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Haptic-GDraw: A Fun and Easy to Use 3D Haptically-Enhanced Sculpting Program

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Abstract. We have developed a simple haptically-enhanced 3D sculpting application which utilizes Hermite spline-based primitives as building blocks to construct more complex solid models. To accomplish this, we have constructed a VR work environment which is intuitive and whose control affordances are made clear through the use of graspable handles. Haptics is used to support handle selection and provide physical constraints on handle movements consistent with their visual affordances. Our goal is to demonstrate how relatively simple haptic force constraints can combine with a visually intuitive and compelling environment to enable a program that is fun and easy to use.

1 Introduction

Applications for 3D solid modeling using haptics have primarily focused upon manipulation techniques that provide the user the ability to work with virtual clay much as they would with real clay. Examples include the commercial FreeForm application [1] and the Virtual Clay sculpting system [2]. The level of capability these systems afford is also their weakness, in that they rely upon the user to learn many tools. Our approach is to support the simple construction of objects from 3D shape primitives we call *geons*, after the work of Irving Biederman [3]. According to Biederman's theory, structured objects are decomposed by the human visual system into component parts consisting of generalized cylinders with various curves, radius profiles and cross sectional shapes. Therefore constructing objects with such primitives should be natural.

The Haptic-GDraw environment is designed to be familiar yet visually stimulating and somewhat whimsical. Manipulation of objects is done using handles whose affordances are clear. The PHANTOM proxy is visually represented as a pincer designed for grasping these handles. Haptic-GDraw utilizes geons, which are essentially a shape solid tube wrapped around a Hermite spline, as sculpting primitives. Positioning of geons is simple and intuitive using spline control handles. Geon cross-sectional shape, color and texture are also adjustable. By combining multiple geons together, the user is able to create more sophisticated sculptures. We employ haptic forces to support selection of handles in 3D as well as to constrain the user's manipulation of handles to points, lines, arcs and surfaces so as to augment the

visual affordances. We have found this use of haptic task constraints to be a simple yet powerful technique for interacting in 3D environments [4]. We also utilize simple haptic effects such as buzzing to provide a richer interaction experience.

Our motivation was to see how far we could push a direct manipulation style of interaction combining visual and haptic channels that would be intuitive, compelling and easy to master, all within an enjoyable application domain. A measure of our success will be to have a user unfamiliar with the system be able to sit down in front of it and easily learn the functionality within a short period of time.

2 System Description

Haptic-GDraw was developed and runs on a Windows PC, with a SensAble Technologies Desktop PHANTOM for the haptic display. Programming was done using C++ with SensAble's GHOST API for haptic rendering. Computer graphics are handled using OpenGL with frame sequential stereo and shutter glasses for 3D viewing.

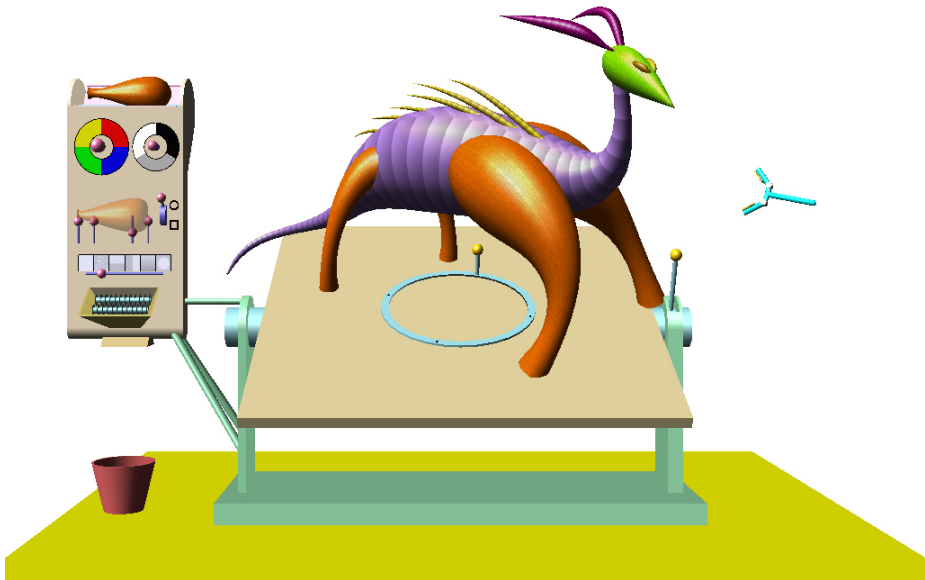


Fig. 1. Haptic-GDraw VR work environment, with dinosaur model

The virtual environment is shown in Fig. 1 and consists of an adjustable workbench, a control panel and a workspace. Sculpting takes place above the workbench tabletop, which has separate pitch and yaw controls for altering the user's view of their work. The tabletop is mounted to a stationary workbench base, which provides a fixed reference frame. A control panel cabinet, located to the left of the

base, is also stationary and contains controls for acquiring new geons, adjusting geon parameters such as shape, color and texture, and deleting geons.

Interaction with geon elements and workspace widgets is done through selection and manipulation of control handles. Handle selection is performed by simply reaching for the handle icon, shown as a colored ball. When the gripper tool jaws (i.e., PHANTOM tip) fall within 4 mm of the handle center, a spring force is applied to pull the pen tip to the handle center. We have found that a spring constant of 0.25 N/mm provides a comfortable snap force. Having selected the handle, the user then presses the pen button. Visually, the gripper tool jaws close and appropriate constraint forces are activated to guide the user's motion. Releasing the button stops the tool action and locks the handle position, allowing the user to pull the pen off of the handle.

To begin a sculpting session, the user reaches to the top of the control panel and grasps the handle of the miniature geon located there and pulls it into the center of the workspace. The newly activated geon enlarges and the spline handles at each end of the shape become visible. Manipulation of geons is done using this centroid handle for translation of the entire primitive, or one of the Hermite spline handles located in pairs at each end of the geon to alter its shape. After a moment, a new geon miniature appears atop the control panel, ready to be taken into the workspace.

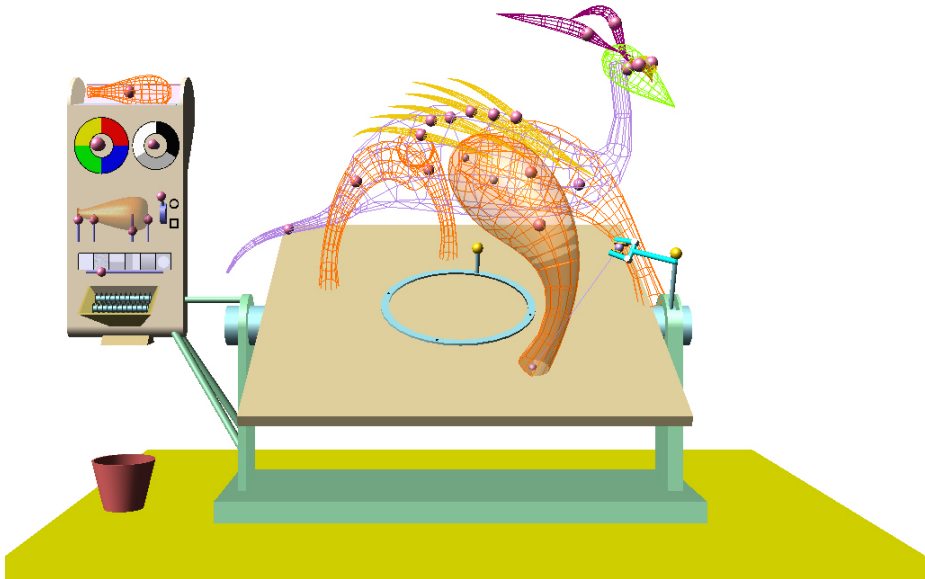


Fig. 2. Manipulating geons in wireframe mode

To support geon manipulation, the user can toggle back and forth from solid view to wireframe view, shown in Fig. 2, by pressing the keyboard space bar. While in solid view, the geon handles are visually hidden but haptically enabled for selection. To reduce visual and haptic clutter while in wireframe mode, we visually and

haptically render only the centroid geon handle for non-selected geons. The last selected geon is visually rendered transparent and displays both the centroid and spline handles for manipulation.

The geon which was last manipulated is termed the active geon, and its shape, color and texture attributes are replicated in a symbolic geon embedded in the center of the control panel. An active geon's shape can be altered by grabbing and moving one of the five handles located next to the symbolic geon. The four handles situated along the lower profile adjust the active geon's radius at those points, while the fifth handle adjusts the cross section of the geon shape. Haptic line constraints keep the handles within upper and lower parameter bounds. Color selection is done using a handle in the center of each color wheel. The user grasps a handle and pulls it in the direction of the desired color; the harder they tug, the faster the tinting occurs. Here a haptic point constraint locks the haptic representation of the handle and the reaction force is mapped to the rate of tinting. Finally, several predefined textures are available and are shown near the bottom of the panel. Moving the attached control handle to the desired texture example makes that texture appear on the active geon. A haptic line constraint with detents is used to reinforce the affordances shown in the control.

Geon deletion is performed using the shredder widget located at the bottom of the control panel. The user simply drags one of the control handles of a geon to the shredder opening, where a haptic snap force grabs the handle and pen. Releasing the PHANTOM button starts the shredder; visually the geon is pulled into the shredder opening while shreds fall from the panel underside into the waste bin. A haptic buzzing effect is also activated giving the feeling of a paper shredder in operation.

We have evaluated the system in informal trials using children between the ages of six and ten, and with several adults. All of them quickly gained the ability to create and delete geons, and change geon shape by manipulating the control vertices. Changing the geon longitudinal profile, via the control panel, took a little longer but was also mastered by even the youngest users. All of the children especially liked the shredder. Features that have not yet been implemented but would be highly desirable include the ability to scale and group objects.

References

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