Perceptual Cues for Orientation in a Two Finger Haptic Grasp Task

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Abstract

Single-point interaction haptic devices do not provide the natural grasp and manipulations found in the real world, as afforded by multi-fingered haptics. The present study investigates a two-fingered grasp manipulation involving rotation with and without force feedback. There were three visual cue conditions: monocular, binocular and projective lighting. Performance metrics of time and positional accuracy were assessed. The results indicate that adding haptics to an object manipulation task increases the positional accuracy but slightly increases the overall time taken.

1. Introduction

In the area of multi-finger haptics, perceptual studies are particularly sparse when compared to investigations using single-point devices. The value of multi-fingered devices seems self-evident; the use of multiple fingers allows natural interactions. Objects can be grasped, lifted and rotated and manipulated in intuitive fashions. Additionally, information regarding object properties such as weight and surface features can be gained through exploratory procedures [1]. Most perceptual studies involving haptics as a sensory modality automatically assume a multi-fingered environment. It is possible to adapt the majority of activities requiring multiple points of contact to a simpler interaction. Thus, it is important to assess the advantage, or not, of a multi-finger haptic interaction. This paper presents our initial findings in the area of multi-fingered haptic perception using two-fingered haptics in a simple manipulation task.

2. Methodology

The aim of this set of trials is to assess the contribution of the haptic sense in simple object manipulation tasks. In a within subjects design participants were required to complete a pick-and-place task that involved picking up a non-symmetrical object and placing it correctly in a defined position and orientation. The task is performed both with and without haptic feedback and with a range of visual cue combinations, as detailed in Table 1 below. The quantitative metrics of time taken and positional accuracy were used to assess performance.

Condition	Haptics	Shadows	Stereo
1	X		
2	X	X	
3	X		X
4			
5		X	
6			X

Table 1. Table of experimental conditions[1]

In the haptic conditions force feedback was provided by two Phantom 1.5 devices, in the non-haptic conditions the Phantoms were used only as positional input devices. Object to object collision detection was turned off in the non-haptic conditions.

The objects in the task were a movable ellipsoid (5cm x 4cm x 4cm mass 0.5kg) whose axis of rotation was locked around the y-axis (up) and a fixed torus.

2.1 Equipment.

Two Phantom 1.5 haptic interfaces were used running rt-linux version 2.4 on a dual processor 2.8 Xeon. The haptic update rate was 2000Hz with graphics updated at 100Hz. Haptic rendering was implemented using the friction cone algorithm [2] with maximal friction μ=20. Stiffness provided a maximum applicable force of 10N. Gravity was turned off.

Stereo images were displayed on a Iiyama 19” crt monitor and viewed using nuVision 60GX wireless shutter glasses. The focal plane was fixed midway between the torus and ellipsoid (at the start position). Shadows were created using directional lighting projected from 45° off directly above the target location (Figure 1).

[1] The standard visual display is monocular.

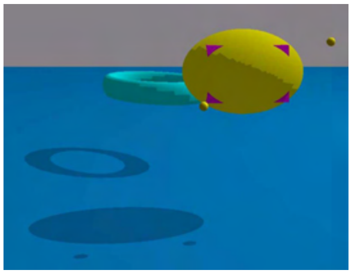

Figure 1. Screenshot of shadows condition

2.2 Procedure.

13 male postgraduate Reading university students (aged from 20 to 35 years) volunteered to take part in the experiment. All subjects had normal or corrected to normal vision. The conditions were presented in random order. In each condition there were a total of 16 trials. Four practice trials, to familiarise participants with the task, followed by 12 experimental trials. In order to reduce confounding error, both torus and ellipsoid were randomly rotated about their respective y-axis by the following angles (0° 45° 90° -45°).

Subjects initiate a new trial by contact with a start button, whereupon the ellipsoid and torus are loaded into the environment. Subjects are then required to grasp the ellipsoid and position it centrally within the torus as accurately and as quickly as possible.

3. Results and Discussions

The results show a reduction in the overall positional error when haptic feedback is introduced (Figure 2). Some of this accuracy must also be attributed to the object-object collision detection, which prevents object penetration in the haptic conditions.

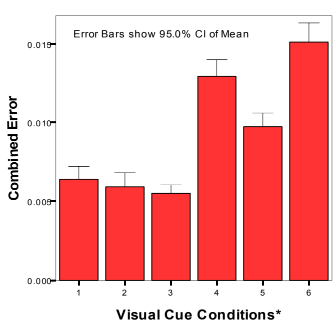

Figure 2. Combined X Y and Z error results*

The introduction of stereo appears to have no significant benefit on positional accuracy in both the haptic and non-haptic conditions. However, the results demonstrate that the inclusion of shadow cues significantly improves performance in the non-haptic condition, though this improvement comes with a significant increase in time taken (Figure 3).

Figure 3. Subjects mean total times*

Adding stereo in the absence of haptics reduces the task time but increases the positional error.

It is clear that shadows allow the subject to line the objects up in a more orthogonal way but it is less clear why adding stereo vision should reduce accuracy. It may be that by introducing stereo subjects found the task more natural and feel surer about the position of the objects, performing the task quickly may result in a loss of accuracy.

4. Conclusions

On the results analysed so far haptic feedback offers benefits in terms of improved positional accuracy compared to non-haptic conditions. The inclusion of stereo cues did not appear to offer appreciable performance benefits. The addition of shadow cues in the non-haptic condition had the effect of increasing the time taken whilst also reducing the positional accuracy.

5. References

[1] Lederman S. J, and Klatzky R.L. 1993. Extracting object properties through haptic exploration. *Acta Psychologica*, 84:29-40.

[2] Harwin., W.S. and Melder., N. 2002. Improved Haptic Rendering for Multi-Finger Manipulation Using Friction Cone based God-Objects, *Proceedings of Eurohaptics Conference*, 82-85.

* The visual cue conditions are numbered in accordance with Table 1.