HardBorders: a New Haptic Approach for Selection Tasks in 3D Menus

Caroline Essert-Villard *, Antonio Capobianco †
LSIIT / University of Strasbourg – Pôle API, Bd Sebastien Brant – F-67412 ILLKIRCH cedex – FRANCE

Abstract

In this paper, we introduce a 3D menu with a new technique of haptic guidance, for virtual environments. The 3D menu consists in a thin polyhedral shape, with the items at the corners. The HardBorders technique haptically simulates the collisions of the pointer with the borders of the polyhedron, making it glide towards the items of the menu. A comparison with 2 reference modalities has been performed, showing a clear advantage of our HardBorders technique.

CR Categories: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Graphical user interfaces, Haptic I/O, Interaction styles; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques;

Keywords: Haptic interfaces, Menus, Virtual reality, 3D Interaction, Computer-Human Interfaces, Force Feedback Devices

1 Introduction

In the past few years, the development of virtual reality techniques has been enhanced by the apparition of new 3D interaction peripherals . More particularly, the development of force feedback devices has known a great interest. Those peripherals are usually used for realistic tactile simulations, or as a help for 3D scenes perception.

The overall objective of our research work is to find interaction metaphors making the most of force feedback, improving the performances and the feelings of efficiency, without disturbing him with annoying functionalities. This paper presents a first study, restricting the framework to a 3D haptic menu.

2 Background

Currently, haptically enhanced interaction mainly relies on magnetic effects [Oakley et al. 2000], or as a gradient force all over the environment [Vidholm and Nystrom 2005]. When applied to menu interaction, haptics seem to bring benefits [Komerska and Ware 2004]. However most of the time classical flat 2D menus are simply adapted for 3D and enhanced with haptic clues, and the vertical disposition as in 2D screens is kept. Moreover in some cases haptics can also decrease performances for example in terms of task selection times [Oakley et al. 2001]. We propose an approach that can improve users performances and satisfaction for designation tasks in 3D environments, and can be applied to item selection in a menu.

*e-mail: essert@unistra.fr
†e-mail: a.capobianco@unistra.fr

3 3D Haptic Menu

3.1 Design of the 3D Menu

The 3d menu has been designed as a polyhedron (extruded polygon). This shape has been chosen because it is easy to extend in the future to a pile of levels, and/or a hierarchy of coplanar levels.

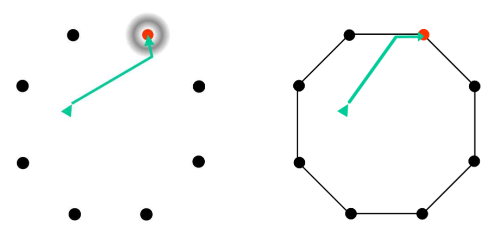
The items of the menu are represented as spheres located at the vertical edges of the polyhedron. The number of vertices/edges of the polygon depend on the number of items. The vertices are located along a circumcircle centered at the cursor initial location, and have an homogeneous distribution. The extruded polygon is lying on a 3D plane, which has been made haptically solid to guide the user within the polyhedron, help with the perception of depth, induce less muscle fatigue.

For all modalities, the modifiable parameters are: the number of items, the diameter of the circle, and the inclination of the plane. We chose to fix identical parameters for all modalities: the inclination has been fixed to 20 degrees, the number of items to 8, and the diameter to 8 cm. Of course, those values would also be interesting topics to study more precisely in the future.

3.2 Haptic Modalities

For this study, we tried 3 different haptic modalities:

- **NoHaptics**: in this modality, the only force feedback guidance is the 3D plane the pointer relies on, as for all other modalities. Apart from this, the pointer is free.
- **Magnet**: this classic haptic modality consists in simulating a magnetic attraction around the target, by attracting the device pointer towards the target when it arrives inside a certain radius of influence, as illustrated on Fig.1(a). The radius of influence around the items has been fixed to twice the radius of the spheres representing the items. The attraction is increasing while the distance to the target decreases, until a threshold of 80% of the distance, then it decreases to avoid oscillations.
- **HardBorders**: this modality consists in materializing a convex hull around the targets, as shown on Fig.1(b), and considering it as an impassable border. When a collision occurs between the pointer and the border, the pointer glides along the border until it reaches a target, or the user moves it away. The menu is seen as a convex cell, the vertices being the items of the menu, forming the constriction polyhedron.



(a) Magnet (b) HardBorders

Figure 1: *Illustration of magnet and hardborders modalities*

4 Protocol and Experimental Setup

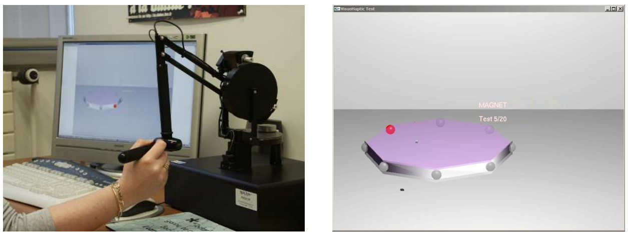
The experiment is divided in 3 series of tests (one for each modality), performed with a specifically designed application (see Fig.2(b)). Each series is composed of 20 selection tasks. Before the experiment, the subjects perform a training session. For each subject, the experiment lasts for about 10 mn. The ordering of modalities changes between subjects according to a latin square algorithm.

The menu appears centered at the point where the button is pressed. We display as a sphere the area of “safe” initial centers, to prevent the menu from having items outside the haptic workspace.

During the experiment, we store the following experimental values:

- *task completion time (TCT)*: time necessary to select the item
- *precision*: distance between the center of the target and the location of the pointer at the moment of the selection
- *number of target re-entry (TRE)*: number of times the pointer leaves the target and then goes again inside the target
- *number of axis crossings*: traversals of the line between the starting point and the center of the target

We performed our experiments using a quadri processor PC at 2,60 GHz, with a 17 inch 2D screen with a resolution of 1280*1024. The haptic device was a PHANToM Premium 1.5 (see Fig.2(a)).



(a) Experimental setup (b) Haptic menu display

Figure 2: *Experimental setup and application display*

5 Results and Analysis

The experiment was conducted on 24 subjects, with different levels of experience with haptics interfaces. We performed a post-hoc statistical analysis on the collected data. An Analysis Of Variance (ANOVA) was run to compare the techniques. The results (Table 1) clearly show a significant effect of the interaction technique on:

- *task completion time (TCT)*: $F(2, 1437) = 69.001$, $p < 0.0001$. HardBorders is the most effective technique, followed by Magnet, and NoHaptics which is the slowest.
- *precision*: $F(2, 1437) = 55.722$, $p < 0.0001$. HardBorders shows a gain of precision of 7.7% compared to NoHaptics, while Magnet leads to a gain of only 3%.
- *number of target re-entry (TRE)*: $F(2, 1437) = 2936.146$, $p < 0.0001$. HardBorders is better than NoHaptics, the result being significant with $p < 0.0001$. Surprisingly, the Magnet technique obtains the lowest performance.
- *number of axis crossings*: $F(2, 1437) = 6.752$, $p < 0.0001$. A pair-wise comparison has been run, showing significant differences between HardBorders and Magnet ($p < 0.0001$) but no significant difference between NoHaptics and HardBorders, or NoHaptics and Magnet ($p = 0.06$ and $p = 0.083$ respectively).

For all the measured data, pair-wise comparisons show that the differences between HardBorders and the two other techniques are statistically significant, except for the number of axis crossings for which only HardBorders *vs.* Magnet is significant.

We think that the better results of HardBorders compared to Magnet, both in terms of precision and target re-entry, could be due to the characteristics of the Magnet technique. Magnet can induce an unexpected drift in the trajectory of the pointer that the users cannot anticipate, as the magnetic area is not visible. This can lead to an unwanted resistance from the users that may try for a while to continue their initial movement, thus exiting the target. On the contrary, with the HardBorders technique the collisions with the visible borders can be easily anticipated.

HardBorders also obtains the best results both in terms of task completion time and number of axis crossings. We think an explanation can be that the users just have to approximately aim at the target and then let the pointer be driven by the borders towards the target. On the contrary, with the Magnet modality the user must aim more precisely at the active area to obtain the haptic guidance.

Table 1: *Mean values for the precision, number of target re-entry, task completion time, and number of axis crossings*

Modality	Precision (mm)	TRE	TCT (sec.)	Axis Crossings
HardBorders	0.460	0.496	1.125	1.308
Magnet	0.483	0.604	1.302	1.390
NoHaptics	0.498	0.585	1.348	1.478

6 Conclusion

We introduced a 3D menu with a new haptic technique. This approach, called HardBorders, consists in simulating the collisions of the pointer with the gliding borders of the polyhedral shape of the menu, leading the pointer towards the items at the vertices.

When comparing HardBorders with Magnet and NoHaptics modalities, results show a clear advantage for HardBorders regarding precision, task completion time, and the number of axis crossings and target re-entries. This suggests that the user is more comfortable with our technique, which is more intuitive (borders are visible so the gesture can be anticipated), quicker and more precise (the user does not need to focus on precision, as the pointer is guided precisely for him).

References

KOMERSKA, R., AND WARE, C. 2004. A study of haptic linear and pie menus in a 3d fish tank vr environment. In *Proceedings of International Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems*, IEEE Computer Society, Los Alamitos, CA, USA, 224–231.

OAKLEY, I., MCGEE, M. R., BREWSTER, S., AND GRAY, P. 2000. Putting the feel in ’look and feel‘. In *ACM CHI ’00: Proceedings of the SIGCHI conference on human factors in computing systems*, 415–422.

OAKLEY, I., BREWSTER, S., AND GRAY, P. 2001. Solving multi-target haptic problems in menu interaction. In *ACM CHI ’01: ext. abstracts on human factors in computing systems*, 357–358.

VIDHOLM, E., AND NYSTROM, I. 2005. A haptic interaction technique for volume images based on gradient diffusion. In *WHC ’05: Proceedings of the First Joint Eurohaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems*, IEEE Comp. Soc., 336–341.