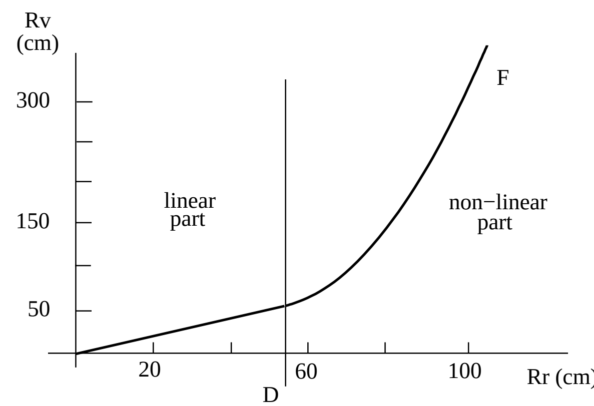

Figure 2: Example of mapping function F, for Go-Go technique. Reproduced from [4].

stays in this region, it uses linear mapping. When the cursor leaves this region, virtual representation of the cursor begins to move faster due to non-linear mapping. This way we extend range of manipulation at the expense of manipulation preciseness. Modification of this method is the Fast Go-Go technique [1] which has no local region and applies more rapidly growing mapping function. Next there belongs the Stretch Go-Go technique that extends arm length according to which region around the user the cursor is located in. On the contrary, the Indirect stretch Go-Go technique realizes the change of length using two signals.

3.2.2 Virtual pointer metaphor

With the virtual pointer metaphor, selection and manipulation is realized by a ray (ray-casting technique) [1, 3]. The ray is defined by its position and orientation. Object selection and grabbing is confirmed by the user using some signal. This technique has specific disadvantages, especially selection of very small or distant objects is complicated.

This disadvantage is solved using technique called flashlight [1] [8]. The user can select objects that are located within spotlight's cone. To select among more objects contained in the cone, it is possible to use an aperture technique [9] (Figure 3). It is modification of flashlight technique where the selection of objects within the cone is done using a collision plane (represented by aperture circle here).

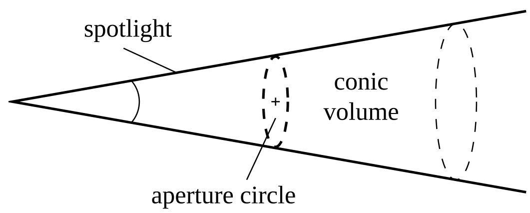

Figure 3: Aperture technique (Forsberg, et al. 1996).

3.2.3 Manipulation with egocentric techniques

To manipulate object only some methods based on virtual hand metaphor are appropriate. Especially the classical virtual technique, the Go-Go and Fast Go-Go technique [1, 4]. With the Stretch Go-Go and Indirect stretch Go-Go, the manipulation is not so easy.

From methods based on virtual pointer metaphor, the ray-casting technique [1, 3] is used to change object location. During manipulation, the object is being relocated using the ray. The change of position can be done relatively easily, but object rotation is rather difficult because we can rotate object easily only around a ray axis. Also during manipulation it is suitable to use fishing reel technique [2] [1] that allows to pull and push objects along the ray. It is realized using two buttons. The rotation around another axis can be enabled using additional signals.

4 The experiments

In our experiments we tested the properties of interaction techniques with haptics in immersive VE. Our goal was to find out if these methods allow users to interact better and faster with the virtual scene. We also wanted to discover what problems they bring along and how we can handle them.

The experiments used the virtual environment with several simple objects, such as cube and sphere, and PHANT*o*M stylus was represented by a virtual stylus (Figure 4). Position and orientation was derived from the real stylus location. Using scene geometry and collision detection application computes appropriate force and applies force feedback to user's finger in PHANT*o*M. All computations were done on dual PC system with RT Linux.

Thus, with the virtual hand metaphor, we can touch and feel the objects within the scene and select them at end-point of the virtual stylus. The object selection is confirmed when the user touches object and presses the stylus button at the same time.

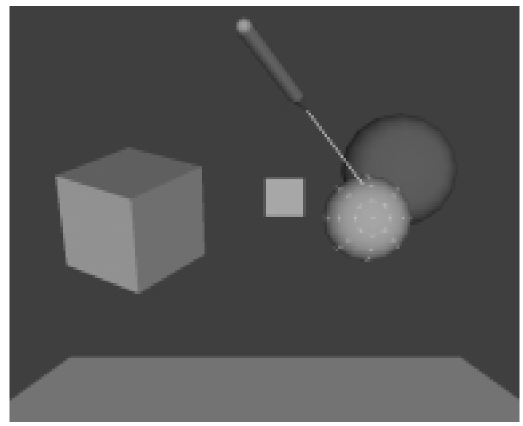

Figure 4: Example of the scene and the virtual representation of PHANT*o*M stylus.

With virtual pointer metaphor, the location of ray was determined by the position of the real stylus and direction was derived from its orientation. Thus the ray is casted from the virtual stylus and is visualized by a short segment. In this case, the user performs object selection by intersecting some object with the ray. When feeling haptic contact, user may confirm selection by pressing the stylus button.

4.1 Properties of selection techniques with force feedback

The selection task can naturally exploit contact information provided with *force feedback*. It helps to detect a contact with object in a faster and more convincing way. Here we show various approaches of force feedback application, together with assets and problems they bring along.

4.1.1 Classical virtual hand technique

This is a typical technique which is used for selection of objects most often. Here force impact is

[1] This method is also known as spotlight or also cone-casting technique

[2] This technique is also known as ray-casting with reeling.

realized in the moment, when it comes to collision between cursor and object. Repulsive force is applied by PHANT*o*M device to simulate natural haptic feeling.

The advantage of this approach is, that it allows the user to explore the scene in a given scale factor (depending on adopted linear mapping). Subsequently, the user is able to create a partial visualization of a real shape of the individual objects. Unfortunately, with this method we are restricted only to space mapped to physical PHANT*o*M space, accordingly. Moving in larger virtual space using suitable scaling we achieve faster motion of the cursor but we disallow precise manipulation in the whole scene.

4.1.2 Go-Go techniques

The disadvantage of the classical virtual hand technique is partly solved using Go-Go techniques [1, 4]. When the cursor is located in the local region this method has the same properties as previous one.

When the cursor enters outer region, a user can move deeper into the scene using non-linear mapping. The disadvantage is that, due to the non-linear mapping the distances get shorter, and object shapes appear *deformed* (Figure 5). Another problem associated with this technique shows up, when cursor approaches the borders of the maximal reach. When it collides with a distant object close to the border, the interaction with it is very sensitive and unstable. Force feedback loop detects faster and deeper penetration of cursor in an object, resulting in enormous force grows, user's reaction and unpleasant vibrations. This undesirable property can be partly eliminated using appropriate force filter included to interaction loop (e.g. quadratic filter).

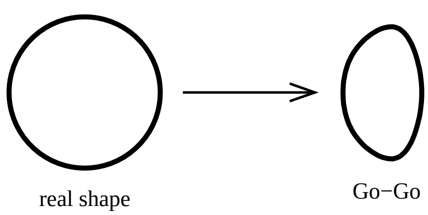

Figure 5: Shape deformation of sphere using Go-Go technique.

The next problem is occurrence of the so called *fast skidding* along an object surface when the cursor moves into the scene (Figure 6). This problem is notable especially in the case of faster motion. We tried to solve these problems by establishing the *local region* surrounding every object within the scene. When the cursor is located in such a local region, we apply linear mapping. Together with it we create a mild force barrier. This purposely created artificial force field holds the user close to the object and it helps him to not leave the object region unknowingly. Of course, it means that user would feel this force field and we experiment with its proper setting. With this approach, the user is able to recognize the real object shape, and the effect of the shape skidding is almost eliminated. Local region with force field also improves object manipulation (see section 4.2.2).

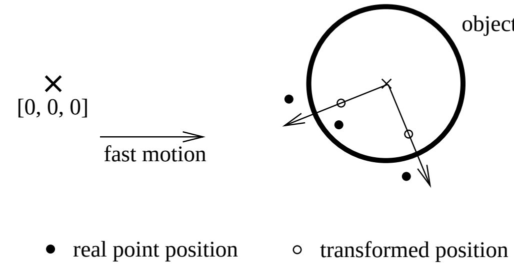

Figure 6: Fast skidding along the surface that is due to usage of the Go-Go technique.

However, this solution has also some drawbacks. The problem appears when the cursor leaves the local region of an object and non-linear mapping is again switched on. To change mappings immediately could lead to the situation when the cursor is relocated to the inside of some other object. Subsequently repulsive force changes very rapidly. This problem may be solved using an algorithm that realizes smooth transition between both types of mappings.

4.1.3 Ray-casting technique

With ray-casting technique [1, 3] there are two obvious solutions how to apply the force feedback. The first way is same as with virtual hand metaphor where the ray repulsion from the object is used. Force is applied in point that is the centroid of the ray intersections with an object. Situation is shown in Figure 7a. Using this solution, the user is partly able to recognize a profile of the object shape.

The second way is to derive the force acting against a ray motion inside the object (Figure 7b). When entering object with ray the user perceives the feeling of steering some volume with liquid. This way he/she detects, when scanning the scene, the objects with which ray collides. But in the quiescent state of the ray we do not feel any force resistance even in the collision

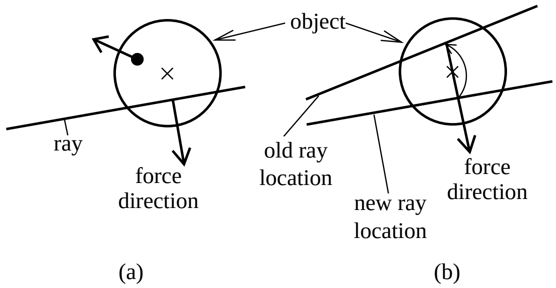

Figure 7: Applying the force when ray collides with an object. (a) Ray repulsion from the object, (b) Force acting against a ray motion inside the object.

situation. We have solved this drawback by application of a small force in direction opposite to the ray. Now we can easily detect the collision with an object even in the quiescent state. In both approaches rapid force changes may occur, which results in vibrations. It happens in the cases when ray collides with some distant object. Only a small angular change in ray's direction results in very fast penetration speed and unexpected force jumps. Here we also must use sophisticated filter, or rather an algorithm which reduces these vibrations.

4.1.4 Flashlight

With flashlight method [8] we can use both previously mentioned forms of force feedback, i.e. ray repulsion and force acting against a ray motion inside the object. When using ray repulsion feedback it may be difficult to approach some objects from some locations. To allow easy movement in densely populated space we have to either apply only a small repulsive force, or to narrow cone apex angle.

The second approach provides better and a more comfortable solution. Using the cone we may select objects easily and with supplementary force feedback both in static and dynamic form, the interaction is easier. As in previous case, the force have to be applied carefully to prevent "enemy behaviour" of interaction loop.

4.1.5 Aperture

When using aperture circle for selection inside cone space the second method, i.e. force acting against a ray motion is the preferable solution. Using this approach a user need not to strain when passing through the objects in front of object under interest. In addition, we have used two levels of the force feedback. The smaller force is used to indicate to the user that some objects are located within the cone. The second, greater force signals the collision of some object with the aperture circle (Figure 8). Again, the size of these forces has to be chosen carefully so that a user recognizes it but is not restricted in interaction freedom.

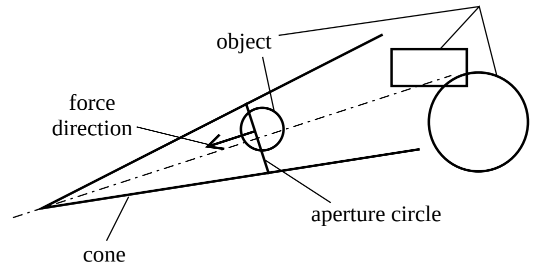

Figure 8: Usage of the force with aperture technique.

4.2 Properties of manipulation techniques with force feedback

4.2.1 Manipulation with virtual hand technique

The advantage is that this technique enhanced with haptics allows the user to relocate the object faster and with great precision. Of course the properties of 3D environments are exploited to support precise positioning. On the contrary, force feedback may extend the time of manipulation when we want to relocate object in the dense space. This situation could be solved by switching force feedback off. Unfortunately we lose haptic contact with the scene. The more preferable solution is to apply smaller forces appropriate for this situation.

4.2.2 Go-Go techniques

Manipulation using Go-Go techniques [1, 4] with haptics meets the same problems as simple virtual hand technique. Due to non-linear mapping especially in farther part of the workspace it is more difficult to achieve the precise location of the object (mostly, this problem occurs when we move one object close to another). Here we can again establish the *local region*, defined in the section 4.1.2, around all objects, and to perform more precise location of the object.

4.2.3 Ray-casting technique

Manipulation with this technique displays the similar properties as previous techniques, but in addition, another problems appear as in the case of selection. The main problem is, that a small change of the ray orientation results in a big change of distant object position. Again we can partly solve this problem using appropriate force filter which reduces vibrations.

The next question is, how to grab an object by ray. The first solution is to transfer the scene so that the ray intersecting the selected object is in its center. The second possibility is to move the object in the plane orthogonal to ray, and to pull the object to ray. This choice brings along the problem of the unexpected penetration of selected object into another one, after grabbing it. To avoid unexpected force jumps, we use dynamically growing repulsive force which, starting from zero, subsequently resolves colliding situation. And finally, the third solution we can use, is to allow grabbing the object at any place.

Only the third solution seems to be optimal, because it allows us to choose any rotation axis and to manipulate with objects quite freely.

5 Conclusions and future work

In this paper we show that well known interaction techniques for immersive VE can be naturally combined with haptics. Force feedback may improve the user's interaction in virtual worlds. Techniques enriched with haptics support faster interaction with the objects. On the other hand their usage also brings many problems. We mentioned some partial solutions of these problems, but many others still remain opened.

In the future we want to find more general solutions of problems related to combination of two interaction spaces. The first one is the visual space of immersive VE with non-linear coordinate system and the second one is the haptic space with a different and, as we found, even dynamically changing coordinate system. There are also many other techniques that we want to adapt for haptic VE (such as the WIM technique [6], Voodoo Dolls [7], etc.). We also plan to continue in the search for novel interaction techniques for VE that would allow us to interact better with VE. Long distance goal focuses on the ways of interaction that would be appropriate for visually impaired people.

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