3D Haptic Modeling System using Ungrounded Pen-shaped Kinesthetic Display

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ABSTRACT

We propose a three-dimensional (3D) haptic modeling system that enables a user to create 3D models as though he/she is drawing pictures in mid-air and touch the created models. In the proposed system, we use our ungrounded pen-shaped kinesthetic display as the interface. The kinesthetic display device can generate kinesthetic sensations on the user's fingers. Because our system does not use mechanical linkages, the user can freely move his/her hand and feel the sensation of touching virtual objects. In the proposed system, the user can easily and intuitively create various 3D shapes by drawing closed curves in air using the device. The created shapes are generated in a physics-based simulation environment and are displayed as 3D images. Therefore, the user can touch and see the drawn shapes as though they exist in reality.

KEYWORDS: Haptic interface, kinesthetic display, 3D modeling.

INDEX TERMS: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Haptic I/O; H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 INTRODUCTION

In recent times, three-dimensional (3D) modeling methods have been researched extensively. Traditional 3D modeling systems are difficult to use, and only skilled users are able to create complex models. However, several intuitive 3D modeling methods that enable general users to create complex 3D models have been developed. For example, Igarashi [1] proposed a 3D sketching interface named Teddy. Teddy allows its user to create freeform surfaces and 3D models by sketching two-dimensional (2D) strokes using a mouse or a pen-tablet system. Another study related to 3D modeling using 2D strokes was conducted by Rivers er al. [2]. In this study, multiple 2D vector art drawings of a cartoon character were used to construct a two-and-a-half-dimensional (2.5D) model. The constructed model was used to simulate 3D rotations and generate reasonable renderings of the cartoon from any angle. Using the techniquies employed in the abovementioned studies, users can create various 3D models without prior knowledge of 3D modeling.

The methods used in the abovementioned studies were proposed to realize intuitive 3D modeling with 2D input devices. Another approach is to use 3D input devices such as haptic interfaces. By using haptic interfaces in 3D modeling systems, the user can treat virtual 3D models as though he/she were touching or manipulating the model in reality. FreeForm [3] is a 3D modeling system used in conjunction with a popular pen-shaped haptic display PHANToM [4]. Using PHANToM, the user can create 3D models by shaping virtual clays as if he/she were actually touching the clays displayed in the monitor. Some studies [5, 6] have also been conducted on 3D modeling systems that use PHAToM as the interfaces and allow users to create 3D models aided by visual and haptic feedback. Although the abovementioned systems consider actual 3D movements of the user's hand as input, some unavoidable problems are caused by the use of PHANToM. PHANToM has mechanical linkages that represent intimate kinesthetic sensations and must be grounded. Therefore, it restricts the user to a limited range of movements. SenStylus [7] is a pen-shaped device that provides dual-rumble feedback. When using this device, the user can move his/her hand freely, and such spatial movements are used as input. Although SenStylus does not restrict the user's movements, it can produce only vibrations as feedback, which do not generate a realistic sensation of touching a 3D model.

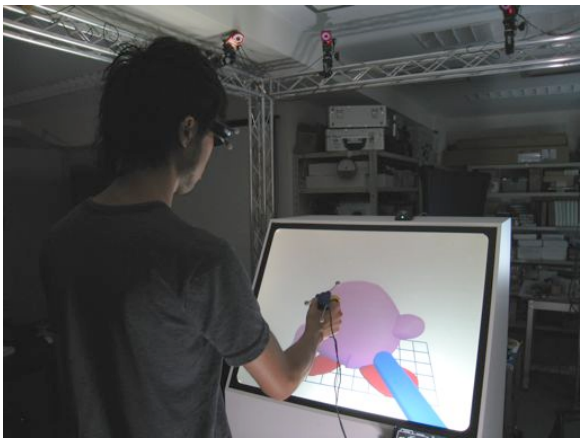

Figure 1. 3D haptic modeling system. A user can see a created 3D model thorough 3D glasses, and touch the generated model with an ungrounded pen-shaped kinesthetic display.

In our previous study [8], we proposed and implemented an ungrounded pen-shaped kinesthetic display. Although our device is ungrounded and portable, it can generate kinesthetic sensations on a user's fingers. The device consists of two parts; a grip at he position where the pen is held by the user, and a base that is attached to the user's hand. Three motors inside the base part control the three-degree-of-freedom motion of the grip, and this motion generates forces on the user's fingers. In this poster, we describe the construction of a haptic 3D modeling system that enables the user to create 3D models as if he/she were drawing them in air (Figure 1). The use of our ungrounded pen-shaped kinesthetic display as the system interface allows this system to simultaneously support a wide-range input area and provide realistic haptic feedback for intuitive object manipulations.

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2 System Overview

Figure 1 shows the constructed 3D haptic modeling system. The user wears 3D glasses (3D Vision, nVidia Corp.), holds an ungrounded pen-shaped kinesthetic display in his/her hand, and stands in front of the chassis.

In the proposed system, the introduction of an easy and intuitive modeling method is desired, and the manipulation that the user has to perform to create a 3D shape should be as simple as possible. To this end, we developed a system that allows users to create 3D models by sketching 2D figures in air. The user can draw figures in air on a virtual canvas reproduced by the system. The grip of the ungrounded pen-shaped kinesthetic display has a button that can be pushed and released to switch operations. When the user pushes the button for the first time, the virtual canvas appears at the tip of the pen. Motion tracking cameras (OptiTrack, NaturalPoint, Inc.) track the device position, and the user can place the virtual canvas at a desired position by moving his/her hand. The virtual canvas is generated in a physics-based simulation environment constructed using PhysX (nVidia Corp.) and is displayed as a 3D image. When a user touches the canvas, the kinesthetic display device generates reaction forces based on the degree of contact. Therefore, the user can draw images on the virtual canvas as if he/she were drawing on a real canvas.

To create a new shape, the user selects the desired shape from among a sphere, a box, and freeform surfaces. Then the user sketches a 2D figure of the desired shape on the virtual canvas, for example, a circle, rectangle, or free closed curve. The motion trajectory of the tip of the pen is recorded for the time that the input button is pushed and held. Based on the tracked trajectory, parameters of the shape are calculated and the desired shape is created in the physics-based simulation environment (Figure 2). Thus, 3D shapes were successfully created by sketching 2D figures in air.

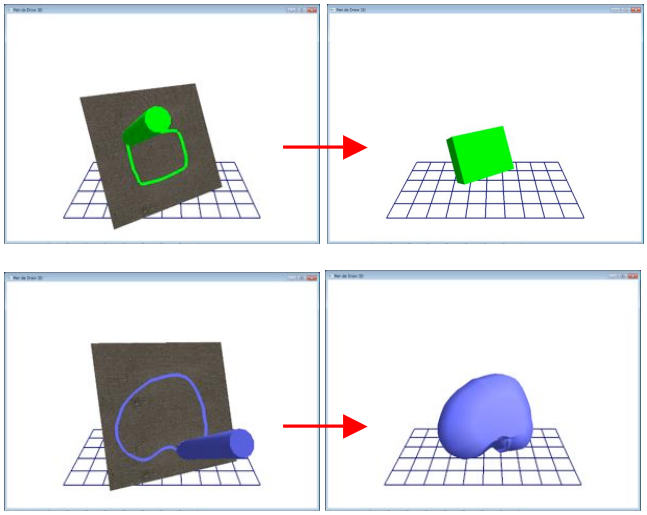

Figure 2. Creation of shapes from motion trajectory
(Top: Box, Bottom: Shape with freeform surfaces)

The created 3D shapes are generated in the physics-based simulation environment and displayed on the screen as 3D images. The user can see the created shape through 3D glasses and touch it in real time using the kinesthetic display. Therefore, the user feels as though he/she is creating 3D shapes in reality.

Further, using our system, the user can touch the created 3D objects and feel their shape. This feature is beneficial not only in checking the modeling process, but also in demonstrating the created models to other users. Haptic 3D models are not popular now. However, such content will be necessary in the future because of the predicted widespread use of 3D televisions and gaming systems that use the user's body movements as input. Our system will serve as a basis for the creation of such haptic contents.

3 Conclusion

In this poster, we have described the construction of a 3D haptic modeling system to easily and intuitively create 3D models. We propose an input method wherein the user draws 2D figures on a virtual canvas to create 3D shapes. The constructed system realizes 3D modeling by creating and combining shapes on the basis of the spatial movements of the user's hand, and enables real-time haptic interactions with the created 3D models.

Although the input-related manipulations in our system are simple and the user can quickly create 3D models, other approaches for model creation with 3D input will be developed. An alternative method is to use multiple 2D figures to create one 3D shape. The user will intuitibely be able to create various oval spheres or complex box shapes by combining two circles or two rectangles, respectively. Another method is to indicate a surface of desired shapes by drawing spirals. In the future, we intend to incorporate these shape creation methods in our system. In Addition to the shape creation, we intend to exploit the force feedback generated by the kinesthetic display device in order to enable other manipulations of 3D shapes, such as transforming and painting.

Acknowledgements

This work was supported by CREST of the Japan Science and Technology Agency.

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