Shuffler: Modeling with Interchangeable Parts

Alla Sheffer
(joint work with Vladislav Kraevoy & Dan Julius)
Motivation - Easy creation of 3D Content

- Currently 3D modeling requires a lot of time & expertise
- Observations:
  - Practical modeling limited to small set of classes
  - Models have intuitive breakdown into interchangeable parts
- Can create rich & detailed models by shuffling parts
  - \(n\) models with \(m\) parts \(\rightarrow n^m\) new models
Modeling System
Shuffler Modeling System

- Fast & Trivial to use
  - Mouse click based
  - No geometric input from user
  - No user parameters
Under the hood...

I. Meaningful Segmentation
II. Component Correspondence
III. Shuffling: alignment & blending

Details at www.cs.ubc.ca/~vlady/shuffler/shuffler.htm
Mean-Value (Pyramid) Coordinates for Mesh Editing

Vladislav Kraevoy & Alla Sheffer

To appear in IJ SM
Motivation – Model Editing

- Simple control mechanism
- Intuitive results
  - “Optimal” rotation
  - Not restricted to convex combination of anchor rotations
Motivation - Motion Reconstruction

- No normal information
Other Local Shape Representations

- Linear
  - Triangle based [Yu et al. 04, Zayer et al. 05,...]
  - Vertex (Laplacian) based [Alexa 01, Sorkine et al. 04, Lipman et al. 04, Lipman et al. 05]
  - Require normal info to obtain rotational deformation
  - Rotational component – combination of anchor rotations
- Non-linear [Sheffer & Kraevoy 04, Kraevoy & Sheffer 06, Botsch 06]
  - No normal requirement
Local Coordinate Frame (per vertex)

- Define local coordinate frame
  - invariant under rigid transformations

1. Use vertex normal [Kraevoy & Sheffer’04]
   - Circular dependency
     - Depends on current vertex position
   - Stability issues
2. Use *Laplacian normal* [Kraevoy & Sheffer’06]

Area averaged normal of local Laplacian mesh

Function of neighbour vertices ONLY
Provides closed form solution
Allows efficient (hierarchical) solution
Encoding

Tangential component

\[ w_{ij} = \frac{\tan(\alpha_{jk+1}/2) + \tan(\alpha_{jk}/2)}{l_i} \]

Normal component - \( h_i \)

[Floater03]
Decoding

Tangential component

\[ v'_i = \sum_{(i,j)\in E} w_{ij} v'_j \]

Normal component

\[ v_i = v'_i + h_i n_i \]
Explicit formulation

\[ v'_i \] – position in the tangential plane

\[
v_i = F_i(V) = v'_i + h_i n_i = \sum_{(i,j) \in E} w_{ij} (v_j - (d_i + v_j \cdot n_i) n_i) + h_i n_i
\]

\[ v'_j \] – neighbor projection

offset above the tangential plane

Properties
- Reconstruction (everywhere)
- Invariance under rigid transformations
- Shape preservation
Global Reconstruction

- Least squares minimization problem

\[
\text{arg min } G(V) = \frac{1}{2} \sum_{v_i \in V} (v_i - F_i(V))^2
\]

- For editing add positional vertex constraints

- Solve
  - Global
  - Local
    - Gauss-Newton iterations
      - closed form – have analytic derivatives
Multiresolution
Examples - Deformation
Results

Movie
Compare

Normal propagation/Laplacian

Our method
Comparison

[Sorkine et al. 04] with normals [Sheffer & Kraevoy 04]  [Kraevoy & Sheffer 06]
Summary

- Novel local coordinate representation

Advantages

- Shape preservation - No shearing artifacts
- Closed form formulation
- Invariant under rigid transformations
- Does not require anchor normals
- Rotations not restricted to convex hull of anchor rotations
Summary

- Applications
  - Deformation/Blending/Morphing
  - *Motion from MoCap*

- Multiresolution
  - Interactive performance

- Future
  - Material awareness
    - see [Julius, Popa and Sheffer, SMI 2006]
  - Realistic muscle movement (noise)
Thank you

Any questions?