Abstract

Emerging novel 3D interaction technologies allow precise tracking of bare hands and fingers, but due to the differences between these devices and traditional trackers, it is not clear how to design effective interaction techniques using these technologies. Using the Leap Motion Controller, we designed travel techniques with bare-hand interaction. We prototyped both unimanual and bimanual techniques using various metaphors (e.g., airplane and camera-in-hand), control mappings (position- vs. rate-control), camera movements (scene vs. camera dependent) and methods for speed control. Based on our experiences with these prototypes, we discuss the challenges and design issues for bare-hand interaction techniques. We present the results of a user study comparing the usability of five representative techniques for three travel tasks: absolute travel, naïve search and path following. We found that the limited workspace of the Leap caused movements with the camera-in-hand metaphor to be faster and less accurate, making it more effective for search but less effective for path following tasks. In addition, the Leap’s ability to precisely track small finger movements benefited the usability of continuous speed control techniques.

Keywords: Bare-hand gestures, 3D interaction, travel techniques, Leap motion controller, two-handed interaction, virtual reality.

Index Terms: H.5.2 [Information Interfaces And Presentation]: User Interfaces-Input devices and strategies.

1 Introduction

Emerging novel 3D interaction technologies are becoming more common. In particular, a new class of devices enables bare-hand interaction, in which the user’s bare hands, with no devices or wires attached, provide input via postures and gestures. A few studies have started to investigate this form of interaction. For example, Ni et al. studied menu selection using freehand gestures [1] and text entry to freehand gesture interfaces [2]. However, further research is needed to guide designers for effective technique design with emerging bare-hand interaction technologies.

Using the Leap Motion Controller as an input device, we designed travel techniques [5] for bare-hand interaction using various metaphors, control mappings, camera movements and methods for speed control [3][4][6][7][8][9]. An example is shown in Figure 1. We ran a user study to understand how the usability of different travel techniques is affected by the Leap’s characteristics. Our results indicate a significant difference of technique for various tasks, and lead us to some general observations and design guidance for both the Leap device and bare-hand interaction in general.

2 Technique Design

The Leap Motion Controller (www.leapmotion.com) is a novel 3D interaction technology, able to detect and track hand and finger position and orientation with a high level of precision. The Leap device can distinguish inputs from about 3 cm up to 50 cm from the device, and its field of view spans about 150 degrees above the device. Although the Leap device is highly capable, it has some limitations. The Leap may not recognize fingers individually if they are right next to each other or crossed over. Also, the Leap might lose tracking of the fingers and palm if the hand is rotated (rolled or pitched) by more than about 80 degrees. The amount of fatigue caused by using the Leap may also be significant.

Our strategy in designing travel techniques for the Leap was to use the user’s hand for two different metaphors: airplane metaphor (A) and camera-in-hand metaphor (C), based on [3] and [4]. Since the Leap device can recognize how many fingers are visible, we tried discrete speed control methods (M), which map the number of visible fingers to movement speed. To use the Leap’s ability to detect hand and finger position and orientation, we designed continuous speed control methods: thumb speed control (T) and gas pedal metaphor (G).

We designed both unimanual (U) and bimanual (B) techniques to have a better understanding of the usability of these types of techniques with the Leap. In bimanual techniques, we dedicated the more precise task of steering to the dominant hand and the coarser task of speed control to the non-dominant hand [7][8].

The Leap is unable to detect 360-degree rotation. If the hand is rotated more than about 80 degrees around the roll or pitch axes, the Leap may lose tracking. While position control mappings can provide a more natural control method, rate control can increase coordination and provide a smoother and steadier movement due to the Leap’s limitation [7][8]. To study these limitations, we implemented rate-controlled and position-controlled pitch and yaw.

After exploring the design space and trying many combinations of these components, we selected five candidate prototype designs to evaluate. We used both the camera-in-hand and airplane metaphors in the user study. The camera-in-hand metaphor (CU) used a direct mapping of the Leap’s workspace to the virtual world. For the airplane metaphor techniques, the forward direction of movement was defined by the current orientation of the camera. Different techniques using the airplane metaphor are shown in . Rate-controlled mappings were selected for the airplane metaphor techniques.

A position-controlled mapping was selected for the camera-in-hand metaphor to provide a natural feeling of mapping hand position and orientation to camera position and scene.
Table 1: Selected designs for airplane metaphor

<table>
<thead>
<tr>
<th>Speed Control</th>
<th>Continuous</th>
<th>Discrete</th>
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<tr>
<td>Thumb Speed</td>
<td>Unimanual</td>
<td>Unimanual</td>
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<td>Control (TU)</td>
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<td>Speed Control (MU)</td>
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<tr>
<td>Gas Pedal Speed</td>
<td>Bimanual</td>
<td>Bimanual</td>
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<tr>
<td>Control (GB)</td>
<td>Multi Finger</td>
<td>Speed Control (MB)</td>
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3 Evaluation

The goal of our study was to understand how different travel techniques were affected by the characteristics of the Leap device, so that we could give guidance to designers of such techniques. We had two main research questions:
1. How do the characteristics of the Leap affect the usability of different sorts of techniques?
2. Which bare-hand technique designs are most effective for various travel tasks?

To examine these questions, we designed an experiment to evaluate the five travel techniques for different standard travel tasks. Twelve unpaid volunteer participants were recruited for this study. The ordering of the five selected techniques (CU, TU, GB, MU, and MB) was counterbalanced. We designed three travel tasks based on [5].

The first task, absolute travel, required the user to travel from a starting position to a known target position. The second task, naïve search, required the user to search for targets in a specific timeframe. The third task was path following, in which the user was required to follow a specific path by passing through a number of rings. All of the tasks were set in a simple virtual city environment as seen in Figure 1.

We ran a one-way analysis of variance (ANOVA) on the results of the five techniques for each task. For the absolute travel task, we measured time to reach the target. We found that the effect of technique on time was not significant (p = 0.3724).

In naïve search, participants were asked to find 12 objects in a 120-second timeframe. We measured the time it took to find three (T₃), six (T₆), nine (T₉) and twelve (T₁₂) objects. We observed a significant effect of technique on efficiency for naïve search. The camera-in-hand metaphor (CU) was significantly faster than all four airplane metaphor techniques for all measured times (except TU technique for T₉). For the final time T₁₂, CU was faster than TU (p = 0.0049), MB (p = 0.0008), MU (p < 0.0001) and GB (p = 0.0014). The comparison between the camera-in-hand and airplane metaphors is depicted in Figure 2.

For the third task, the user was expected to pass through 20 rings in a 60-second timeframe. Our score function added the time for this task to a penalty of five seconds for missing a ring. We found a significant effect of technique (p < 0.0001) on path following. The four airplane metaphor techniques were significantly better than the camera-in-hand metaphor.

4 Lessons Learned

For naïve search, camera-in-hand was significantly faster in finding objects. As mentioned in section 2, the Leap has a relatively small workspace. Mapping a small workspace to a comparatively large 3D environment can result in fast travel in the environment while decreasing movement precision. In naïve search, it was more important to explore the environment quickly to find the targets than to precisely follow a given trajectory, so the camera-in-hand technique performed well despite its lack of precision.

Additionally, results indicated that the GB technique was significantly slower than the other continuous speed technique TU, for finding the first six targets in naïve search. GB and TU are both continuous speed airplane metaphor techniques but GB is bimanual and TU is unimanual. The GB technique was not significantly slower for the second half of the naïve search to find targets seven to twelve. Bimanual techniques require the user to focus on both hands. The increasing efficiency of the GB technique over time may indicate that for continuous speed control, more training is needed for bimanual techniques as compared to unimanual.

In path following, on the other hand, the airplane metaphor was significantly more efficient than the camera-in-hand metaphor. This is because the task requires precise trajectory control, and because the airplane metaphor does not require hand translation for traveling in the environment. Thus, it can be used in devices with relatively small workspaces for accurate bare-hand interaction.

Based on our experience with designing the techniques and user’s opinions, we observed that continuous speed control can provide a better user experience. Additionally the Leap’s accurate palm and finger detection ability benefits navigation for the delicate task of path following.

References


