6 Degrees-of-Freedom Manipulation with a Transparent, Tangible Object in World-Fixed Virtual Reality Displays

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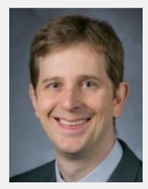

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Motivation

Inspired by historical "Specimen Jars", we propose a tangible interaction technique, "Specimen Box" [1], in which the user handles a tracked acrylic box. With this technique, the user sees the content inside the transparent box (see center image).

World-fixed displays (such as CAVE-type systems) have shown advantages for increased presence and reduced simulator sickness [2]. World-fixed displays also provide potential advantages for: group social experiences, extremely high frame rates, and unencumbered viewing via autostereoscopy.

Haptics have been shown to increase presence and heart rate. They have also been shown to reduce completion time and error rate [3]. Haptics have been more difficult in world-fixed displays because the display apparatus cannot hide the haptic device.

Related Work

Two early projects (Virtual Pallete and Transluscent Sketchpad [4]) suggest using a sheet of transparent plastic as a "tablet" in world-fixed displays. Through careful tracking of the plastic sheet, text and graphics were rendered on the plastic.

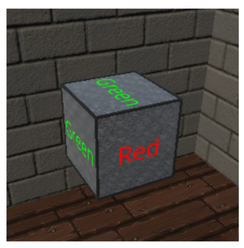
Another related work is the idea of "Object Oriented Displays". The premise was to project images onto the tangible objects. Later extensions of the idea utilize boxes, where each face of the box is an autostereoscopic screen which displays the content.

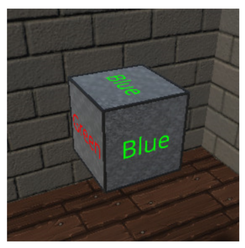
Evaluation

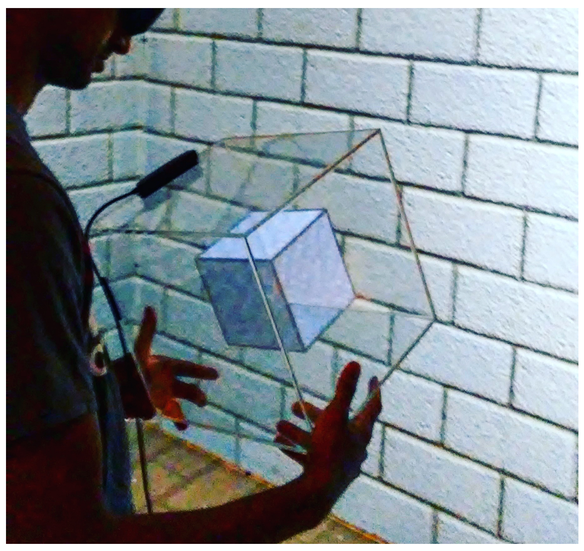
In order to evaluate the Specimen Box technique we conducted a user study to compare our technique with an existing bimanual technique called "Grab-and-Twirl" [5]. We tested 20 subjects in our CAVE-type system. We utilized a within subjects design, so all subjects evaluated each technique.

We developed a face counting task, in which the user was asked to count how many faces had a certain word. For example "How many faces have the word green?". We recorded the time to complete each trial (answer each question) and all the movements they made (how much they rotated the box).

In the most difficult condition, we utilized the Stroop effect. In this case the ink color doesn't match the textural word which increases reponse times (see image below).







Our proposed "Specimen Box" interaction technique. User handles a tracked clear acrylic box in a wold-fixed display system.

We compare our interaction technique to an existing bimanual technique "Grab-and-Twirl". Note that a virtual acrylic box is rendered.

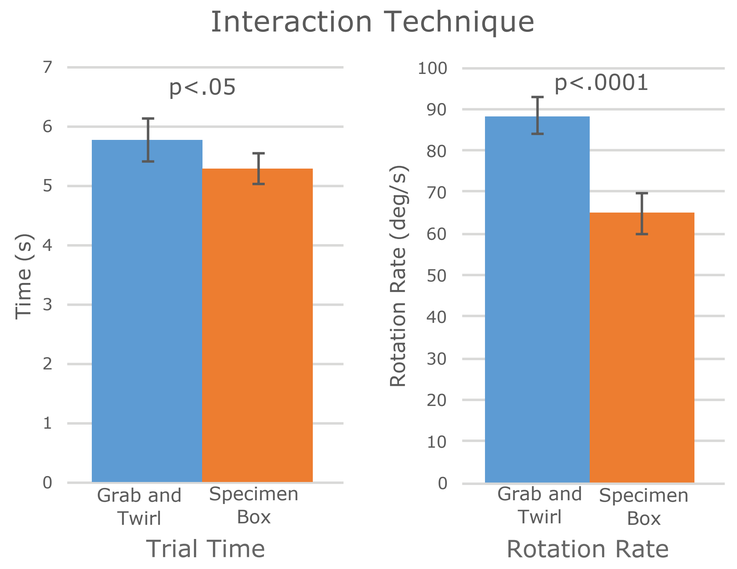
Result 1: Specimen Box allows significantly faster completions with less rotations

Lower task time for Specimen Box was statistically significant (p<.05). Lower rotation rate was also statistically significant (p<.0001)

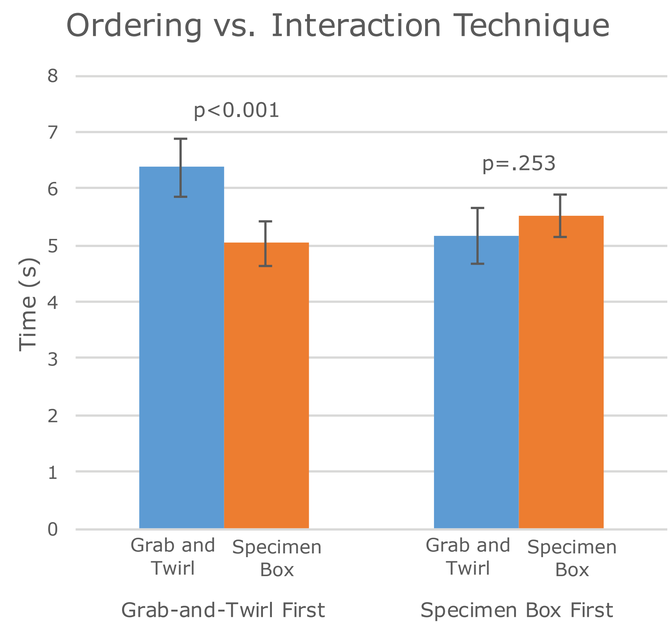
We have several hypotheses that may account for the reduction in task time and decreased rotation rate observed with Specimen Box.

- Specimen Box affords greater accuracy?
- With Specimen Box, users could leverage proprioception to keep track of which faces had already been visisted?
- When handling a weighted object, we natually try to avoid spending excess energy?

Future experiments are needed to determine what was driving the lower task time and lower rotation rate.



Result 2: Learning if Specimen Box first?



No main effect of ordering (i.e. which sequence of the technique) (p=.55). However, the interaction of ordering and technique was statistically significant (p<.005).

Pairwise comparisons showed:
GT first: SB was faster (p<.0001)
SB first: no significance (p=.253).

Our hypothesis is that perhaps when used first, Specimen Box trained the user to use a more optimal strategy?

Conclusion and Future Work

Specimen Box opens up exciting tangible interaction possibilities for wold-fixed display systems. Compared to Grab-and-Twirl, Specimen Box showed reduced task times and rotation rates.

Future work is needed to create a lighter weight box, compare other interaction techniques, and explore object translation and placement.

References:
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