The Use of Haptic Guide with 3D Interactions in a large Scale Virtual Environment

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Abstract

Interaction techniques play a vital role in the virtual environment's enrichment and have profound effects on the uer's performance and sense of presence as well as realism of the virtual environment(VE).In this paper we present new haptic guide models for object selection. It is used to augment the Follow-Me 3D interaction technique dedicated to object selection and manipulation. we divide the VE into three zones, in the first zone the user can freely navigate and does't need any guidance, the second zone provides visual guidance to the user near an object and the third zone gives haptic guidance very near to the object. The haptic and visual guides assist the user in object selection. The paper presents two different models of the haptic guides, one for free and multidirectional selection and the second for precise and single direction selection. The evaluation and comparison of these haptic guides is investigated.

1. Related Work

A lot of work related to interaction in the EV has already been done. Bowman [2] has carried out a detail taxonomy of object selection and manipulation based on task decomposition.

Similarly [11],[10] have partitioned the interaction into two broad categories: exocentric interaction and egocentric interaction. In exocentric interaction user interacts with VEs from the outside.The World-In-Miniature [16] and automatic scaling [5] falls in exocentric type interactions.In egocentric interaction, which is the most common case for immersive VEs, the user interacts from inside the environment. The egocentric interaction further has two metaphors: virtual pointer and virtual hand. In the first case, the user selects and manipulates objects pointing them via a vector originated from the virtual pointer [8]. For example, we may refer to the Ray-Casting technique [5]. The flash light technique [4] uses the same principle as the Ray-casting technique, but the laser pointer is replaced by an infinite cone. In the case of virtual hand [17] metaphors, virtual representation of their real hand is used which require to touch the object for selection and/or manipulated. The Go-Go technique [9] also called arm-extension technique is based on the Virtual Hand Metaphors. The PRISM [3] technique is used as an addition to other existing techniques to increase precision.

In order to make the interaction in VE easier and increase user performance, various aids like stereoscopic display, 3D audio or force feedback [19] may be utilized. In the context of assistance for 3D interaction, virtual guides [14] are valuable tools, for example in the context of teleoperation [6].

On the other hand, the haptic virtual Fixtures (virtual Fixture), currently being used only in robot-assisted manipulation tasks, are simply software-generated forces and position signals that guide the user along a specified path and/or prevent penetration into forbidden regions [1]. In these types of haptic virtual fixtures users not only have very little freedom but also lack visual guides that may reduce performance. Similarly [12] has proposed haptically augmented surgical system limiting the surgeon movement in certain areas.

2. Description of the Proposed System

2.1. Introduction

The proposed system gets its inspiration from the Follow-Me 3D interaction technique [7]. This technique divides VE into three zones, the first zone provides free and

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realistic movements in the VE (free manipulation zone), second allows a secur approach toward the target without loosing any degree of freedom (scaled manipulation zone) and finally approach to the target and manipulate it easily with high accuracy (precise manipulation zone). In precise manipulation zone the *Follow-Me* technique reduces the degree of freedom of the virtual pointer to 1DoF (i.e. only forward and backward movement is allowed) but physically the user is free and can move his hand held pointer in any direction. This may puzzle the user and may also create problems at cognitive level. To solve this problem we used haptic guides which not only provide active guidance (attractive force toward the object) to the user to select an object but also physically restricts his/her hand's movement whenever required.

2.2. Proposed Models for Haptic Guides

We start to present the spherical haptic guide. Here each object in VE is surrounded by two concentric spherical zones, having different radii. The outer sphere acts as a visual guide and is activated (becomes visible) when the condition $D_p < R_v$ becomes true and remains active till the object is selected for manipulation. Here D_p represents the distance between the virtual pointer and the object whereas R_v is the radius of the visual sphere. Similarly haptic guide activates itself when the condition $D_p <= R_h$ is true, where R_h is the radius of the haptic sphere (not visible). Once haptic guide is active, the user feels an attractive force towards the object. The haptic guide is deactivated when the above mentioned condition becomes false or the object is selected for manipulation. The magnitude F of the attractive force in haptic guide is calculated according to the following equation.

$$F = \frac{(K * R_h)}{D_p}, D_P \neq 0 \qquad (1)$$

Here $K > 0$ is a constant which signify the minimum attractive force felt by the user. Care should be taken in determining R_h, in order to avoid the overlapping of haptic sphere of two objects if they are close to each other. The force calculating mechanism is very interesting in the sense that we keep count of the user's intensions i.e. if he/she approaches towards the object, the attractive force increases as a consequence and vice versa. Here the attractive force in our haptic model provides assistance to user in object's selection but may be termed an amalgamation of both impedance and admittance [1] type guidance because if we keep the value of K not too big, we will have a small attractive force more influenced by the user's movement in the outer volume of the haptic sphere, but this effect will be opposite very near to the object.

In the second implementation we make use of cones both for visual and haptic guides, in order to confine users to select objects from a single and specific direction. The virtual pointer always emanates a laser ray in the direction of the selection. The visual guide is activated over the nearest object in virtual world through which not only the laser ray passes but the condition $D_p = L_v$ also becomes true. Here D_p is distance between the virtual pointer and object, L_v is the length of visual cone. In the active visual guide (cone), if the user further moves towards the object the haptic guide is activated when $D_p = L_h$ occurs, where L_h is the length of the haptic cone. The attractive force is calculated as follows:

$$F = \frac{(K * L_h)}{D_p}, D_P \neq 0 \qquad (2)$$

Here again $K > 0$ is constant signifying the minimum attractive force. Like the first case of our haptic guide, here also the Force increases as the distance D_p decreases and vice versa. An additional function associated with this guide is that it prevents the user to go out of the cone through its walls, once haptics are active. Therefore this haptic guide combines the characteristics of both guidance virtual fixtures and "forbidden region virtual fixtures". Granularity is an important concept associated with interaction in VE, and maps the relationship between the user's movement in the real world with that of the virtual world [7]. For example, mapping large movements (in real the world) of the user into small ones (in the VE) and vice versa, or some loss in the degree of freedom etc. may create some difficulties for the user at cognitive level, for example, when he/she can freely move the real world's pointer in all directions but the corresponding virtual pointer is restricted to move in a single direction. In our solution, once the user is inside the haptic cone, his/her movements are not only restricted in the virtual world but also in the physical world, through the force feedback device SPIDAR (Space Interface Device for Artificial Reality) [15],[18],[13], thus providing more realistic interactions.

3. Experiments

3.1. Experimental Protocol

For experiments, 20 subjects (16 M and 4 F) participated. They were master, PhD or post doc students having age from 23 to 35 years.We divided the participants into two groups of 10 persons. The first group, including 8 males and two females, performed the experiment to evaluate the spherical guide, while the second group(containing 8 males and 2 females) performed the experiment to test the second guide(hatpic cone). The VE contains four small spheres in the same vertical plane and a batton used as pointer whose movement is directly controlled via SPIDAR.The subjects were asked to select an object and place it on the red zone from where it comes back to its initial position and the user

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select it again. In this way each object is selected and displaced five times in a single trial. All users did exactly two trials of their respective experiment. Two conditions were used for the experiment. The first condition make use of stereoscopic display and visual guide while the second condition use haptic guide plus stereo and visual guide. in both groups half of the subjects performed the experiment under first condition in their first trial while the second half used the second condition in their first trial. The only constraint on the second group was to select the object from the front. We gave each user a short explanation about the task to perform and how to make the interaction with VE via SPIDAR, but no training trial was given to them. We recorded the task's completion time of each user and gave them a questionnair to fill for the subjective evaluation.The environment implementing the haptic guides is given in figure 1

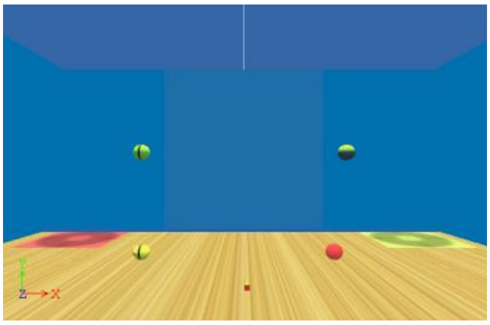

Figure 1. Illustration of the environments used for experiments

The user had to respond to each of the following questions on a scale from 1 to 7. The scale was formatted according to the table 1. 1. To what extent the object selection was easy without force Feedback? 2. To what extend do you think that force feedback provided you guidance in object selection? 3. Do you think, the interaction becomes more realistic with force feedback?

Q1	Not easy	1-2-3-4-5-6-7	Very easy
Q2	No guidance	1-2-3-4-5-6-7	Guidance of high level
Q3	Not realistic	1-2-3-4-5-6-7	Very realistic

Table 1. Scale to respond to the questions

3.2. Results and Analysis

In this section we present and analyze the results based on both task completion time and user responses collected through questionnaire.The general ANOVA for task completion time is ($F(1,9)= 12.13$, $P < 0.005$) significative. comparing the task completion time of the two visual guides,we have means 56.7 and 88.3 with std (18.5, 20.8) for sphere and cone respectively, showing non significant ANOVA($F(1,9)=12.77$,$p=0.006$).comparision of the two haptic guides (sphere and cone) give means 51.9 and 67.0 with std(13.6,10.9) respectively, having ANOVA ($F(1,9)=6.99$,$P<0.005$)as significant.comparing the performance of visual sphere with haptic one gives us means of 56.7 and 51.9 with std(18.5,13.6) respectively,for which ANOVA is($F(1,9)=1.59$,$P>0.005$)non significant.similarly if we compare visual cone vs haptic cone,we get means of 88.3 and 67 with std(20.8,10.9) respectively has significant ANOVA($F(1,9)=25.78$,$P<0.005$).The anslysis of task completion time can be seen in the figure 3.2, where :

cond 1: spherical guide(no haptic) + stereo diplay cond 2: spherical haptic guide + stereo diplay cond 3: Conical guide(no haptic) + stereo diplay cond 4: Conical haptic guide + stereo diplay

Carrying out the analysis of the mean values of the responses for the spherical haptic guide. we got the mean value for the first question is 5 with std as 1. Similarly a mean value of 5.6 has been shown in the graph for both question no.2 & 3, having std 1.1 and 1.2 respectively. It means that object selection in first condition (stereoscopic display + visual guide) is easier, but the haptic guide significantly helped user in object selection. Similarly analysing the mean of responses given to the questionnaire by the second group. We observed that the mean of the responses of the first question is 5.1 with std 1.36. In addition for the question no.2 & 3, we have mean of 5.5 and 5 with std 0.79 and 1.5 respectively. again object selection in the first condition is easier but the haptic guidance has a significant effect on the user's performance.

If we compare the task's completion time for the two groups we observe that it has increased for the second group mainly due to the object's selection from a specified direction which increased task complexity.

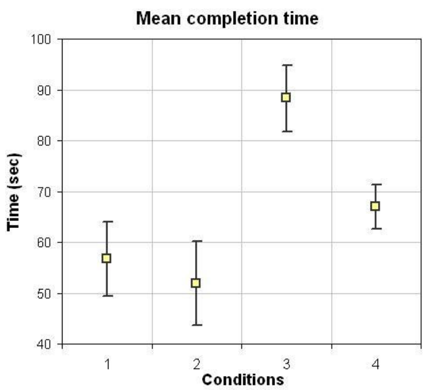

Figure 2. Illustration of task completion time & level of guidance under various conditions. for the first and second group

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4. Conclusion

we proposed two two models of haptic guides.The spherical haptic guide that provides assistance in object selection from all directions. The second is a conical haptic guide which impart guidance when the object selection is required from a specific direction. Here the guide not only gives attractive force towards the object but also resist the exit of virtual pointer through the walls of the cone.

We observed for both types of haptic guides a reduction in task's completion time, especially for the conical haptic guide.It was also noted that task's completion time increased in case of conical haptic guide as compared to the spherical haptic guide. Evaluating the subjective responses collected through questionnaire, we observed that the two groups found it easier to select object under the first condition. Similarly both the groups reported that haptic guides provided them significant guidance in object selection.Another important point is that SPIDAR can be successfully used in large scale virtual environment not only to have free movements (without force) in the environment but also to generate realistic forces if required.

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