Assembling and Rearranging Digital Objects in Physical Space with Tongs, a Gluegun, and a Lightsaber

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ABSTRACT

We present an interface for the arrangement of objects in three-dimensional space. Physical motions of the user are mapped to interface commands through tangible props. Tongs move objects freely, a gluegun binds objects together, and a lightsaber breaks these bonds. The experimental interface is implemented on the Responsive Workbench, a semi-immersive 3D computer. We conducted a small user study comparing our approach with the 2D interface of Maya. The results suggest that our system is much faster than Maya for object assembly. Users qualitatively found the system to be far more intuitive than the monitor-based alternative.

Keywords

object assembly, physical interface, tongs, gluegun, lightsaber, tangible tools, augmented reality

INTRODUCTION

Specifying the relative position and orientation of multiple objects in space is difficult with a mouse/monitor interface because both input and output are of lower dimensionality than the task. Three-dimensional VR-style systems have the correct number of degrees of freedom, but lack the affordances which make these actions so intuitive in the natural world.

We presented a fully tangible interface for creating 3D shapes[3], but our system allowed objects to live in only one coordinate frame. This work extends that system, allowing objects to be cut up, moved relative to one another, and reassembled. The interface presented herein brings the physical, tactile language developed in our previous system to a new task. This interface allows for a richer modeling space, and also applies to general spatial manipulation.

The testbed for this experiment is the Responsive Workbench[2], a semi-immersive stereoscopic display table. The result should carry over to other immersive display environments such as the CAVE.

TOOLS

We present four tools: two pairs of sensed tongs that place objects relative to one another, a gluegun that binds shapes so they move as one, and a lightsaber that cuts these bonds allowing recombination. The tongs were described in our

previous article[3]. They work just like they do in the kitchen or at the barbecue – when they are closed around an object, the object moves with them. Users found them very intuitive, so we used a similar philosophy for our new devices: hack a familiar tool.

Gluegun

A hot glue gun emits glue which joins lightweight physical objects, such as pieces of cardboard. We have made an analogous gun which allows shapes to be attached to one another, after which they move in the same transformation frame. The glue is displayed to visually reinforce this relationship, although the user can choose to place the glue less visibly. As the gluegun is waved in the air, a line from its tip visually suggests a possible bond location. On clicking the trigger, it attaches at this point. Another click completes the glue bond.

Lightsaber

A lightsaber is used in the internationally known film Star Wars as both weapon and cutting tool. Our saber consists of a physical handle, with a switch that causes the light beam to be extended or retracted. The light beam is emitted in digital space, allowing the user to cut despite inaccurate trackers. The saber cuts through glue bonds, allowing objects to be individually moved. This metaphor is preferable to scissors, since scissors act through haptic resistance which is lacking in this system. The imagery of light makes the saber well suited to the environment of weightlessness.

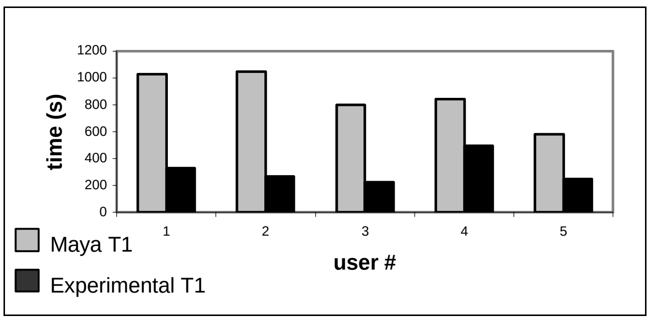
EXPERIMENT

A small, informal study compares the experimental interface with Maya, a popular commercial 3D modeling package that works with a mouse and 2D screen. Quantitative performance times, and qualitative times from a survey are presented.

Maya's interface is too complex to describe here in full. For our study, we taught users to use the Move and Rotate tools, to navigate the scene using Alt-Shift and the mouse buttons, and to bond the pieces together using the Parent and Unparent commands. We taught users to visualize grouping relationships with the Hypergraph.

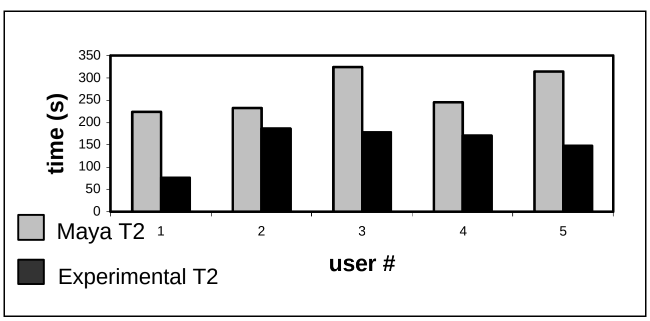
Task 1 (T1)

We presented the users with eleven pieces of a stick figure, laid out in a row, and asked them to combine them to form a skeleton. The pieces were: one head, one torso, one skirt, two legs (straight lines), two shoes, two arms (bent at the elbow) and two hands. We asked the users to place them in a position so that the arms were in a pose (not parallel to the torso). This forced the users to rotate the hands.



Task 2 (T2)

Continuing with the shape built in task 1, we asked the users to move the shoes so that they were bound to the wrists, and the hands to the ankles. This exercised the lightsaber/unparent features which break bonds. Since we had asked the users to pose the arms gesturally, this command also forced them to rotate both hands and feet.



RESULTS

One of the users (#4) had experience with commercial 3D modeling software. None of them had experience with virtual reality. We timed the trials and asked for a brief typed comment. The full comments, along with the data are online at http://www.cs.caltech.edu/~ss/lightsaber.

Task completion was faster in every case in the experimental system. The data suggest (although are too few to prove) that the experimental system allows objects to be placed much more quickly than the commercial state-of-the-art.

The affective, emotional part of a user's experience is as important as speed and productivity. Direct quotes from the user surveys qualify the experience. Users had a lot of difficulty getting a sense of space with Maya:

> To visually determine the location of a shape I had to rotate the screen several times; it was hard to translate the 2D picture into 3D.
>
> Maya system was frustrating and difficult to really see what I was working with. In the experimental system I never had this problem. The experimetal [sic] system is superior to maya in every way.
>
> It was very intuitive how to use the [experimental] program because it was almost exactly like putting together tangible objects.

We encourage readers to see the full comments online.

ANALYSIS

This interface argues:

- Motions of the body are a powerful mode of interaction that is at once intuitive, quick, and versatile.
- The physical affordance of props builds an immediate intuition.
- 3D is important for object manipulation.
- Virtual space is best when it acts in terms of real space.

We envision a system where a user would choose their working set of props before starting to do a certain task. The other tools, wireless, could rest in a cabinet out of sight. This approach to interface allows a toolset to be specialized to individual users, with a physicality that builds intimacy.

In the future we will incorporate this interface into our modeling system. We are also interested in scientific applications, such as building molecules and DNA configurations. These applications, which require a sophisticated understanding of space, will surely benefit from the intimacy that physical immersion in a tangible space provides.

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