Conversion of Performance Mesh Animation into Cage-based Animation

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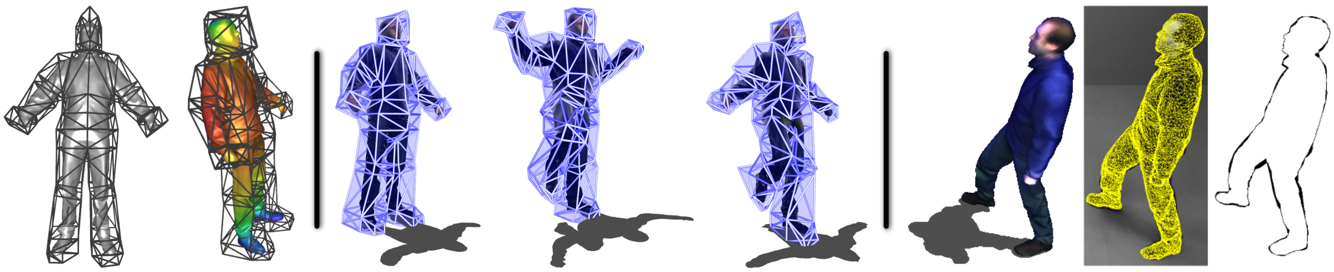

Figure 1: *The default bounding cage is rigged to the enclosed model using harmonic coordinates (left). Given performance mesh animation (obtained using silhouette-based multi-view reconstruction) as input, our system estimates optimal cage parameters (middle) and regenerates 3D video using cage-based deformation. Backprojected cage-based meshes and silhouette overlap error are proposed as evaluation (right).*

1 Introduction

Markerless highly-detailed performance capture is an emerging technology in vision-based graphics and 3D video. For instance, a framework for generating mesh animations from multi-view silhouettes is presented in [Vlasic et al. 2008]. Achieving inverse animation by approximating dynamic mesh using rigid skinning has inspired researchers to convert video-based reconstructed mesh sequence into rigid kinematic parameters as seen in [de Aguiar et al. 2008]. In contrast with previous techniques using skeleton-based animation paradigms, we describe an efficient linear estimation framework to convert non-rigid performance animation into cage-based animation. Our approach retrieves animation parameters through a single-pass minimization process without the need of an underlying rigid kinematic structure.

2 Cage Sequence Extraction

Motivation & Overview Initially, harmonic cage-based deformation enables to create the illusion of realistic deformation of a model accurately [Joshi et al. 2007]. In addition, differential geometry is well-known for reconstructing an edited surface [Sorkine and Cohen-Or 2004]. Consequently, we focus on linear estimation of sequence of optimal cage geometry parameters expressing the time-varying mesh via inverse regularized cage-based process. Our pipeline takes as input a video-based reconstructed mesh sequence with a default cage, and produces as output a sequence of cages sharing same mesh connectivity (Figure 1). Thus, we embed models $\mathcal{M}$ in a coarse cage $\mathcal{C}$ using generalized barycentric coordinates having local smooth properties. The set of n cage vertices is denoted by $\mathcal{V}_{\mathcal{C}} = \{c_1, \cdots, c_n\}$ where c_k is the location of the k^{th} cage vertex. The set of m model vertices with $\mathcal{V}_{\mathcal{M}} = \{v_1, \cdots, v_m\}$ where v_i is the location of the i^{th} model vertex. We refer respectively by v_i^t and c_k^t the geometry of the input model and estimated cage parameters at the animation frame t.

Laplacian-based Harmonic Subspace The spatial relationship between the subspace domain and the model is pre-computed at the default pose using harmonic rigging. Harmonic coordinate $h_k(i)$ is a generalized barycentric weight representing the deforming influence of the k^{th} cage vertex on the i^{th} model vertex. We therefore introduce the notion of *Laplacian Cage* defining a cage structure enhanced with laplacian regularization thanks to a Dual Laplacian operator $\mathcal{L}_C(\cdot)$ directly applied on the cage shape. The cage differential coordinates $\hat{\delta}$ encode each control vertex relatively to its neighbourhood preserving the local geometry. Besides, *Laplacian Cage* has interesting properties to edit large deformation over laser scanned surfaces with sparse constraints, as well as to ensure their local features independently of the high-resolution.

Least-Squares Cage Optimization Our optimal estimation of cage parameters is formulated as a least-squares consistent minimization of an objective function, expressed exclusively in term of cage geometry as follows:

$$\min_{c_k^{t+1}} \left(\underbrace{\sum_{k=1}^{n} \left\| \mathcal{L}_C^t(k) - \hat{\delta}_k^t \right\|_2^2}_{\text{smoothness term}} + \underbrace{\sum_{i \in \mathcal{S}} \left\| v_i^{t+1} - \sum_{k=1}^{n} c_k^{t+1} \cdot h_k(i) \right\|_2^2}_{\text{data term}} \right)$$

The subset $\mathcal{S}$ is composed of sparse deformation constraints, driven by the surface evolution. Such constraints are automatically selected irregularly over the enclosed surface. The smoothness term contains the laplacian-based cage regularization, meanwhile the data energy term transfers a collection of surface deformation constraints into the subspace domain by the quasi-conformal harmonic mapping. This estimation ensures the adaptation along silhouette rims vertices that is already encoded in the input data. Finally, the geometry of performance animation is simply restored and rendered real-time by a 3D free-viewpoint video player.

3 Conclusion

The effectiveness of our system is evaluated successfully on performance mesh animations, reconstructed from multi-video sequences by [Vlasic et al. 2008]. For visual evaluation, we simply backproject cage-based meshes into the video stream according to camera calibration information. For qualitative evaluation, the fidelity of our output is measured using multi-view silhouette overlap error between the reprojected model and the silhouette image. Our harmonic inverse cage-based estimation allows rim vertices to preserve silhouette consistency better than inverse skeleton-based estimation. To summarize, boneless cage-based approach is more convenient than kinematic hierarchy-based approach to guarantee the deformation fidelity of non-rigid surface to multi-video stream.

References

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