Similarity-Based Surface Modelling Using Geodesic Fans

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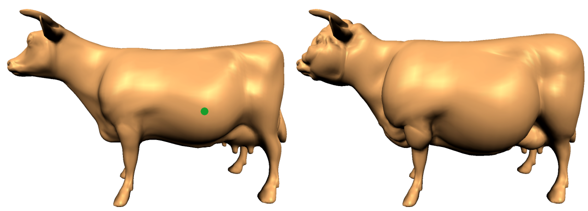

Figure 1: Pulling one vertex (green) simultaneously pulls other vertices according to their degree of similarity. The plump cow results from a single similarity-based deformation.

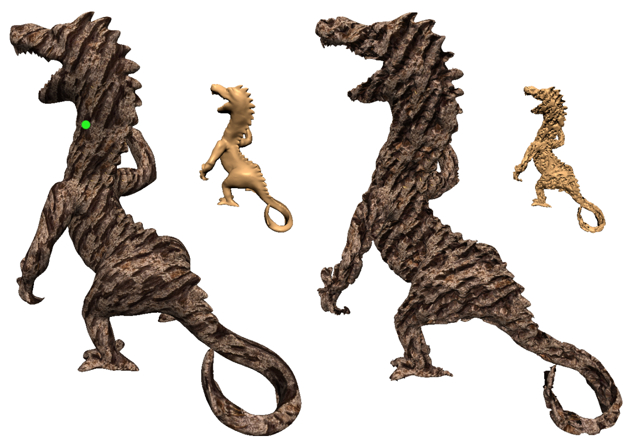

Figure 2: A single deformation based on similarity of texture features produces a much more convincing textured mesh.

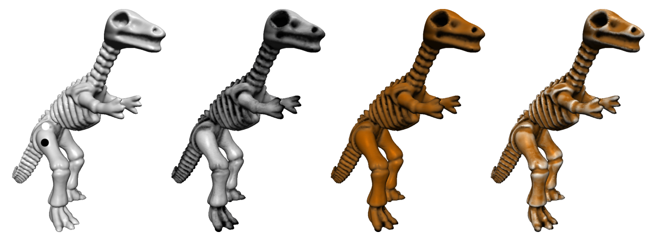

Figure 3: Colour is applied to only two vertices (left). All vertices *different* from the black vertex are given black paint by inverting the similarity-based weights, while the rest are given brown paint. Vertices similar to the white vertex are finally given white paint.

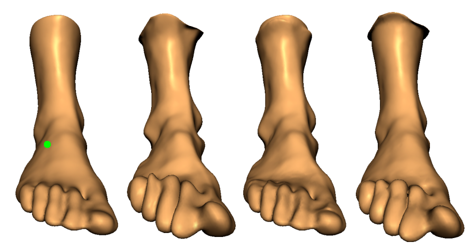

Figure 4: A frequency enhancing filter produces global changes to the model. Similarity-based filtering allows natural exclusion of the toes, or, by using dissimilarity, restriction to the toes.

We develop several powerful new tools for surface modelling based on local surface similarity by extending self-similarity based texture editing [Brooks and Dodgson 2002] to surfaces. The basic paradigm behind these tools is that a user change applied to one part of the surface is automatically reproduced at all sufficiently similar parts of the surface, with the degree of the change modulated according to similarity. *Similarity-based deformation* reproduces a vertex displacement (see Figures 1 and 2), providing fast, intuitive editing of the surface's geometry. *Similarity-based painting* (Figure 3) distributes colours across the surface, while *similarity-based filtering* (Figure 4) modulates an arbitrary mesh filter by similarity. Like image domain tools for modelling by example, these tools are quite flexible and intuitive, and especially useful for non-artists.

These tools rely on geodesic fans, a new method for neighbourhood sampling and comparison on surfaces. Geodesic fans position samples at equal arclengths on geodesics equally spaced about the center of the neighbourhood, overcoming irregular mesh topology to provide a structurally equivalent neighbourhood throughout the surface. They may also be discretely reoriented on the surface by cyclically permuting their spokes, which provides for a fast simultaneous alignment and comparison of two geodesic fans, and overcomes the lack of an inherent orientation for neighbourhoods on surfaces. Typically the value sampled at each geodesic fan sample location is a geometric measure: the 3D offset from the neighbourhood center to the sample location, cast into a local coordinate frame. As in Figure 2, however, we can sample other signals such as textures, vector fields, or other user-supplied signals. This decoupling of the signal being compared from the signal being modelled provides a great deal of flexibility and power to the user.

We can sample 500-2500 geodesic fans from a surface per second, while 25k-200k fan-to-fan comparisons (including alignment) may be made per second (timings are on an Athlon 1.5 Ghz PC). For the models shown, this means a few seconds to a couple of minutes to pre-process the mesh, and at most two seconds to compute similarities over the mesh when a vertex is selected for editing. Geodesic fans used extended 1-3% of the model bounding box diagonal, with 10-30 spokes and 5-15 samples per spoke. Reducible to flat vectors, geodesic fans are also amenable to standard indexing techniques such as *kd*-trees and PCA. For similarity-based modelling, our fan-to-fan comparison performance includes applying vector quantization to the spokes of the fans, which effectively reduces the vector dimension of each spoke to 1 (quantized spokes may be compared via table lookup). Note that while indexing is not applicable to similarity-based modelling, we expect it to be important for future applications of geodesic fans. We are currently exploring their use in automatic texture or deformation transfer across surfaces ("surface analogies").

References

BROOKS, S., AND DODGSON, N. A. 2002. Self-similarity based texture editing. *ACM Transactions on Graphics 21*, 3, 653–656.

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