Enjoying Virtual Handcrafting with ToolDevice

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ABSTRACT

ToolDevice is a set of devices developed to help users in spatial work such as layout design and three-dimensional (3D) modeling. It consists of three components: TweezersDevice, Knife/HammerDevice, and BrushDevice, which use hand tool metaphors to help users recognize each device's unique functions. We have developed a mixed reality (MR) 3D modeling system that imitates real-life woodworking using the TweezersDevice and the Knife/HammerDevice. In the system, users can pick up and move virtual objects with the TweezersDevice. Users can also cut and join virtual objects using the Knife/HammerDevice. By repeating these operations, users can build virtual wood models.

ACM Classification: H.5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

Keywords: ToolDevice; mixed reality; woodworking

INTRODUCTION

Creating a model using most 3D modeling software is not an easy task for novice users. The user interface of the software is often complex and requires users to have knowledge of mathematics, which many users may lack. Studies have proposed new approaches to make the 3D modeling process easier. One approach is to create models using building blocks that are connected to a computer [1]. Although this approach allows users to intuitively build models, the models' shapes and sizes are limited to those of the available blocks. Another approach is to use a single device to create 3D models in an immersive 3D environment [2]. However, since the whole process of creating a 3D model is performed using a single device, users with no previous experience may have difficulty understanding how to use the device. Multiple physical devices can provide novice users clearer ideas about the possible results from using the devices [5] in AR 3D modeling system. Making the shape of the devices to resemble real hand tools helps users in recognizing how to use the devices [6].

TOOLDEVICE

In previous studies, we have developed ToolDevice, a set of devices that uses hand tool metaphors [3, 4]. ToolDevice imitates the familiar shapes and tactile sensations of hand tools that are used in everyday life. These features help novice users more easily recognize the uses and functions of the devices.
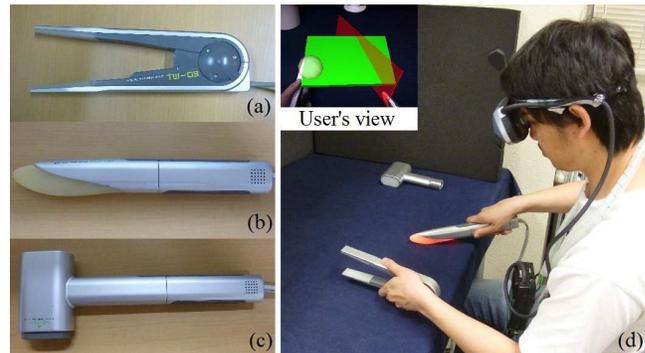
Figure 1: (a) TweezersDevice, (b) KnifeDevice, (c) HammerDevice, (d) MR handcrafting system

We developed three devices:

(1) TweezersDevice that imitates the shape of a pair of tweezers for picking up and moving virtual objects.

(2) Knife/HammerDevice, a specially designed device whose tip can be changed to that of a knife or a hammer, depending on the need. The knife tip is designed for cutting virtual objects, and the hammer tip is designed for joining virtual objects.

(3) BrushDevice that imitates the shape of a brush is designed for painting virtual objects.

In this paper, we describe an MR handcrafting system that utilizes the TweezersDevice and the Knife/HammerDevice (Figure 1).

HANDCRAFTING SYSTEM

We developed a mixed reality (MR) 3D modeling system that imitates real-life woodworking. The system is designed to help novice users create 3D models in MR space by simplifying the operations. There are three basic operations, "pick up and move," "cut," and "join" — that are explained in detail below.

PICK UP AND MOVE

First, users have to pinch a virtual object with the TweezersDevice to pick it up. Moving the TweezersDevice while still holding the virtual object moves the object (Figure 2).

To help users in assembling virtual objects, we implemented movement constraints. When a picked object is close enough to a stationary object, the picked object will snap onto the nearest surface of the stationary object. This surface is called constraint surface. Based on the number of constraint surfaces, the movement of the picked object varies from zero to six degree-of-freedom.

(a) Pick up   (b) Move   (c) Release
Figure 2: Picking up and moving a virtual object.
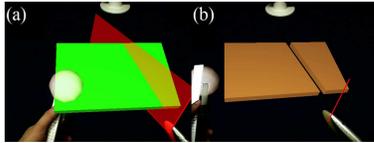
(a) Before   (b) After
Figure 3: Cutting a virtual object.

(a) Before   (b) After
Figure 4: Joining assembled parts.

Figure 5: Example of user results

For operational feedbacks, when the TweezersDevice touches a virtual object, a beeping sound effect is played and a vibration motor is activated briefly to alert the user. These signals indicate that the object can be picked up. When users pinch a virtual object, we utilize a braking system that uses a solenoid to provide force feedback.

CUT

With the knife tip, users can use the Knife/HammerDevice like a real knife to cut virtual objects. First users have to push the knife tip against the table until the LED in the tip turns red. Users can then slide the device in the desired cutting direction. A red plane is displayed to indicate the cutting direction. After users are satisfied, they have to take the device from the table to cut the object (Figure 3).

For operational feedback, a vibration motor is activated briefly when the device touches a virtual object. When users take the device from the table to cut the object, a cutting sound effect is played.
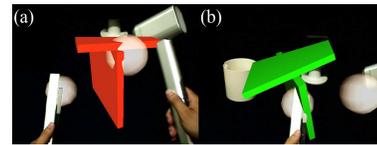
JOINING

With the hammer tip, users can use the Knife/Hammer-Device like a real hammer to join virtual objects. First, users have to assemble multiple parts by placing them so that each part touches at least one other part. After that, users have to hit the assembled model with the Hammer-Device to join the parts into one object (Figure 4).

For operational feedback, a vibration motor is activated briefly when the device touches a virtual object or when the HammerDevice hits an assembled model. A hammer sound effect is also played to indicate that the assembled model was joined.

JIG

We have developed a prototype tool that is shaped like a miter box to help users more accurately align and cut virtual objects. When a virtual object is placed on the jig, the object's measurements will be displayed on top of the jig. Currently, the jig only allows 45 and 90 degrees cut.

PILOT TEST AND DISCUSSION

We conducted an informal user study to verify the intuitiveness of our system. Six people participated in the study. First, we gave a simple demonstration of how to use the devices by showing how to build a chair. Next, we let the participants practice using the devices. After the participants understood how to use the devices, we asked them to build one model. Examples of the results produced by the users are shown in Figure 5. We also asked for comments after the participants finished using our system.

From the comments, we discovered that the participants felt that the operations are intuitive since they resemble real-life operations. However, when the devices touch a virtual object, the sensation is different from real-life operations.

CONCLUSION AND FUTURE WORK

In this paper, we have described an MR handcrafting system that allows users to create 3D models using our Tool-Device. In the future, we plan to implement more life-like haptic feedback, and add new functions such as undo, redo, object resize, etc. to make the operations easier. We also plan to build a device that allows user to cut virtual objects with various degree angles.

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