Feature-Preserving Deformation of Tessellated Surfaces

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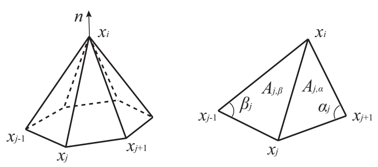
Abstract

The traditional displacement mapping techniques based on the height map suffer from stair-stepping artifacts. Further, in order to combine surface deformation and displacement mapping, complex operations such as Laplacian of surface should be performed by analyzing the surfaces. This paper proposes a novel 3D displacement mapping and map generation techniques, which overcomes the limitations of the existing techniques. Proposed displacement mapping algorithm reduces distortion of surface even though the surfaces are highly deformed. The displacement map generated by our method has the effect of the adaptive tessellation with no additional stage for determining LODs. The rendering performance is as fast as traditional displacement mapping.

Introduction The basic concept of this paper is similar to [Zhou et al. 2007]. To improve high-quality surface deformation combined with displacement mapping, we aim two goals. First goal is to reconstruct the highly-detailed surface with a moderate degree of tessellation with the aid of *curvature-based 3D displacement map*. Second goal is to control distortion of surfaces in concept of *volume-preserving displacement mapping*. The input to our system is the original mesh of a highly-detailed surface. The algorithm proposed in this paper creates the 3D displacement map through three stages: vertex-weight estimation, parametrization, and map generation. On rendering, feature-preserving displacement mapping stage is performed.

Vertex weight estimation This stage assigns a weight value to a vertex of input surface based on the visual importance of the vertex. The vertex weight depends on the Laplacian of the surface. Note that the mean curvature value is proportional to the Laplacian of surface. Additionally The vertex weight should be determined considering the geometric element. In our method, we approximate geometric solution, i.e. we multiply the mean curvature by $4A$. Finally, the vertex weight m is estimated using the following simplified equation:



$$m_i = 4A\bar{\kappa} = -\mathbf{n} \cdot \sum_{j \in N_1(i)} (\cot\alpha_j + \cot\beta_j)(x_j - x_i). \quad (1)$$

Parametrization In order to save the information of the original surface into the 3D displacement map, the one-to-one mapping function from the original surface to the texture space should be defined using parametrization. In our work, we preserve the vertex area in proportion to its weight. If a vertex from the original surface occupies a large area in the displacement map, many vertices of the tessellated mesh will move toward the vertex position. It naturally achieves the effect of adaptive tessellation around feature vertices. Our parametrization algorithm is based on a simple edge-spring method. Each vertex pushes away the 1-ring neighbor vertices. The repulsive force is in proportion to the vertex weight.

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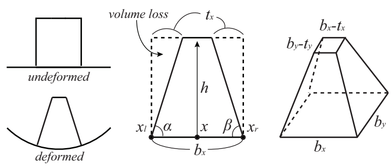
3D displacement map generation Through the parametrization stage, a mapping function from the original surface to the texture domain has been derived. Another mapping function from the coarse mesh to the texture domain is also defined at the modeling stage. Given relations with texture domain, the mapping function from the coarse mesh to the original surface is directly obtained, i.e. the 3D displacement map is generated by evaluating the vectors from the coarse mesh to the original surface.

Feature-preserving displacement mapping When the coarse mesh is deformed by performing animation, collision resolution, skinning, or etc., reconstructed surfaces show the distortions. For example, in case of bending the coarse mesh in a concave manner, the angle between neighboring normals decreases. It leads volume loss. To conserve local volume, displaced vertices by displacement mapping move one more along the surface gradient. In contrast with traditional surface deformation techniques, our solution does not need precomputed data and 1-ring neighbors information. The offset vector for each tessellated vertex is computed independently by considering infinitesimal area near vertex position x. Amount of changed volume is approximated using a quadrangular pyramid model, eq. (2), and vertices offset in proportion to the volume difference. In eq. (2), v_d is a vector obtained from 3D displacement map.



$$s = (b_x \times b_y \times h)/(b_x \times b_y - \frac{t_x \times b_y}{2} - \frac{b_x \times t_y}{2} + \frac{t_x \times t_y}{3}) - h. \quad (2)$$

$$where\ \ h \approx length(v_d), \quad t_x \approx h\cos\alpha + h\cos\beta.$$

Conclusion This paper proposes a novel method for 3D displacement mapping. It overcomes the limitations of the existing techniques, and can reconstruct the highly complex surfaces such as high-quality silhouettes and deformed surfaces.

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References

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