Mesh Painting on Subdivision Surfaces In Virtual Reality Environments

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1 Introduction

We present an algorithm for interactive painting on a subdivision surface using standard texture-mapping hardware. A surface is first parameterized to generate a set of texture maps that covers the surface. These texture maps will be referred to as the *base textures* of the subdivision surface. Polygons are then assigned texture coordinates and mapped into one of the base textures. A set of line segments is used to represent a brush stroke across the surface. As the surface is painted using a brush stroke, the texture maps are updated to reflect the new color of the surface. Multiple base textures covering the surface allow more detail to be painted in certain areas by using textures of different sizes. We have integrated our system into a Virtual Reality environment using an immersive workbench. Our environment is semi-immersive and allows a user to interact with the surfaces using spatial and orientation tracking via data gloves and a stylus tool. The toolkit is now available as part of the the VirtualExplorer framework developed at U.C. Davis, see [2].

2 Base Textures

The base textures are a set of texture maps that cover a surface. The number and size of these texture maps determine how much detail can be painted onto a particular portion of the surface. In order to determine how these base textures cover the surface, we need to define a parameterization of the surface. This parameterization maps a point on the surface to a texture coordinate in a specific base texture. For subdivision surfaces, the base mesh can be used as a parameterization. One base texture is associated with each face of the base mesh, and texture coordinates are associated to the vertices on a per-face basis. As the mesh is subdivided, new texture coordinates are determined for the new faces, or children, by linearly subdividing the texture coordinates of the old faces or parents.

3 Painting Surfaces

3.1 Brush Strokes

To paint on a surface, we utilize the idea of a brush stroke similar to the idea presented by Gregory at al. in [1]. A brush stroke is modeled by a series of line segments on the polygons of the subdivision surface, called *stroke segments*, and a *brush* that describes how the surface properties are modified. Each segment is confined to a single face in the mesh and represents a line in the face's base texture.

Figure 1 shows a brush stroke that spans several triangles. The brush stroke is broken into six segments marked A-F.

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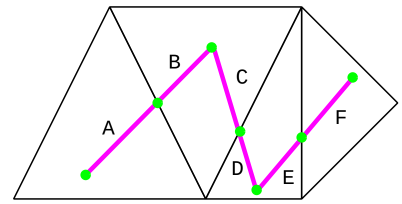

Figure 1: Brush stroke and stroke segments

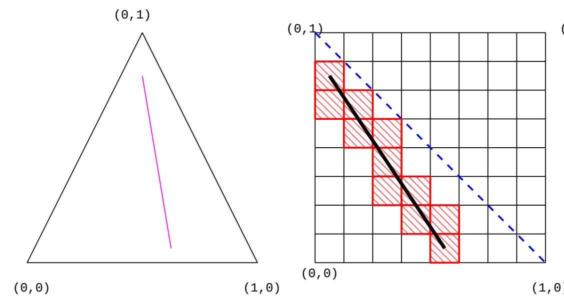

Figure 2: Brush stroke and stroke texels

Each segment is associated with one face. A brush stroke is drawn by rasterizing each of its stroke segments in the appropriate texture maps and then modifying surrounding texels according to the brush properties.

3.2 Brush Characteristics

The rasterization of a stroke segment in a texture map touches a set of texels called the *stroke texels*. Figure 2 shows a single stroke segment in a triangle and the corresponding stroke texels in the texture map. The texture coordinates of the triangle and their mapping into texture space are indicated. The properties of a brush define how the stroke texels and the surrounding texels are modified.

3.3 Texel Modification

The texels surrounding the stroke texels are modified according to the characteristics of the brush stroke. Relative to the stroke texel, the surrounding texels fall into three categories:

1. Texels that lie in the same texture and the same face
2. Texels that lie in the same texture and a different face
3. Texels that lie in a different texture and a different face

These texels are found by placing a sphere at each stroke texel and using the size of the brush to determine the texels that are touched. The position of the sphere in physical space is found by mapping the position of the stroke texel from texture space to physical space.

4 Virtual Reality (VR) Modeling

4.1 Overview

We have integrated our system into a VR environment using an immersive workbench from Fakespace Corporation. The environment is immersive in the sense that is allows stereo viewing using headtracked shutter glasses. Stereo viewing allows a user to model and paint objects in a true 3D manner. The user can interact with the environment using data gloves and a stylus. The Virtual Reality interface has been developed using the *VirtualExplorer* framework developed at UC Davis. The VirtualExplorer framework is an object-oriented, customizable, plugin-based framework for VR applications.

4.2 Data Gloves

The data gloves allow the user to interact with the environment in a two-handed free-form manner. The data gloves report position and orientation information for the hands and pinch information for the fingers. The data gloves are used for these purposes :

1. Interactive viewpoint selection
2. Selection of a surface or surface feature for editing
3. Painting on the surface by interactive placement of brush stroke segments

4.3 Stylus

The stylus tool allows a user to select objects in the scene using a method analogous to pointing out objects using a laser pointer. This enables a user to select distant objects, to bring distant objects into the foreground, or to move them to specific locations. The stylus reports the direction that it is pointing in and push information for its button. The stylus is used for these purposes:

1. Selecting objects for modeling
2. Painting objects using the stylus as a paint brush

The stylus is represented as a ray in 3D space, i.e., it has a 3D position and direction. Painting objects is done by pointing the stylus at the surface to select a starting point and then moving the stylus's ray along the surface to trace out the path of a brush that paints the surface.

5 Results

Figure 3 shows a painted bunny. The base mesh consists of 500 triangles, and has been subdivided 3 times using loop subdivision. There are 500 base textures each with 64x64 texels. The base textures have been assigned color values such that as few adjacent faces as possible share the same color. The letters on the bunny were painted with a spherical brush with a physical size of 0.25 units. The dimensions of bunny's bounding box are about 12x15x10 units. The blend function of the brush replaces the existing texel's color with the brush color.

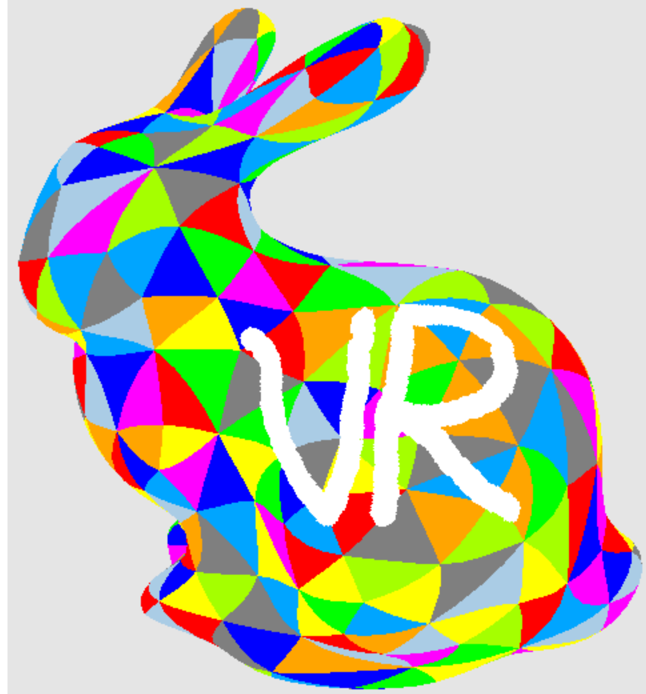

Figure 3: A painted bunny. Brush shape = spherical, Brush size = 0.25, Blend Function = Replace

6 Conclusions and Future Work

We have presented a method for interactively painting on a subdivision surface using texture maps. Our algorithm starts by parameterizing the surface using the base mesh and forming a set of textures that cover the surface. The user is able to paint on the surface by modifying the texture maps.

We have integrated our painting algorithms into a VR environment. The VR environment allows surfaces to be painted in 3D space providing a user with much better spatial perception of the environment. The advantage of the VR environment is the presence of a true third dimension for interaction. The VR environment has great potential for dramatically increasing productivity. Future work will be directed at the development of new interaction paradigms in VR environments and new modeling algorithms that take maximal advantage of the VR environment.

References

[1] A. D. Gregory, S. A. Ehmann, and M. C. Lin. inTouch: Interactive multiresolution modeling and 3D painting with a haptic interface. In S. Feiner and D. Thalmann, editors, *Proceedings of the 2000 IEEE Conference on Virtual Reality (VR-00)*, pages 45–54, Los Alamitos, CA, Mar. 18–22 2000. IEEE.

[2] F. Kuester, B. Hamann, and K. I. Joy. Virtualexplorer: A plugin-based virtual reality framework. In R. Erbacher, P. Chen, M. Groehn, J. Roberts, and C. Wittenbrink, editors, *Proceedings of SPIE*, San Jose, California, USA, 2001. SPIE - The International Society of Optical Engineering.