SplineGrip - An Eight Degrees-of-Freedom Flexible Haptic Sculpting Tool

Pontus Olsson[1,*], Fredrik Nysjö[1], Björn Aneer[2], Stefan Seipel[1], Ingrid B. Carlbom[1]
[1]Uppsala University, Uppsala, Sweden; [2]Independent Artist, Stockholm, Sweden

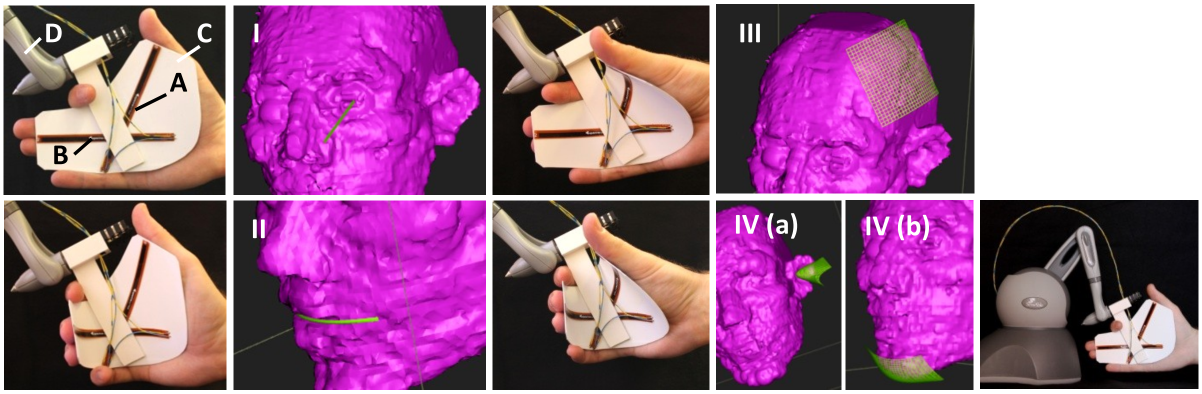

Figure 1. *SplineGrip. Examples of hand articulations and their corresponding virtual sculpting tools.*

1 Introduction

Haptic sculpting allows a designer to create virtual models with the aid of haptic feedback. Just as in real life sculpting, different tools are used to work the model into a desired shape. Several haptic sculpting tools appear in the literature. For example, [GAO 2006] proposes an ellipsoidal tool whose pose (position and orientation) is controlled by a six degrees-of-freedom (DOF) haptic device, and [MCDONNELL 2001] describes a set of modeling tools for virtual clay controlled by three DOF haptics.

We propose a flexible haptic sculpting tool, *SplineGrip*, which senses the articulation and pose of the sculpting hand in eight DOF. The tool captures the hand articulation in two DOF, and uses a commercial haptic device that tracks the hand pose in six DOF, while simultaneously providing three DOF haptic feedback. The eight DOF input is mapped to the pose and shape of a virtual representation of a sculpting tool, offering versatile interaction with a virtual model.

2 Technical Approach

We capture the two DOF hand articulation with two Flex resistive bend sensors (Figure 1, A, B) from Images SI Inc. mounted in two directions on a flexible plastic sheet (C) cut to fit the hand. The bend sensors have curvature dependent resistance, which we sample with an Arduino Leonardo board connected to a PC running a sculpting system. The sensors measure the plastic sheet curvature controlled by the thumb and by the middle and ring fingers, respectively. The user may stabilize the tool with the index and little fingers as shown in Figure 1. The plastic sheet is mounted on a Phantom Omni device (D) from Geomagic.

SplineGrip controls the shape and pose of the virtual sculpting tool from the articulation and pose of the sculpting hand. When all fingers are straight, the virtual sculpting tool takes the shape of a line segment (I). By bending one sensor with the middle and ring fingers, the user changes the virtual tool curvature. By bending the other sensor with the thumb, the user changes the width of the virtual tool. A curvature increase at zero width turns the line into a spline (II), and a width increase at zero curvature creates a plane (III). By bending both sensors, the user may simultaneously control the curvature and width of a NURBS surface (IV). The user may toggle between convex and concave tools (IV a, IV b).

* Corresponding author: pontus.olsson@it.uu.se

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3 Sculpting System

To evaluate SplineGrip, we implemented a simple sculpting system where the user starts with a block of material and uses the virtual sculpting tool to gradually remove material. The virtual model is represented by a voxel grid, with increasing voxel values towards the interior of the model (an approximate distance field), allowing extraction of an isosurface mesh for model surface visualization, and fast calculation of haptic contact forces. We calculate the force feedback by uniformly sampling the virtual tool surface and determining force directions and magnitudes from the corresponding positions in the model distance field. The contact forces are given the direction of the negative distance field gradients and are scaled by the distance field values, which yields repelling forces with magnitudes proportional to the tool penetration depth into the model. Around each sample point on the tool surface, we remove material by decreasing the voxel values using a pre-computed radial-basis-function kernel to retain the gradient at the model boundaries when material is removed. We control the material removal rate by the magnitude of the contact force; a higher user force yields a higher removal rate.

4 Discussion

The tool described herein maps the pose and articulation of the hand to the pose, width and curvature of a virtual sculpting tool, but this mapping is only one of several possible mappings. Furthermore this tool is not restricted to volumetric models, but can equally well be used with surface models, such as those based on B-spline surfaces. We have illustrated the modeling tool with subtractive modeling, but this approach applies also to free-form additive modeling and physics-based modeling.

References

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