Deformation Transfer based on Stretchiness Ratio

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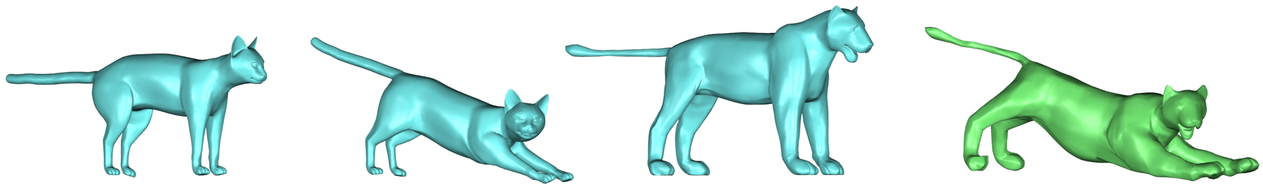

Figure 1: *The result from the proposed deformation transfer technique. From left to right, source reference mesh S, source deformed mesh $\tilde{S}$, target reference mesh T, and target deformed mesh $\tilde{T}$.*

1 Introduction

Recent work for deformation transfer is almost based on the deformation gradient framework [Sumner and Popović 2004], which deforms a target mesh by transferring local affine transformation in an optimization framework. We aim to explore a coordinate-invariant quantity for deformation transfer. What we propose here is to achieve deformation by transferring stretchiness ratio between the source meshes to the target.

2 Proposed Technique

Given a source reference mesh S, a source deformed mesh $\tilde{S}$, and a target reference mesh T, the objective is to transfer deformation between the source reference mesh and the source deformed mesh onto the target reference mesh and produce a target deformed mesh $\tilde{T}$. We assume both S and T are vertex-wise corresponded. A set of mass-spring systems is built for S, $\tilde{S}$, and T, both in their equilibrium state (in other words, the length of each edge in the mesh is equivalent to the rest length of the spring). Let $e_{i,j} \in E$ denote a spring that connects v_i and v_j, and $r_{i,j}$ denote the rest length of the spring. The desired rest lengths for the target deformed mesh $\tilde{T}$ are computed by transferring the stretchiness ratio between the rest lengths of source meshes to the target reference mesh:

$$r^{\tilde{T}}_{i,j} = r^{T}_{i,j} \times \frac{r^{\tilde{S}}_{i,j}}{r^{S}_{i,j}}, \quad e_{i,j} \in E. \tag{1}$$

$r^{T}_{i,j}$, $r^{\tilde{T}}_{i,j}$, $r^{S}_{i,j}$ and $r^{\tilde{S}}_{i,j}$ are rest lengths of edge $e_{i,j}$ in mesh T, $\tilde{T}$, S, and $\tilde{S}$, respectively. Once the desired rest lengths of $\tilde{T}$ are obtained, the equilibrium state is computed based on $r^{\tilde{T}}_{i,j}$ to obtain the vertex positions of $\tilde{T}$. According to Hooke's law,

$$f(v_i) = \sum_{\forall i,j} k_{i,j}(|v_i - v_j| - r^{\tilde{T}}_{i,j})\frac{v_i - v_j}{|v_i - v_j|} = 0. \tag{2}$$

We assume the spring constant k to be inversely proportional to the rest length. This strategy ensures every spring contributes similar amount of force during the optimization process. The mass of each vertex is set as constant and thus can be ignored.

In order to preserve surface properties, the mass-spring systems are augmented with additional bending and internal springs [Ma et al. 2012] to prevent surface from collapsing. The equilibrium state of mass-spring system can be solved with Newton-Raphson method. However, the optimization is difficult to solve correctly if a large condition number of the system matrix presents. We adopt a multi-grid approach to accelerate state convergence. A mesh coarsening approach [Shi et al. 2006] is used to construct different levels. Our system estimates the error of current state on a coarse-level grid of the objective function. The error is diffused on the coarse-level grid, and then it is interpolated to approximate the error on a fine-level grid. The error propagation from coarse-level gives good initial guess of the equilibrium state of the mass-spring system.

Figure 1 shows the deformation transfer result. The proposed method produces analogous deformation on the target mesh. Note that it is possible that the stretchiness ratio can be controlled to allow shape interpolation. One major limitation of the system is that mass-spring system faces element inversion problem such that the nonlinear optimization converges to a local minimum. We would like to investigate other representations that are more stable numerically.

References

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