Poster: Evaluation of an Approach for Remote Object Manipulation Utilizing Dynamic Magnifying Lenses

Anuraag Agrawal†  Kiyoshi Kiyokawa‡  Haruo Takemura‡

Graduate School of Information Science and Technology, Osaka University

ABSTRACT

In this poster, we present a novel approach for manipulating remote objects in an immersive environment using dynamic magnifying lenses. These lenses are created seamlessly as the user focuses his gaze on an object, expanding the target object. The expanded object can then be manipulated as if the user was standing next to it. To determine its effectiveness, this interface was evaluated against three other well-known interaction techniques - direct manipulation, Go-Go hand, and HOMER. Testing showed that the lens interface was superior in accuracy to the others, but it took more time to complete a given task.

Keywords: Immersive Environments, Interaction Techniques, Virtual Reality, Magnifying Lens

Index Terms: I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques; H.5.1 [INFORMATION INTERFACES AND PRESENTATION (e.g., HCI)]; Multimedia Information Systems—Artificial, augmented, and virtual realities

1 INTRODUCTION

There has been much work done in developing new interfaces for use in immersive virtual environments. Virtual reality is often called on to allow a user to accomplish what can only be achieved in a virtual world. For example, a CAD tool can provide a designer with a rich development environment, allowing him to see the results of the design in real-time. However, while viewing this result at a real-world scale allows for heightened perception of proportion and layout, the scale makes navigating to and manipulating distant objects difficult because in the immersive world metaphor, this would involve physically moving to the distant location, whereas a desktop metaphor would allow a simple mouse-wheel scroll.

To bridge this gap between the immersive and desktop metaphors, it is important to provide "better-than-real" mechanisms to the user, including those for manipulating distant objects. In this paper, we present a novel approach for manipulating distant objects by expanding them to the user using dynamic magnifying lenses. This approach is evaluated against three other virtual environment metaphors - direct manipulation, Go-Go hand[2], and HOMER[1].

2 DYNAMIC MAGNIFYING LENS

This interface tries to be as seamless as possible by dynamically crafting these lenses in the viewer’s sight if the user pauses his head movement for several seconds. Polygons inside the lens are shifted toward the user, who can then manipulate the object as if he was standing next to it. The lens effect is applied to the entire scene, with the shift being largest at the center and shrinking as a Gaussian function. When the viewer changes his view, the lens disappears and the object will be in its original position. This approach does not require the user to move, which takes time, or teleport, which disorients the user, while offering a large scale representation of the object that can be easily worked on.

Figure 1 shows the expansion of a target cup (green) by the lens. Note that due to the Gaussian expansion, items between the object and the user, for example, the red grid lines, get pushed to the side and behind the user.

3 USER STUDY SETUP

To evaluate the four techniques, eight graduate students were tasked with using each of the interfaces to move an object from its starting location in a 3D virtual world to a box at another location. The subject returned to an initial position at the start of every trial, and the interfaces and tasks for each interface were given in a random order to each subject. The sizes of the cup and box were about 12x12x10cm and 20x20x30cm respectively. We parameterized this synthetic benchmark by distance between the user and the object (UserObjDistance) and distance between the object and its destination (ObjDestDistance). UserObjDistance consisted of three ranges, near [0.1, 0.5], medium [0.5, 3.0], and far [3.0, 10.0], with all values being in meters. ObjDestDistance consisted of two ranges, near [0.5, 1.5] and far [1.5, 4.5]. As direct manipulation is unable to interact with objects outside the space of the tracker, we limited it to only the near and medium UserObjDistance values and the near ObjDestDistance value. Preliminary trials with Go-Go hand also resulted in incredible difficulty handling objects at far ranges, so UserObjDistance was restricted to near and medium for the interface. Two parameters for the focus time until lens activation (MagicWaitTime) were tested - 1.2 and 2.1 seconds.

The time taken to complete the trial and number of clicks pressed were recorded, and the subjects were polled for their qualitative opinions relating to the experience. The experiment was conducted using the HiBall tracker system, with a tracking volume of approximately 3x3x2.4m, an Olympus MW601 VGA HMD, and a tracked stylus pointer with one button. One click of the button picked up an object, and clicking once more released it.

4 EXPERIMENTAL HYPOTHESES

1. For near distances, direct manipulation and Go-Go hand would perform similarly and provide the most intuitive inter-
face. The lens distortion is unnecessary at these distances, as is the indirect selection method of HOMER.

2. For medium distances, direct manipulation will become tiresome, but Go-Go hand will be able to reach the objects easily. HOMER’s ray selection will become useful, but may be less intuitive than Go-Go hand. Items are still fairly visible, so the expansion of the magnifying lens still isn’t needed.

3. For far distances, the magnifying lens can bring the object to the user to make manipulation simple. Direct manipulation won’t reach, and aiming a distant and hard to see hand (GoGo) or a ray that sweeps across space (HOMER) will be difficult.

5 Results

Variance analysis testing (ANOVA) indicated a significant difference in number of clicks for MagicWaitTime ($F = 15.962, p < 0.0001$), with 2.1 seconds ($\mu = 2.35$) being significantly better than 1.2 ($\mu = 3.34$). There were also highly significant differences between the interfaces in relation to ObjUserDistance ($F = 13.259, p < 0.0001$ for clicks, $F = 8.2375, p < 0.0001$ for time), as we predicted in our hypotheses. The results of Holm’s multiple test for the two dependent variables are shown below.

<table>
<thead>
<tr>
<th>Interface</th>
<th>Far</th>
<th>Medium</th>
<th>Near</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lens</td>
<td>2.2</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>HOMER</td>
<td>6.3</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>GoGo</td>
<td>12.2(+)</td>
<td>5.0</td>
<td></td>
</tr>
</tbody>
</table>

*p<0.05 **:p<0.01 ***:p<0.001 +:pilot study, shown for reference

![Figure 2: Holm’s multiple test between number of clicks and Interface:ObjUserDistance](image)

Figure 2 shows the result of significance testing on the data between clicks (accuracy) and the pair of variables Interface and ObjUserDistance. The results indicate that at near distances, direct manipulation performs better than HOMER, magnifying lens performs better than Go-Go, and direct manipulation performs better than Go-Go. At medium distances, we see that GoGo performs worse than all three of the other interfaces. At far distances, the lens is able to perform significantly better than HOMER.

<table>
<thead>
<tr>
<th>Interface</th>
<th>Far</th>
<th>Medium</th>
<th>Near</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>15.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lens</td>
<td>22.7</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>HOMER</td>
<td>27.6</td>
<td>***</td>
<td>**</td>
</tr>
<tr>
<td>GoGo</td>
<td>54.7(+)</td>
<td>23.5</td>
<td></td>
</tr>
</tbody>
</table>

*p<0.05 **:p<0.01 ***:p<0.001 +:pilot study, shown for reference

![Figure 3: Holm’s multiple test between total time taken in seconds and Interface:ObjUserDistance](image)

Figure 3 shows the result of significance testing on the data between total time taken and the pair of variables Interface and ObjUserDistance. These results indicate that at near distances, magnifying lens is outperformed by all three other interfaces. At medium distances, HOMER and direct manipulation both outperform the lens and GoGo interfaces. At far distances, there is no statistically significant difference between the lens and HOMER.

![Figure 4: User remarks for each interface. Except for ranking, 1 is worst and 5 is best.](image)

6 Discussion

The results for click accuracy follow our predictions for the magnifying lens. At near and medium distances, it performs averagely, but at large distances, accuracy was much higher than HOMER. This is likely due to the nature of the lens bringing the cup to the user, allowing him to grab the cup at full scale and then bring the box up close to put it in with ease; with HOMER, it was difficult to tell when the cup had entered the box because both of the objects were distant and hard to see. Go-Go hand performed worse than expected, but this is probably due to setting the mapping of the range of motion widely to cover the possible distances of the experiment.

On the other hand, when considering total time taken, the lens interface is outperformed in near and medium distance tasks, and is not able to provide a significant advantage over HOMER at long range. The majority of this time was spent trying to force the lens to be generated on the correct cup. As the lens selects the item closest to the center of the screen, when there were many objects in close proximity with the desired cup, the lens would often select these and the user would have to cancel the lens and try again.

Comments given by the participants followed along these lines, mentioning that if the selection of the item performed smoothly when using the magnifying lens, it would have been much easier to use and possibly the best interface for the current task. Users also mentioned that for the GoGo and HOMER interfaces, it was hard to figure out what their distance was relative to the box. This was likely due to the HMD not providing sufficient depth cues as well as the inherent difficulty in understanding depth at long distances.

7 Conclusion and Future Work

This user study shows that while the magnifying lens interface has potential in certain cases, the dependence on having a relatively simple scene is too tight for general use. Significant improvements need to be made in the selection of the expansion item by the lens. One possibility is to project a beam from the hand to provide visual feedback to the user during selection. When a user focuses on an object in real life, they rotate their eyes to pinpoint the target object; because eye rotation is not accounted for in the current implementation that only considers head tracking data, it is unintuitive, and therefore difficult, to select focus objects. Also, users had concerns whether it would be possible to do any real manipulation in distorted space other than simply picking up and placing an object. A study to determine the effect of the distortion on manipulation as well as finding ideal values for this and other parameters of the magnifying lens should be conducted in the future.

References
