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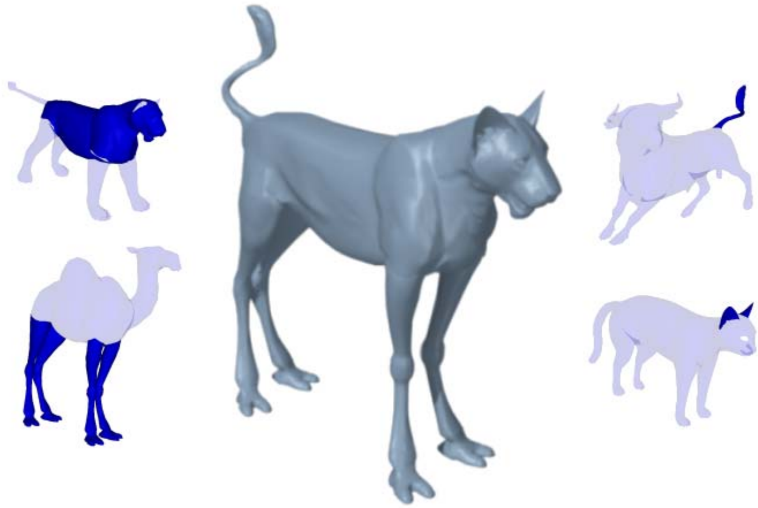
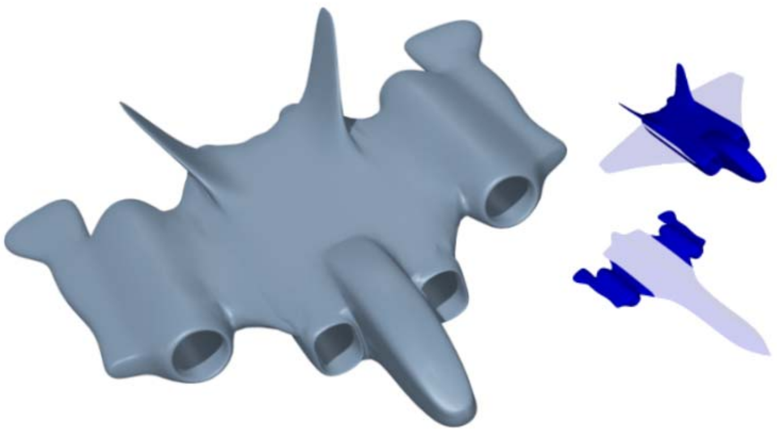
Shuffler: Modeling with Interchangeable Parts

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

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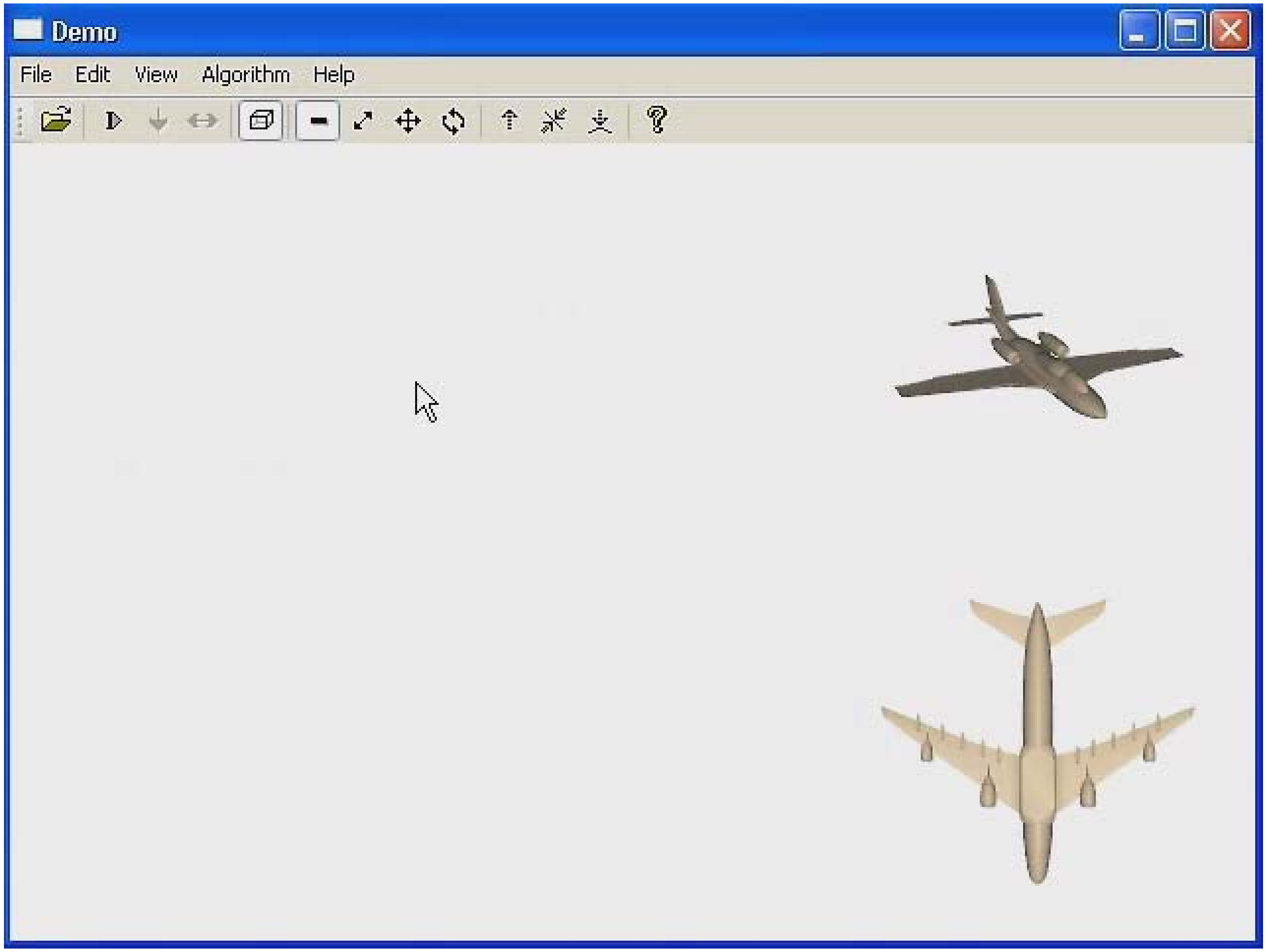
Modeling System



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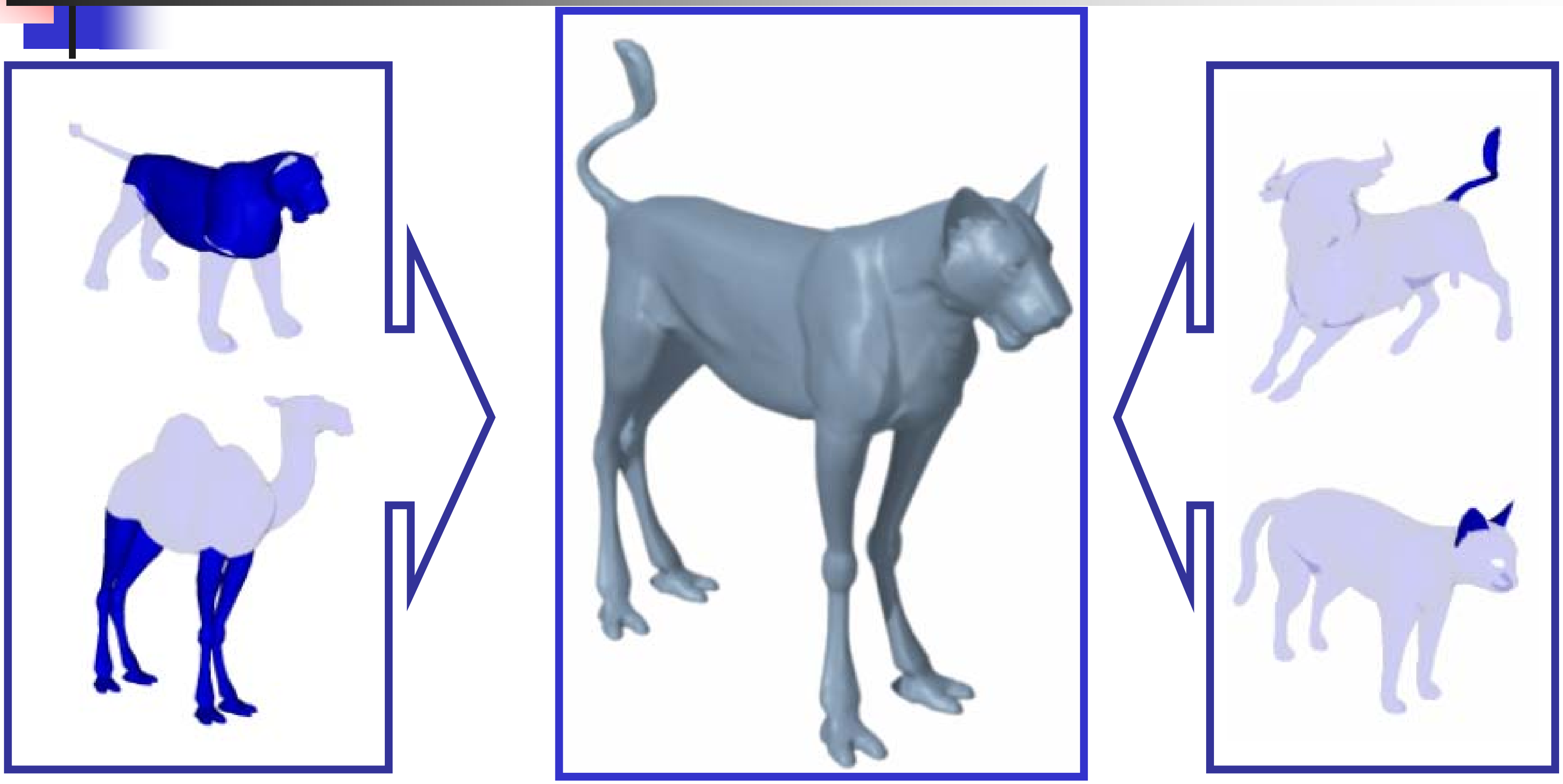
Shuffler Modeling System



- Fast & Trivial to use
  - Mouse click based
  - No geometric input from user
  - No user parameters

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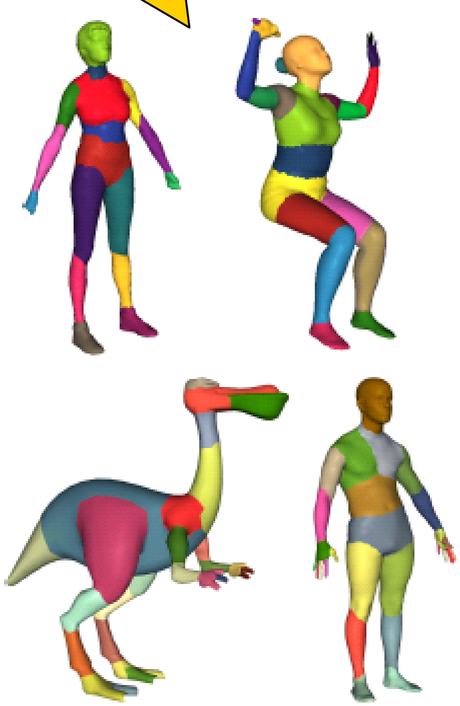
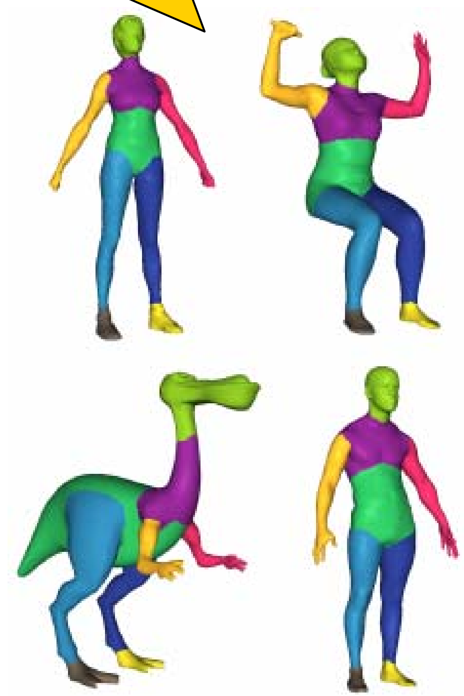
Under the hood...

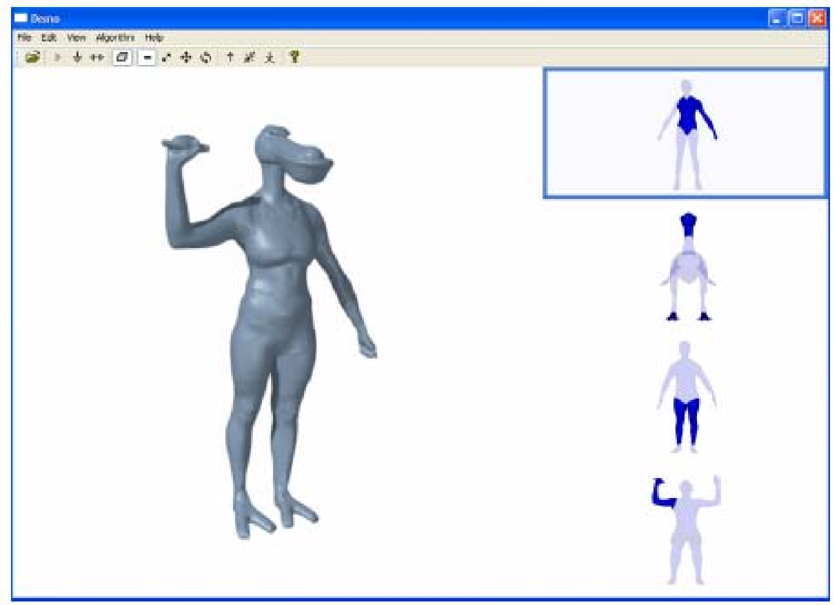
I. Meaningful Segmentation



II. Component Correspondence



III. Shuffling: alignment & blending



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Details at www.cs.ubc.ca/~vlady/shuffler/shuffler.htm

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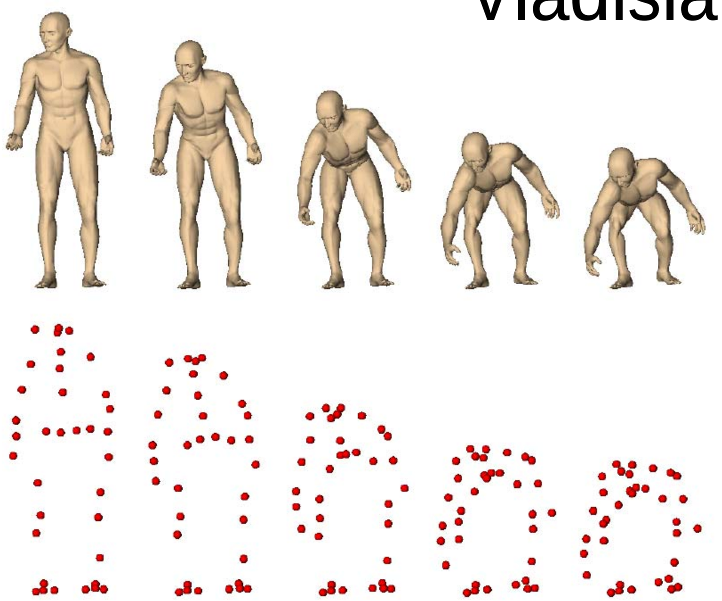
Mean-Value (Pyramid) Coordinates for Mesh Editing

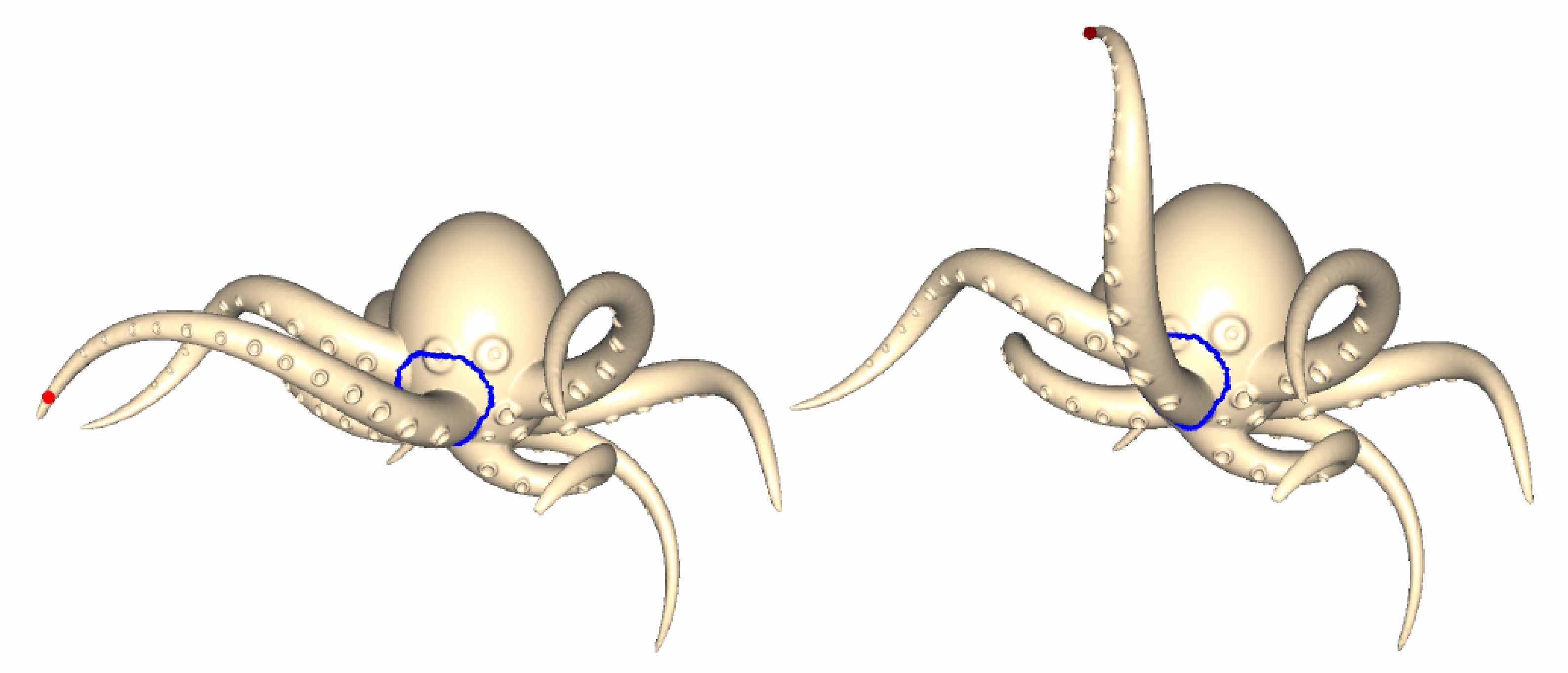
Vladislav Kraevoy & Alla Sheffer

To appear in IJSM



Motivation – Model Editing

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



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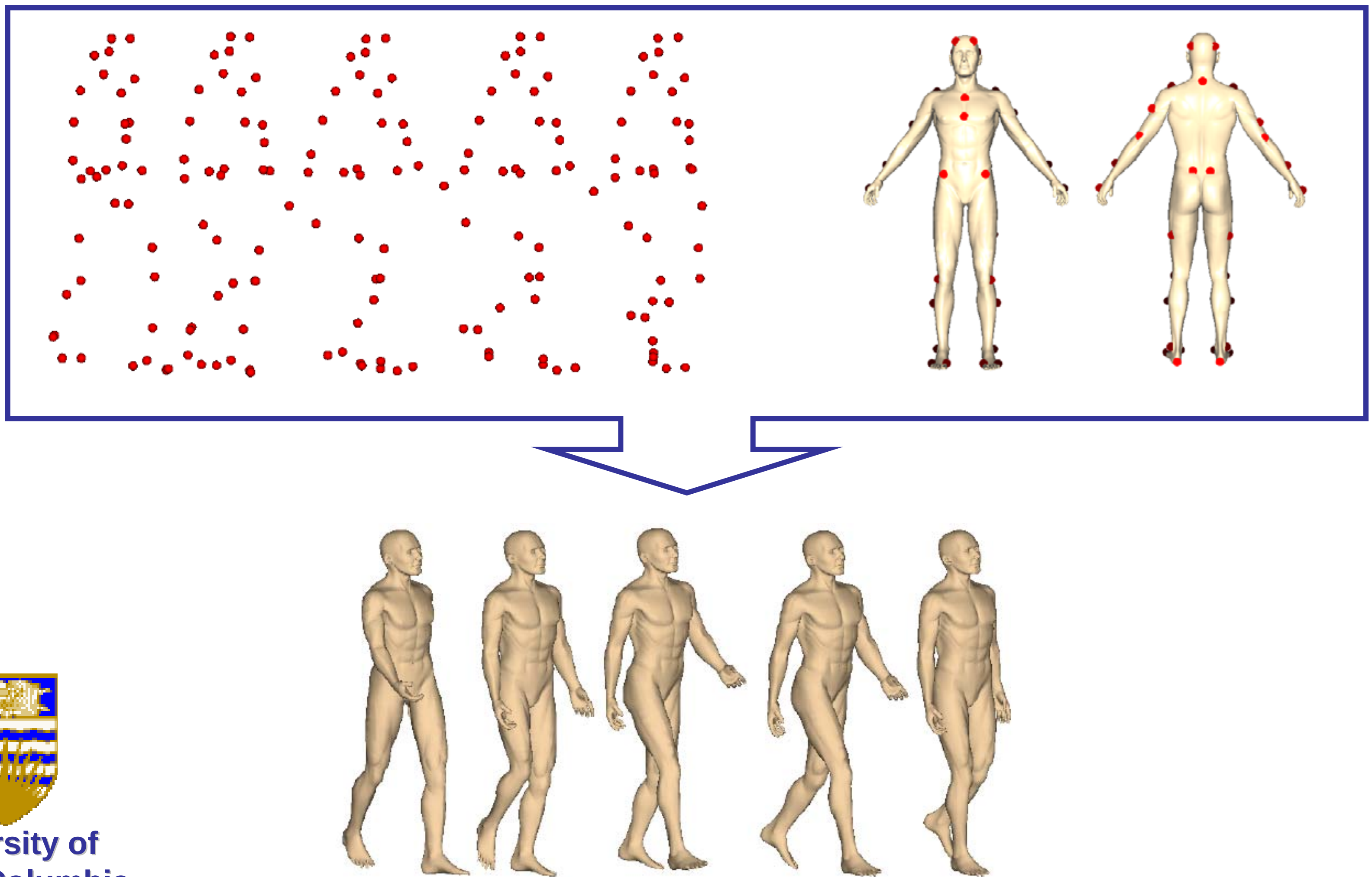
Motivation - Motion Reconstruction

- No normal information



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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

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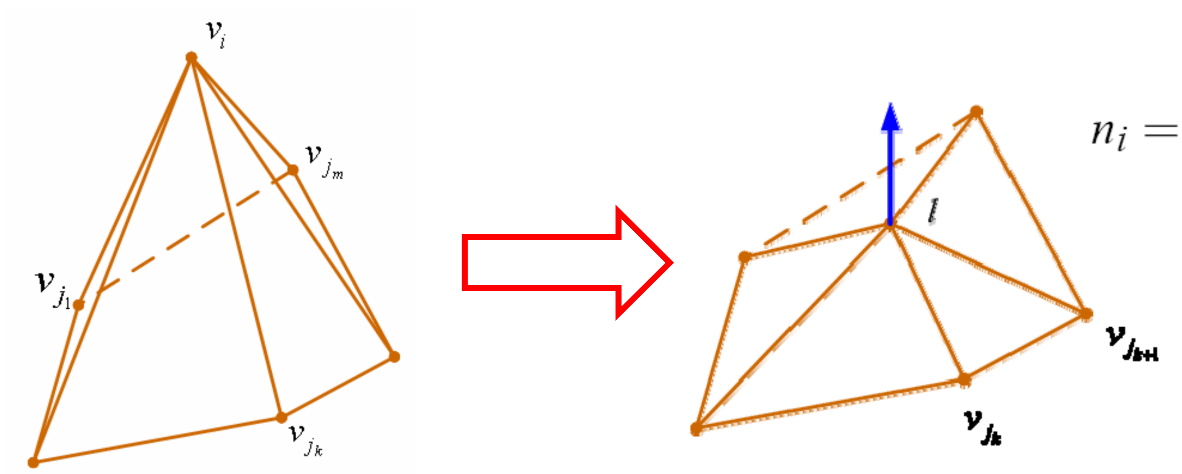
Laplacian Normal Calculation

2. Use *Laplacian normal* [Kraevoy & Sheffer'06]
   Area averaged normal of local Laplacian mesh



$$n_i = \frac{\sum_{k=1}^{m} (v_{j_{k+1}} - l) \times (v_{j_k} - l)}{\| \sum_{k=1}^{m} (v_{j_{k+1}} - l) \times (v_{j_k} - l) \|}$$

$$l = \frac{1}{m} \sum_{(i,j)\in E} v_j$$

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

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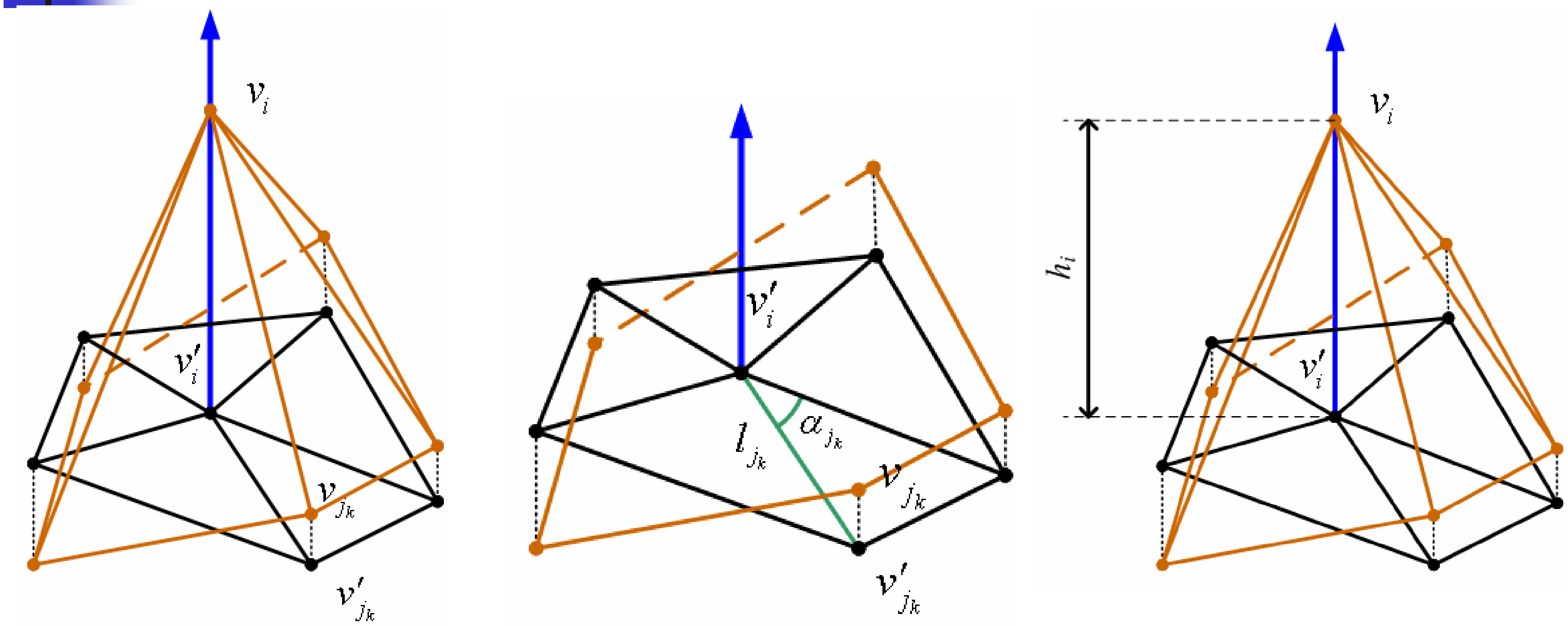
Encoding



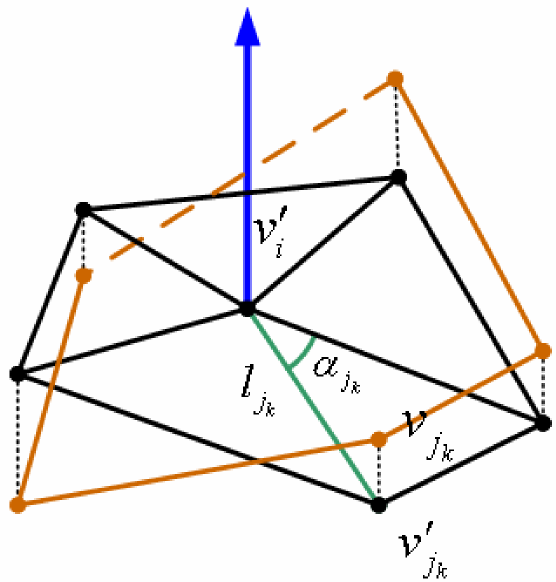
Tangential component

Normal component - h_i

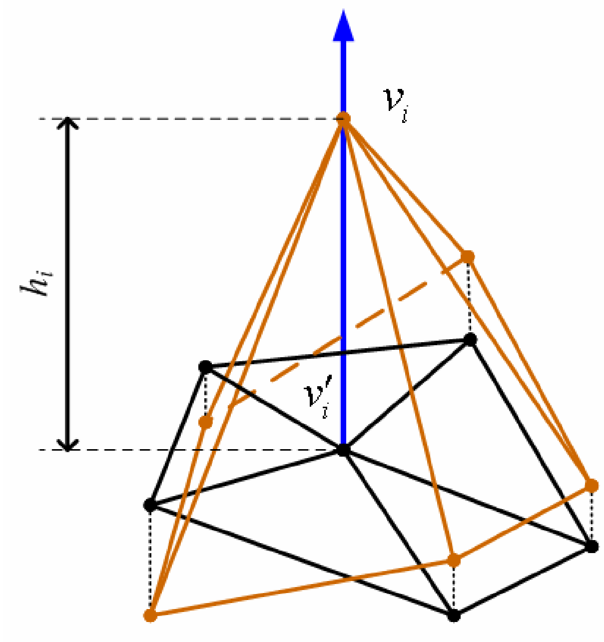
$$w_{ij} = \frac{\tan(\alpha_{j_{k+1}}/2) + \tan(\alpha_{j_k}/2)}{l_i}$$

[Floater03]

Decoding



Tangential component



Normal component

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

$$v_i = v'_i + h_i n_i$$

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Explicit formulation

$$v_i = F_i(V) = v_i' + h_i n_i = \overbrace{\sum_{(i,j)\in E} w_{ij}\underbrace{(v_j - (d_i + v_j \cdot n_i)n_i)}_{v'_j \text{ – neighbor projection}}}^{v'_i \text{ – position in the tangential plane}} + \underbrace{h_i n_i}_{\text{offset above the tangential plane}}$$

Properties

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

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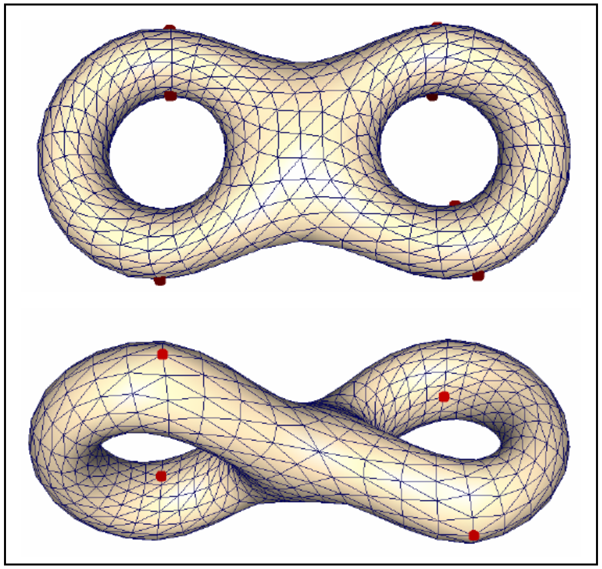
Global Reconstruction

- Least squares minimization problem

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

- For editing add positional vertex constraints
- Solve
  - Global
  - Local
    - Gauss-Newton iterations
      - closed form –
        have analytic derivatives



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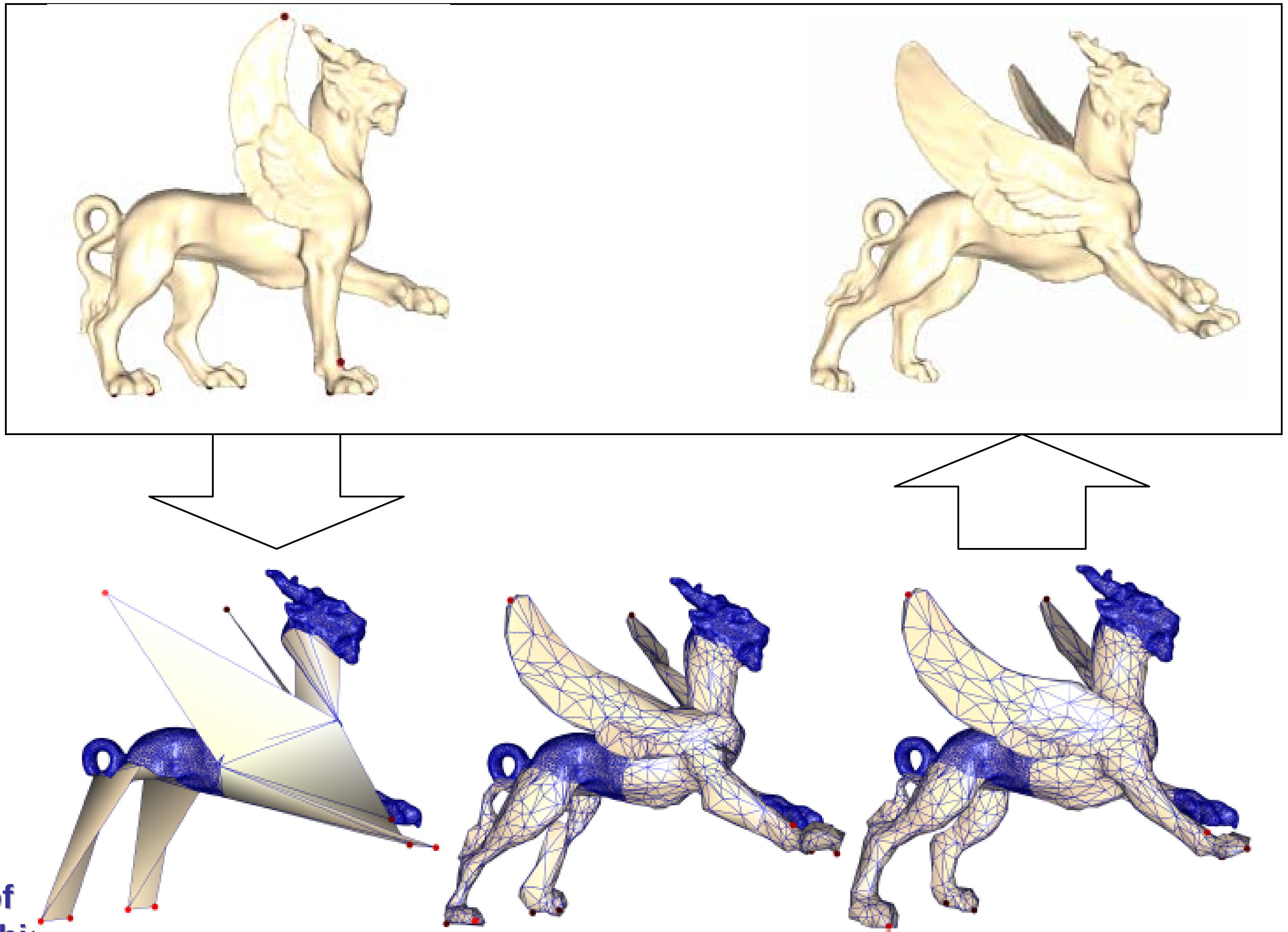
Multiresolution



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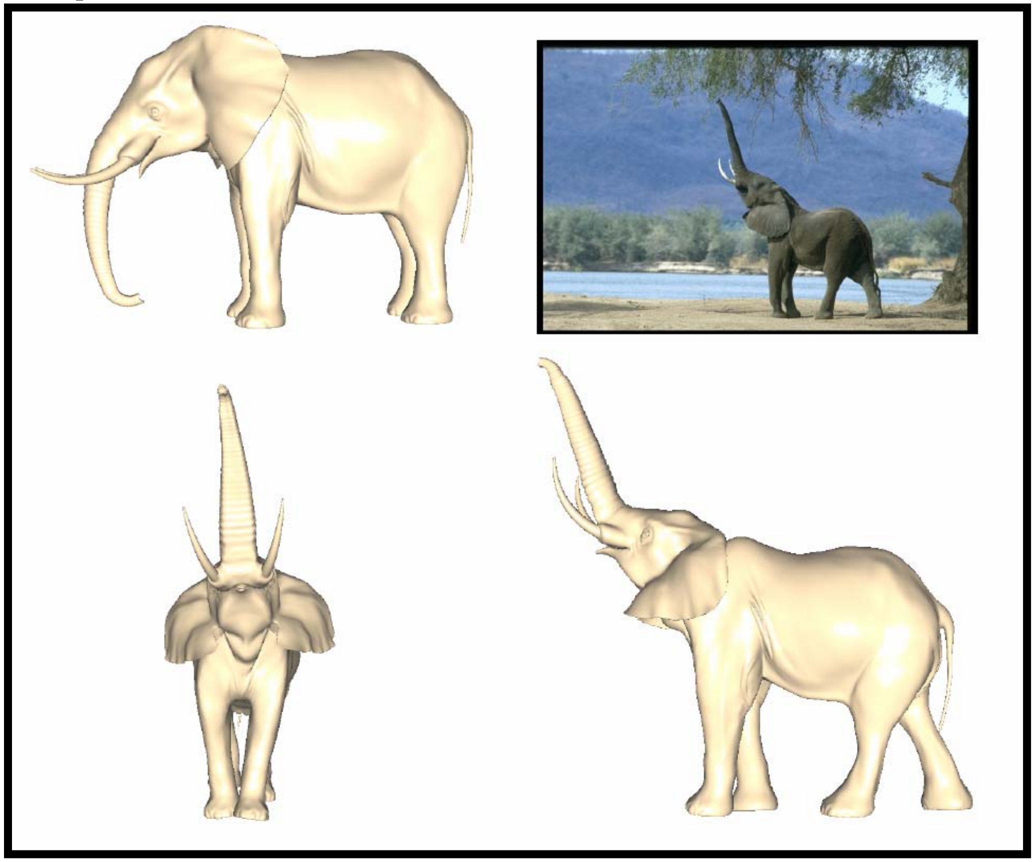
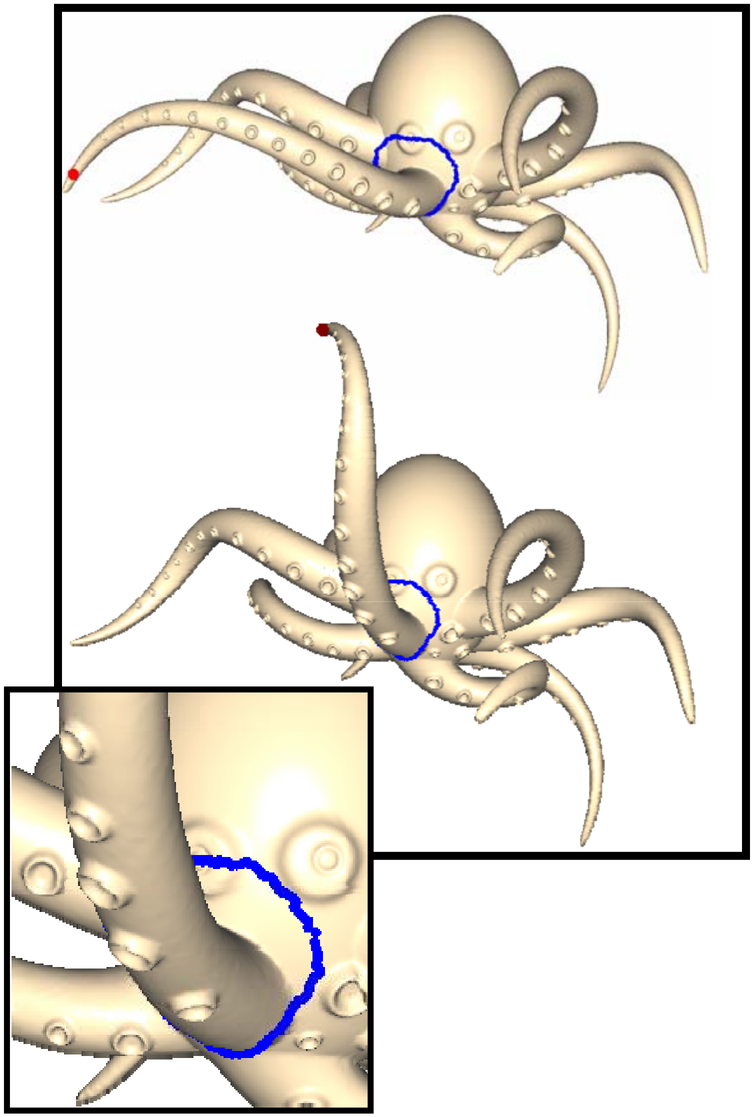
Examples - Deformation





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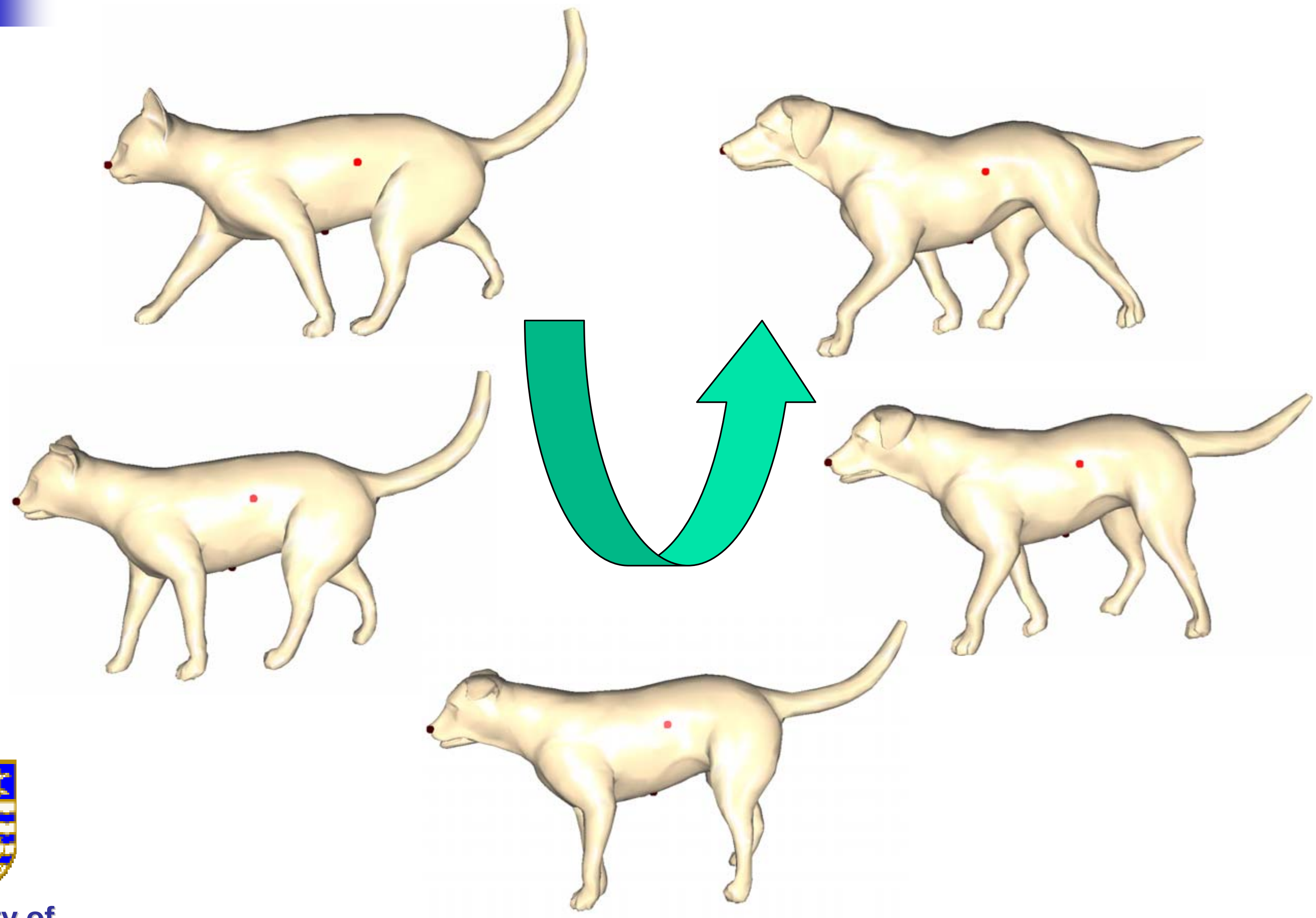
Example - Morphing



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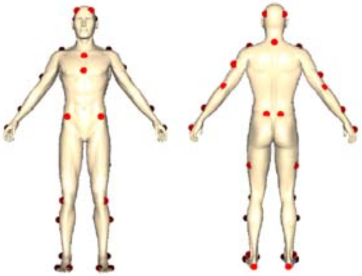
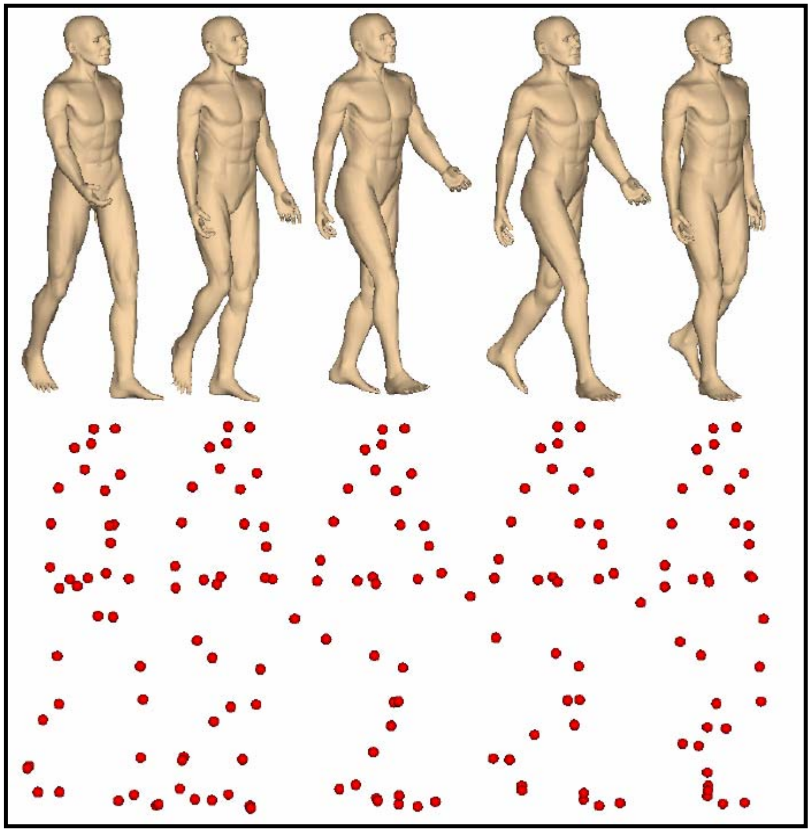
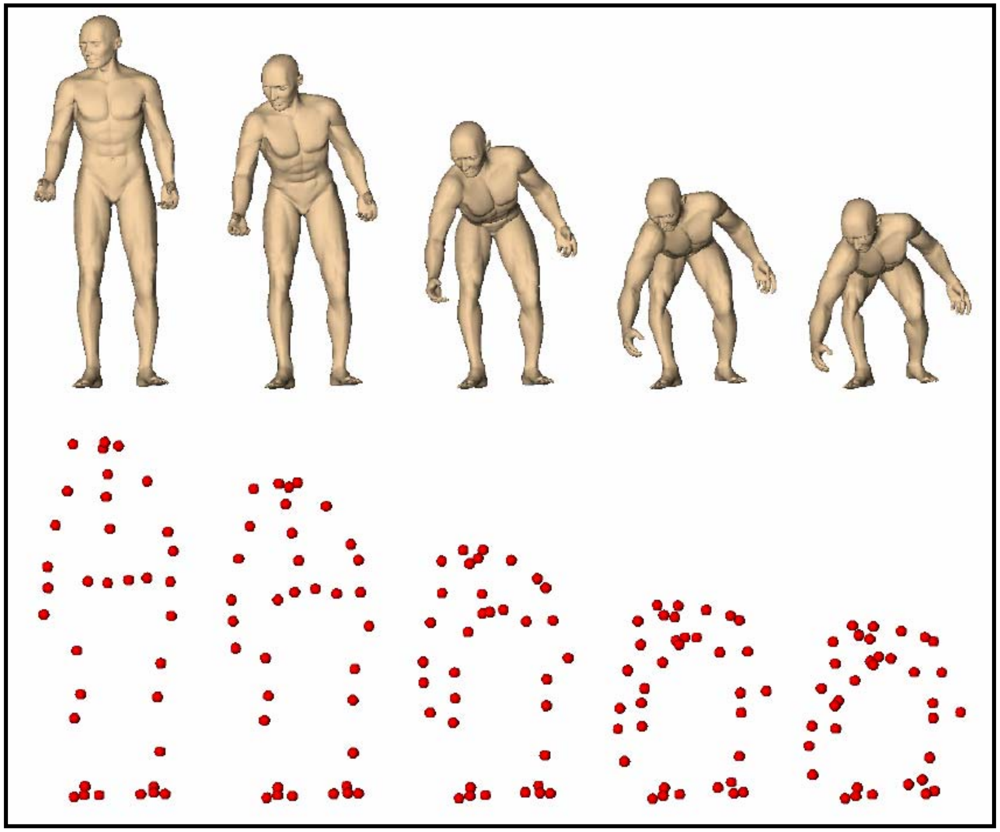
Results







Movie

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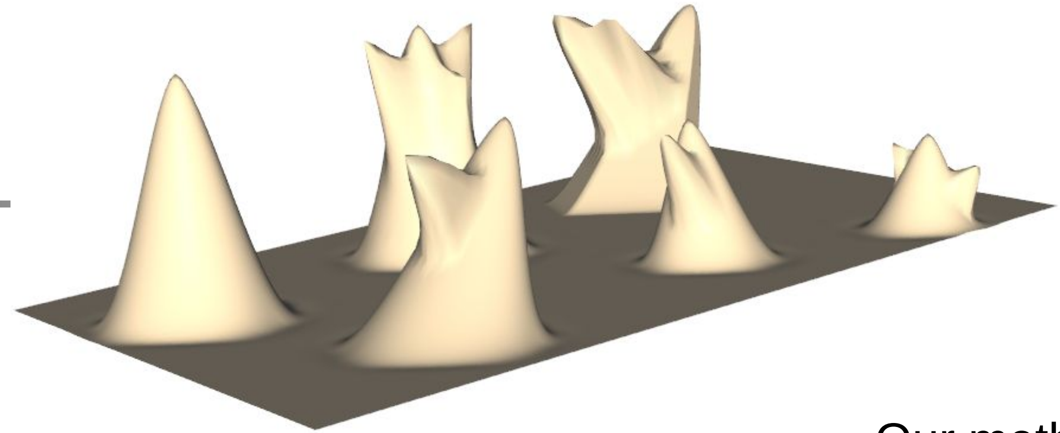
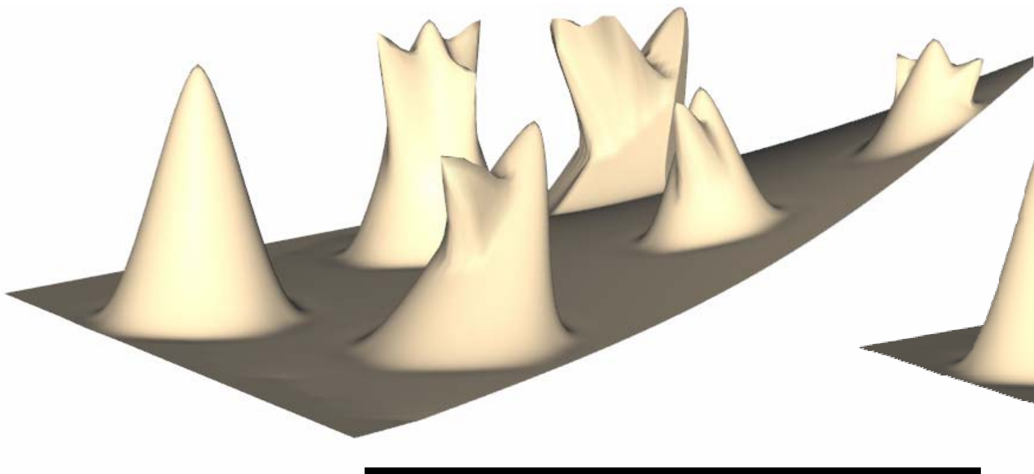
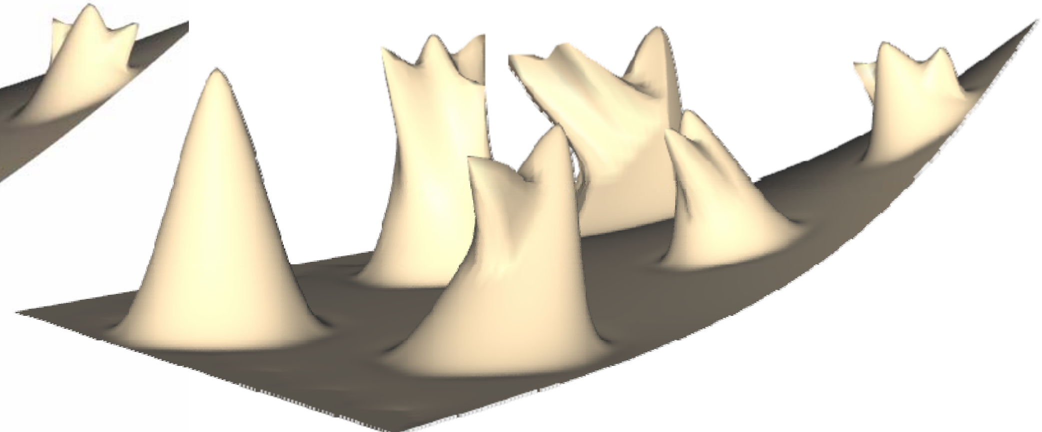
Compare

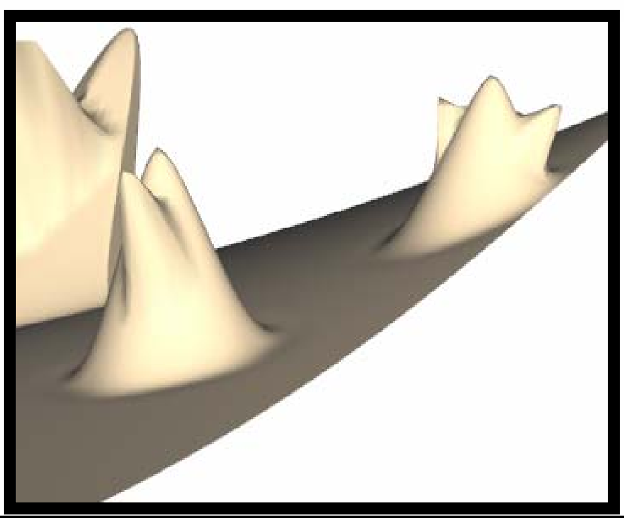


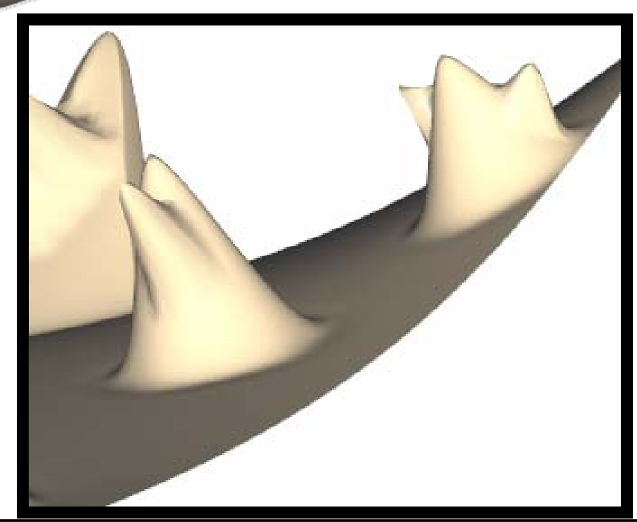
Normal propagation/Laplacian

Our method









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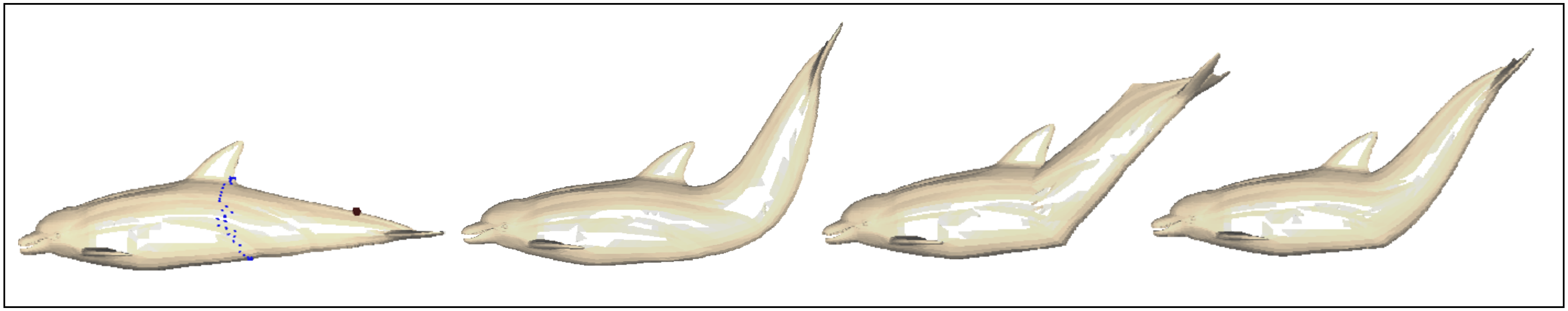
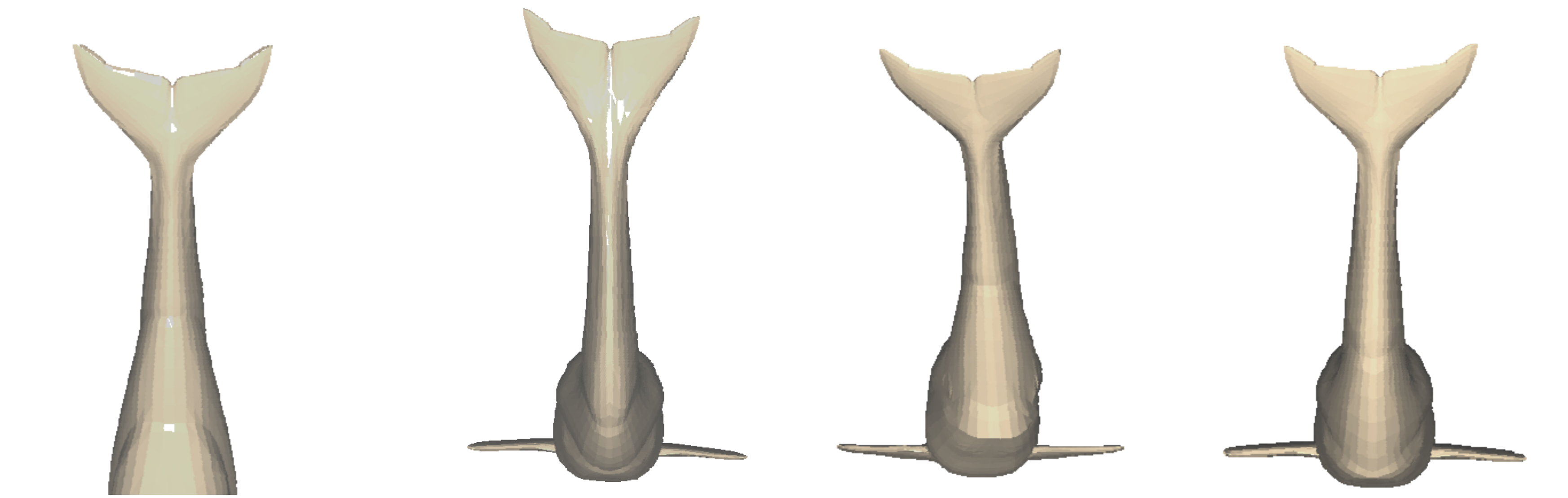
Comparison





[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)

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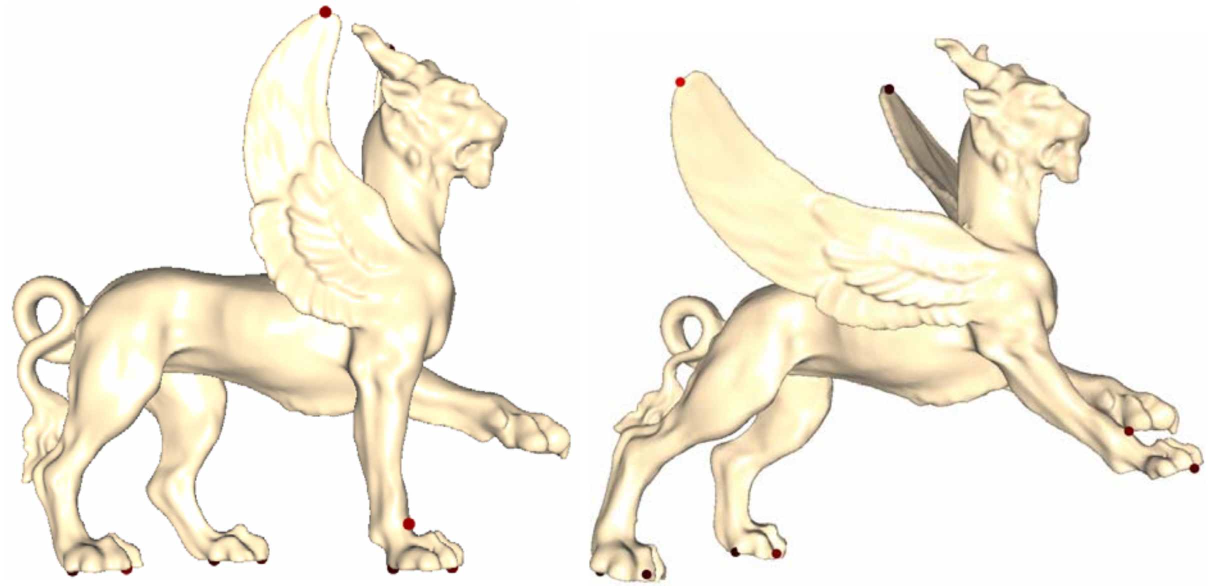
Thank you

Any questions?



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