Surface-based Deformation for Disconnected Mesh Models (sap_0342)

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1 Introduction

Surface-based deformation [Sorkine 2005] plays an important role to reuse existing mesh models. This technique encodes geometric shapes using linear partial differential equations and deforms mesh models in an interactive manner. However, surface-based deformation cannot consistently deform mesh models that include (1) Multiple disconnected components, (2) T-vertices, and (3) Non-manifold edges. These conditions commonly appear in mesh models. This paper shows how to deform such models consistently.

A mesh model can be encoded by introducing the following equations at vertex i [Masuda et al. 2006]:

$$\frac{1}{4A_i}\sum_{j\in N(i)}(\cot\alpha_{ij}+\cot\beta_{ij})(\mathbf{p}_i-\mathbf{p}_j) = R(\delta_i;\frac{\mathbf{r}_i}{|\mathbf{r}_i|},2|\mathbf{r}_i|) \quad (1)$$

$$\frac{1}{4A_i}\sum_{j\in N(i)}(\cot\alpha_{ij}+\cot\beta_{ij})(\mathbf{r}_i-\mathbf{r}_j) = 0 \quad (2)$$

where $\mathbf{p}_i \in \mathbf{R}^3$; $N(i)$ is immediate neighbors; α_{ij} and β_{ij} are the two opposite angles; A_i is a Voronoi area; δ_i is the initial mean curvature normal; $R(\mathbf{v};\mathbf{n},\theta)$ rotates a vector $\mathbf{v}$ around axis $\mathbf{n}$ by angle θ; $\mathbf{r}_i$ is the logarithm of a unit quaternion. In addition, $\mathbf{p}_i=\mathbf{u}_i$ and $\mathbf{r}_i=(\theta_i/2)\mathbf{v}_i$ are defined in the fixed regions and handle regions, where $\mathbf{u}_i$ is a user-defined position; $\mathbf{v}_i$ and θ_i are the rotation axis and angle defined by the user. Then, the coordinates of vertices can be calculated by solving two linear systems for Eqs. (2) and Eqs. (1).

2 Constraint propagation

In our method, a virtual link is defined between a pair of vertices as shown in Figure 1. A virtual link preserves the relative position and angle between the two vertices and is represented as:

$$\begin{cases}\mathbf{p}_i^{(1)}-\mathbf{p}_j^{(2)} = R(\mathbf{d}_{ij};\frac{\mathbf{r}_i^{(1)}}{|\mathbf{r}_i^{(1)}|},2|\mathbf{r}_i^{(1)}|) \\ \mathbf{r}_i^{(1)}-\mathbf{r}_j^{(2)}=0\end{cases} \quad (3)$$

where $\mathbf{d}_{ij}$ is defined as the initial vector of $\mathbf{p}_i^{(1)}-\mathbf{p}_j^{(2)}$. Virtual links can also be set to dividing points on edges and faces. These constraints are added to Eqs. (2) and Eqs. (1).

For specifying constraints between two disconnected meshes, the user specifies regions to be constrained, and then the system calculates the distances from each specified vertex to other disconnected meshes. When the distance to the nearest point is less than a certain threshold, a virtual link is specified between the pair entities.

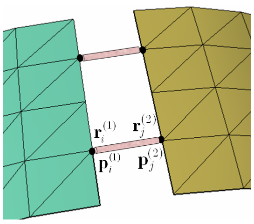

Figure 1: A virtual link.

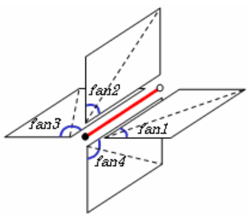

Figure 2: Constraint of non-manifold model.

We can also edit mesh models including T-vertex and non-manifold model by applying the constraint propagation. In the T-vertex, virtual links are set between a vertex and a point on an edge to maintain the distance as 0.

In the non-manifold model, faces around a non-manifold edge are divided into a set of *fans*, as shown in Figure 2. Then, each fan is separately encoded using Eqs. (1) and (2). Since each fan shares the common $\mathbf{r}_i$, the angles between adjacent fans are preserved during deformation.

3 Results

Figure 3 shows examples of the mesh deformation including T-vertex and non-manifold models. Figure 4 shows examples of the mesh deformation using constraint propagation. These examples show that our method produces reasonable deformed results.

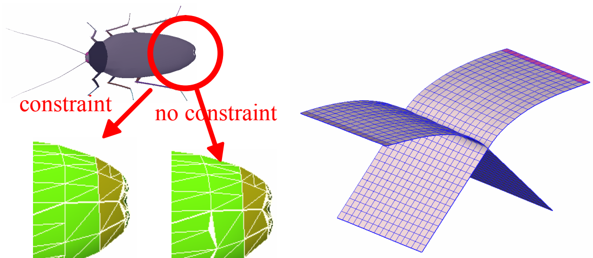

Figure 3: Deformed Results (T-vertex and Non-manifold model)

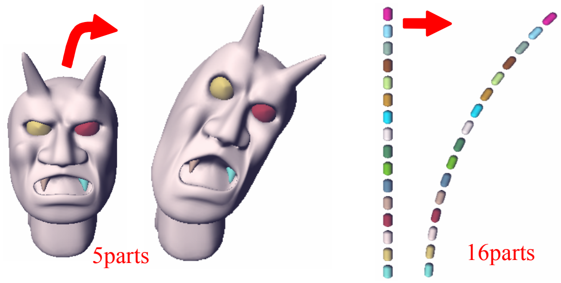

Figure 4: Deformed Results (disconnected models)

References

O. Sorkine 2005. Laplacian Mesh Proceeding. *Eurographics STAR State-of-the-Art Report.*

H. Masuda, Y. Yoshioka, Y. Furukawa, 2006, Interactive mesh deformation using equality-constrained least squares, *Computers and Graphics*, Vol.30, No.6, 936-946.