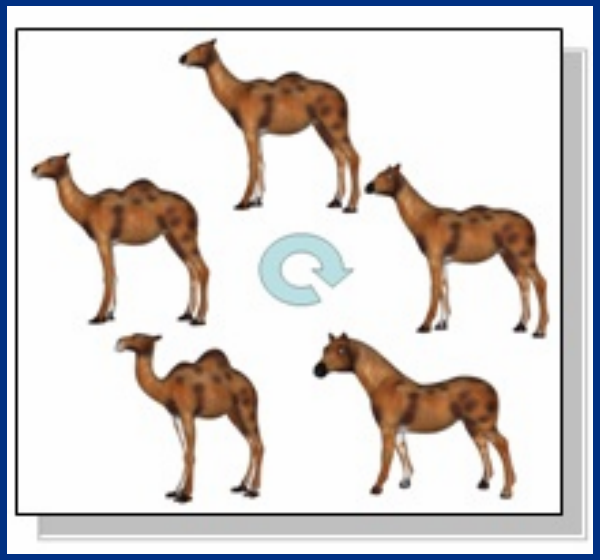
Siggraph Course

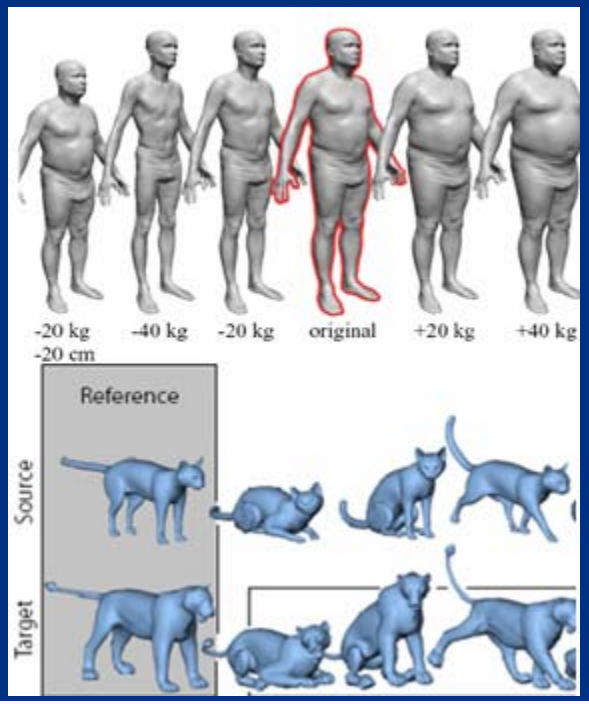
Mesh Parameterization: Theory and Practice

SIGGRAPH2007

X-parameterization/Inter-surface mapping

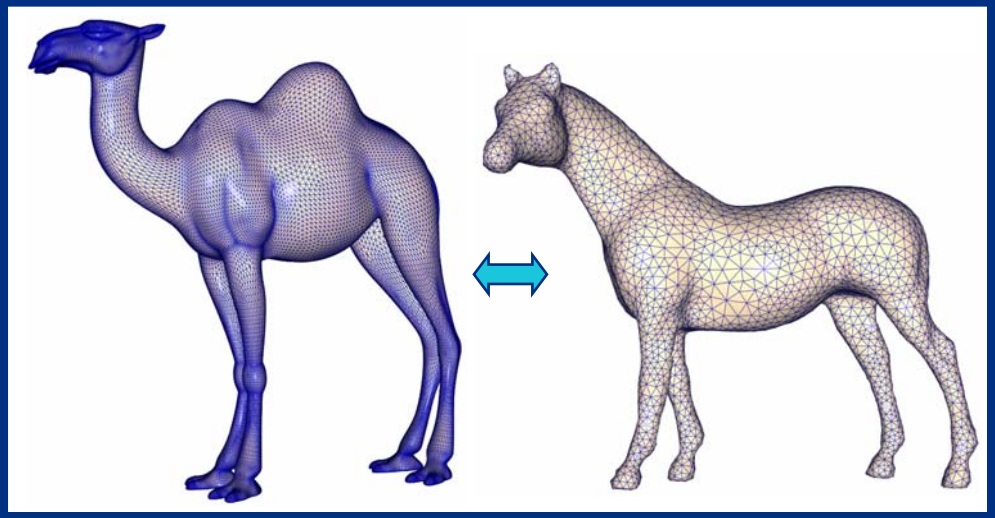
Alla Sheffer

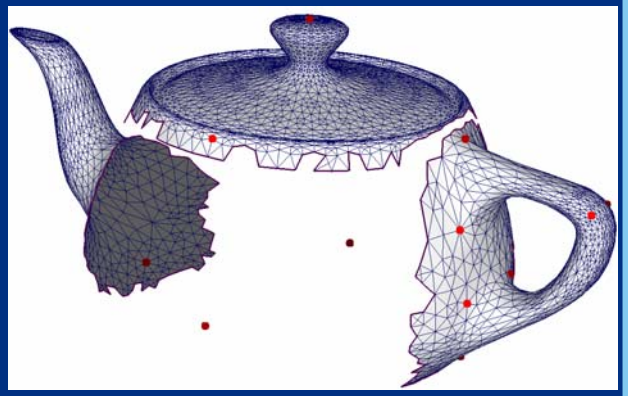


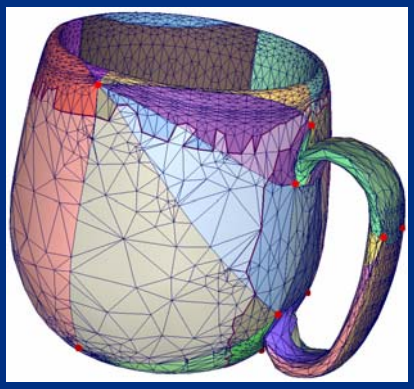


X-Parameterization/Inter-surface mapping

- Mapping between surface models (meshes)







  - One-to-one
  - Or not..

- Often enforce feature correspondence

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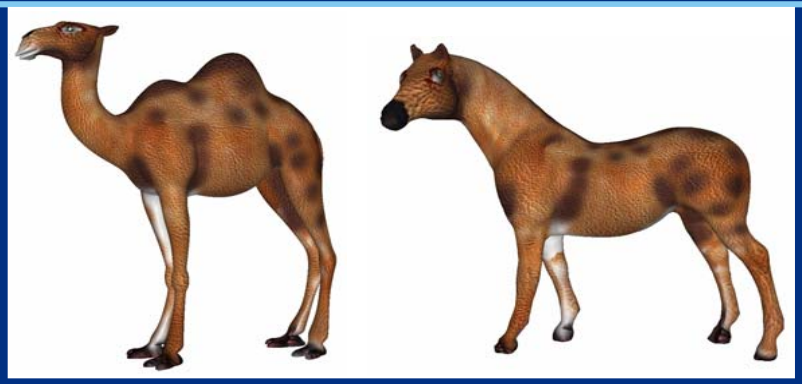
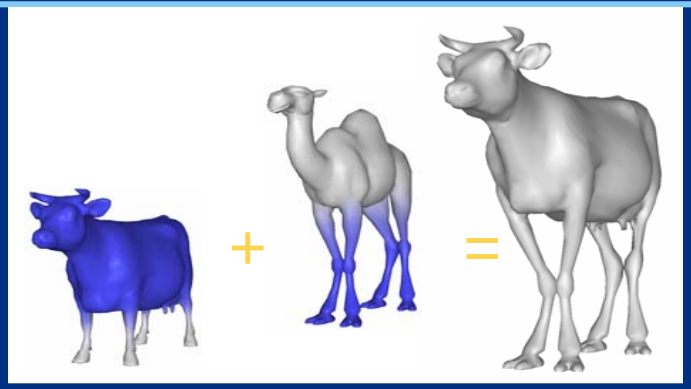
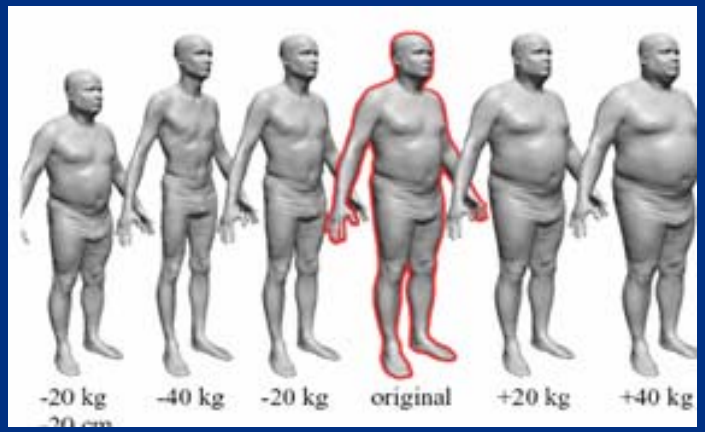
Applications



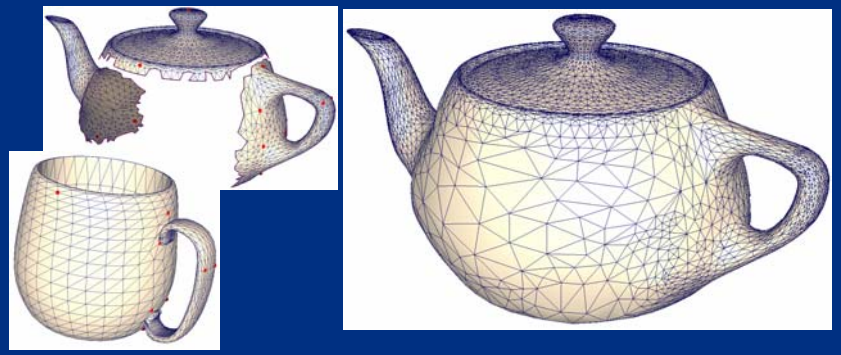
Properties Transfer



Morphing/Blending



Shape Spaces



Mesh Completion

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Main Approaches

- Compatible Segmentation
  - Coarse-to-fine [Schreiner:04]
  - Base-Mesh parameterization [Praun:01; Kraevoy & Sheffer:04; Kraevoy & Sheffer:05]
- Global Matching [Allen:03;Anguelov:05; Bronstein:07]
  - With/without specified feature correspondences

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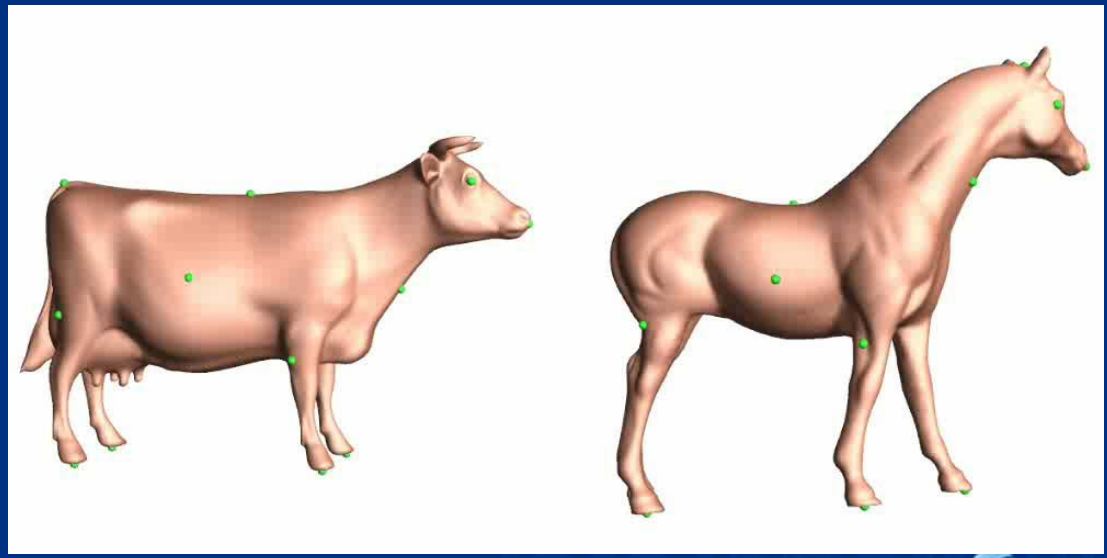
Coarse-to-fine [Schreiner:04]

- Segment meshes into compatible patches
  - Use input features as corners
- Simplify each patch to triangle
- Compute map by coarse-to-fine optimization
  - Can relax feature correspondence



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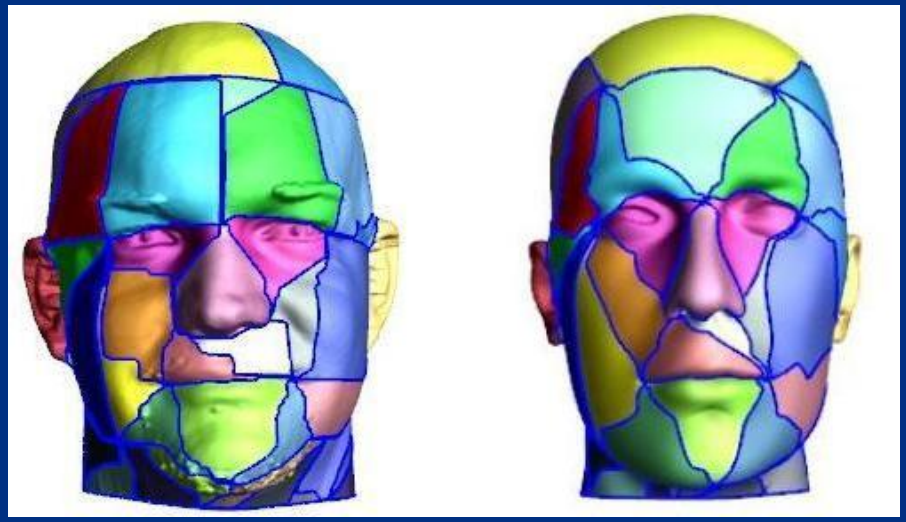
Compatible Segmentation [Schreiner:04; Kraevoy & Sheffer:04]

- Add pairs of matching (shortest) paths between feature vertices
  - Validity checks
    - Intersection
    - Order
    - Blocking
  - Add vertices when necessary
- Extends [Praun:01;Kraevoy:03]



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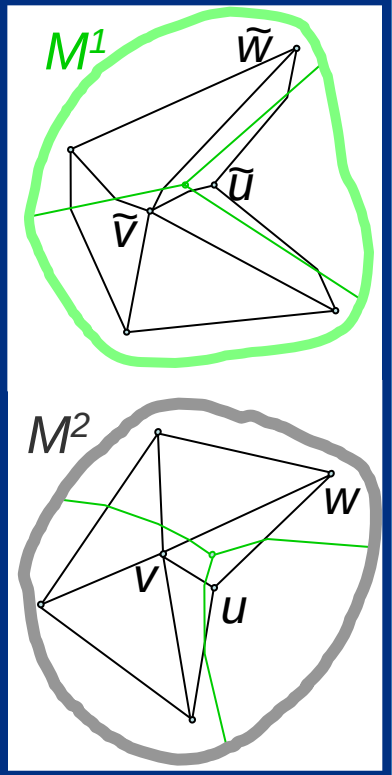
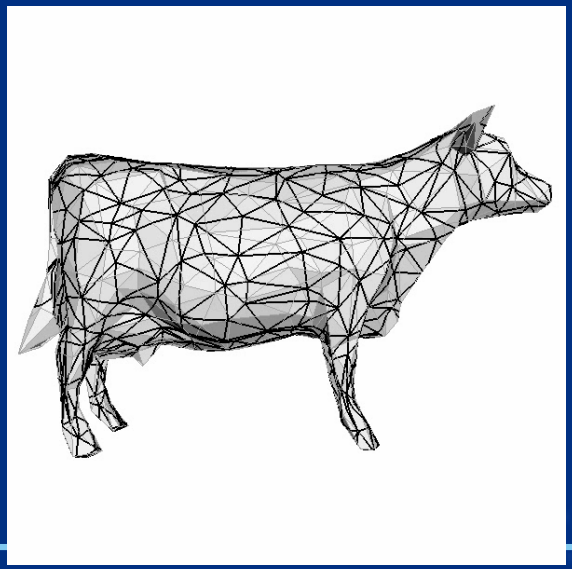
Coarse-to-fine Optimization

- Insert vertices incrementally
  - Map each vertex inserted in one mesh to the other
    - Use local 2D parameterization
    - Use stretch metric
- Relax surroundings
  - Fairly time consuming
    - Time/Quality tradeoff





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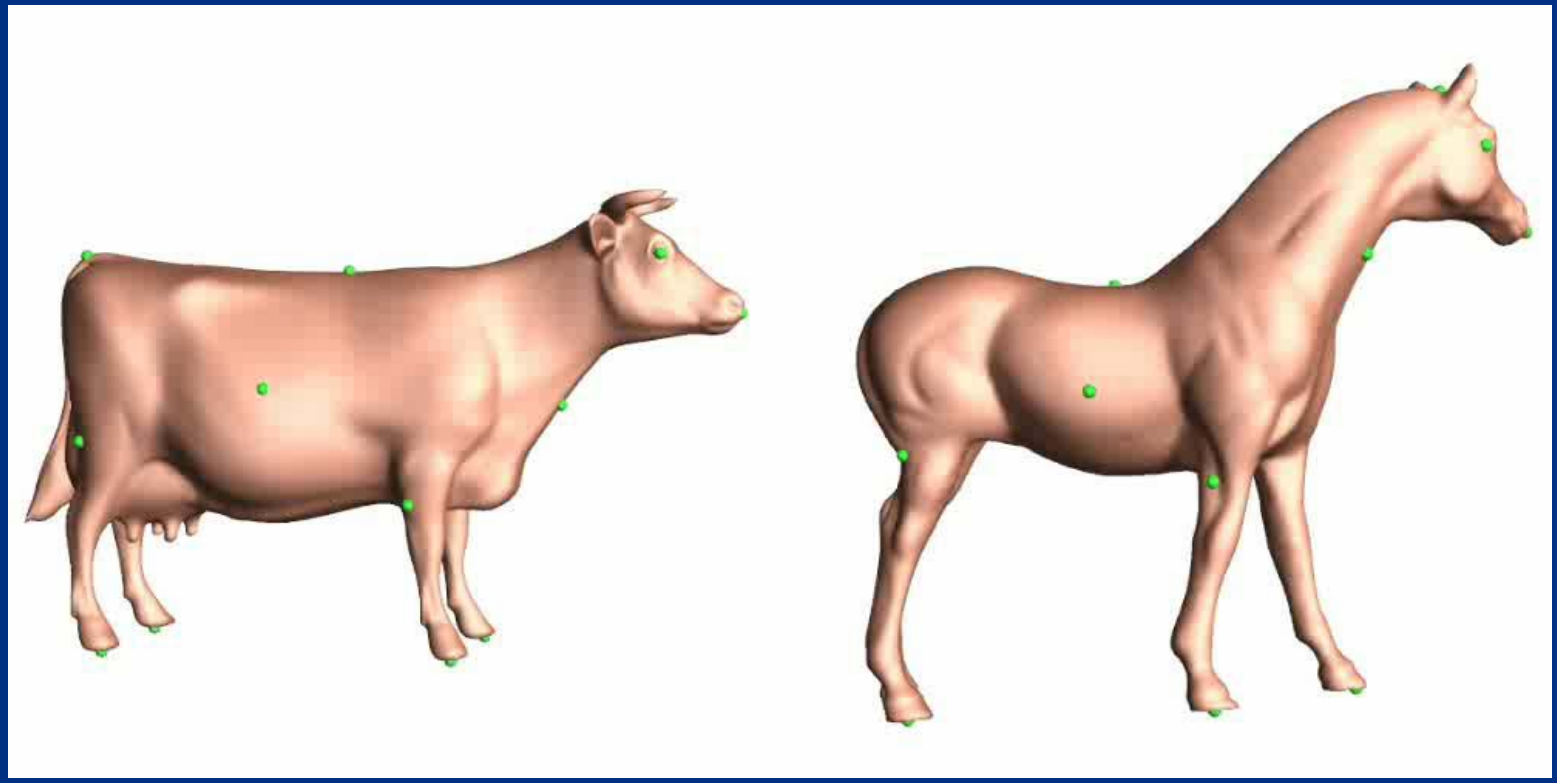
Coarse-to-fine - demonstration



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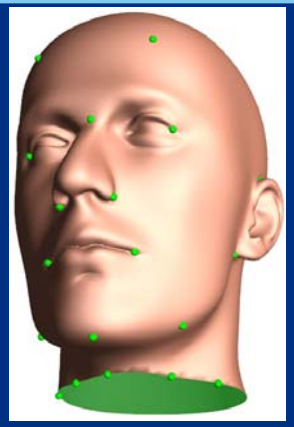
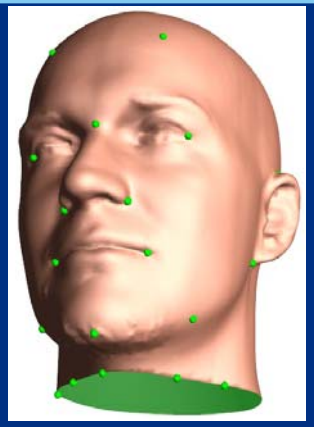
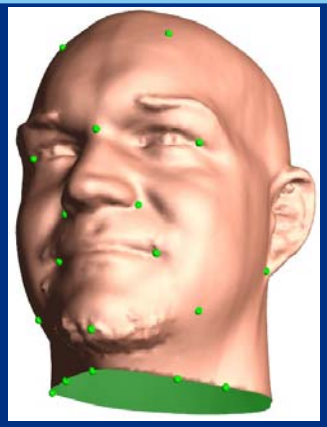
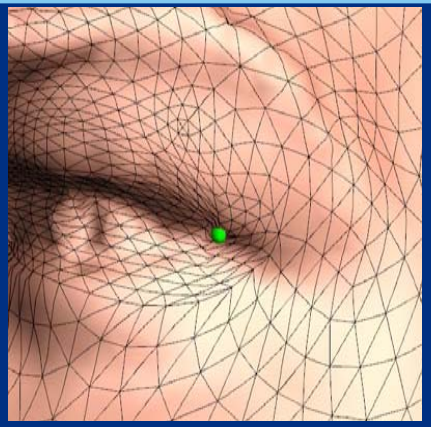
Examples

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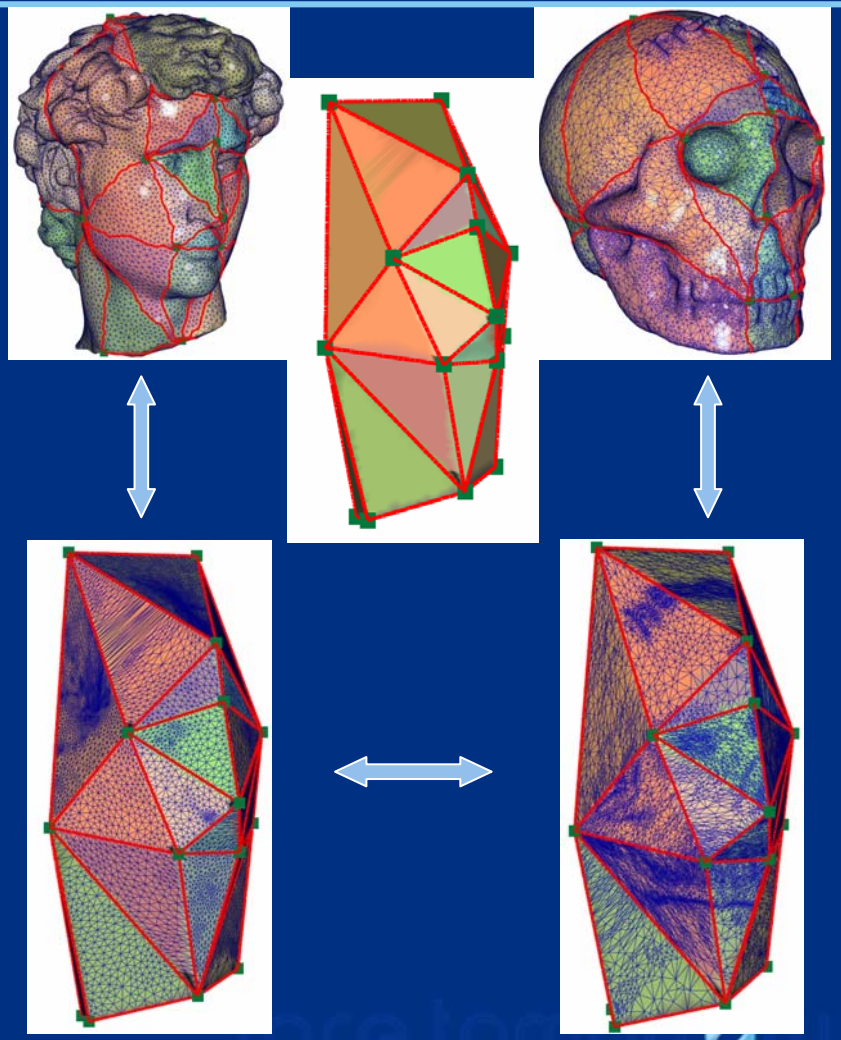
Common Base Mesh

- Segment meshes into compatible patches
- Compute initial mapping
  - Construct base
    - triangle per patch
  - Barycentric mapping
    - Guarantee bijectivity
- *Improve mapping*



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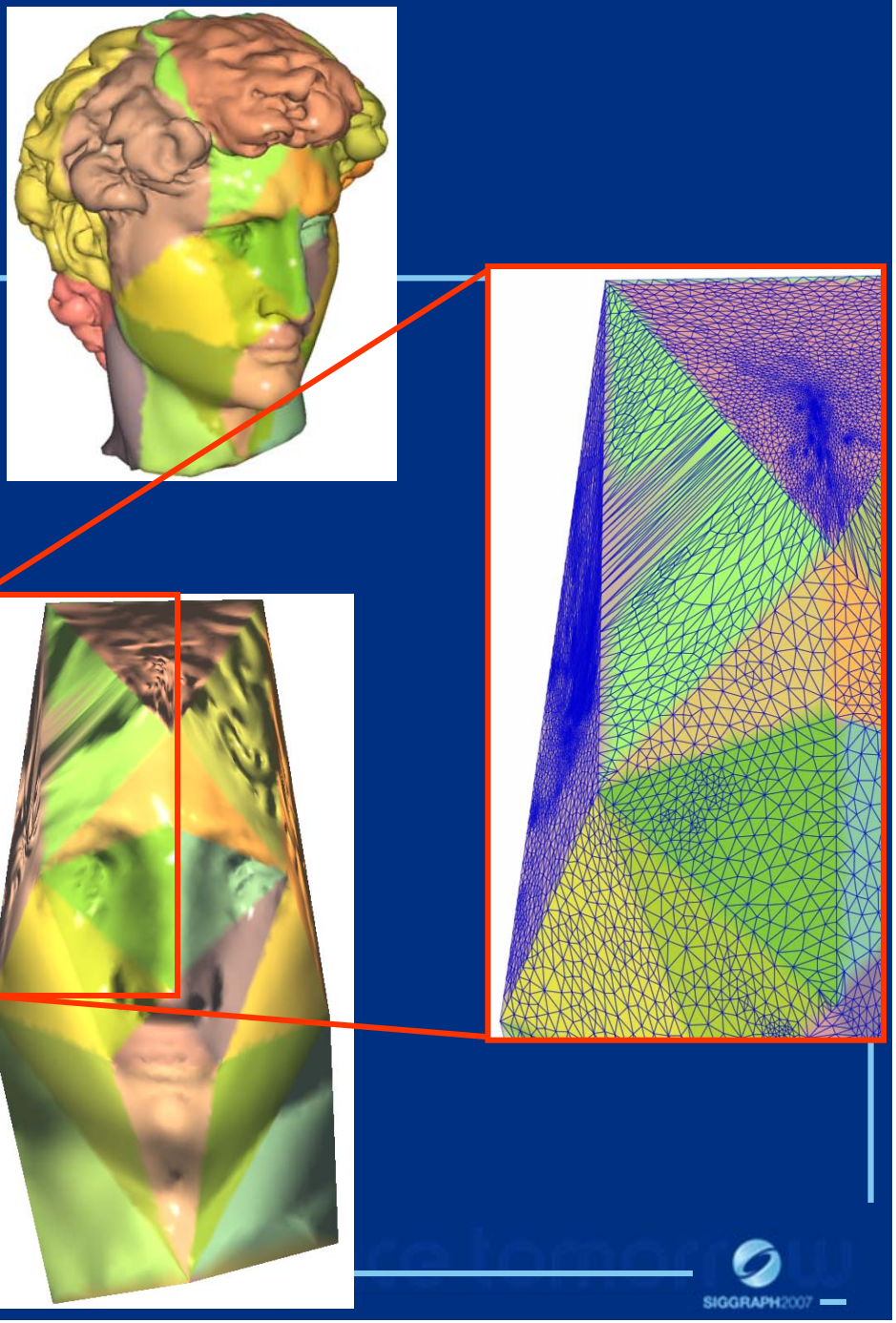
Distortion & Artifacts

- Badly shaped patches = high distortion
- To reduce distortion *must move vertices between base triangles*



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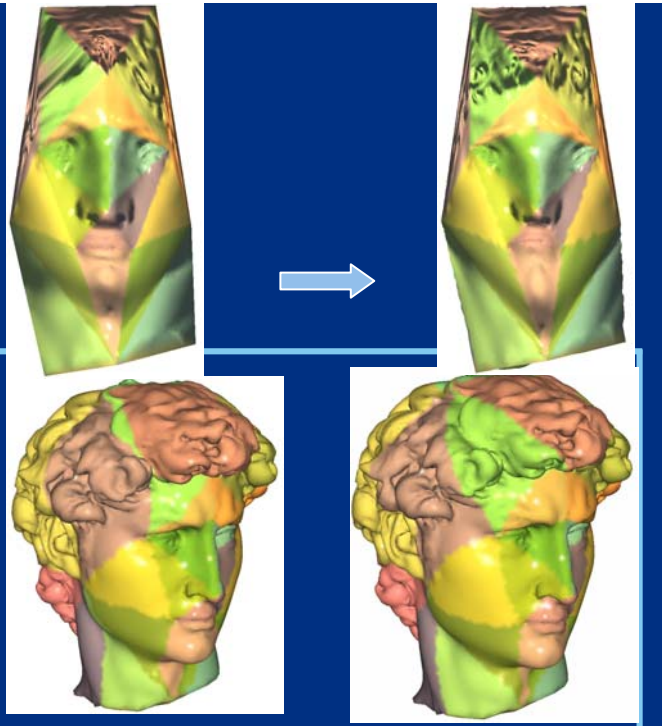
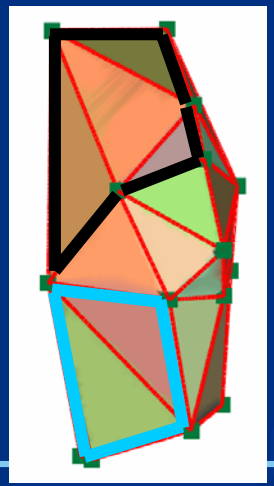
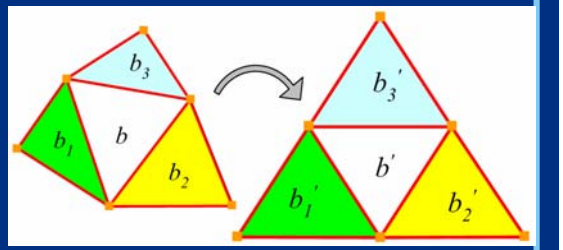
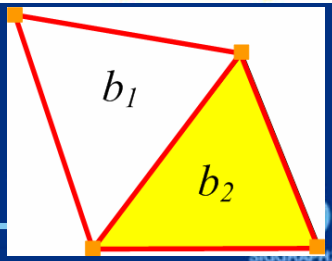
Improvement Approaches



- Global [Khodakovsky:03;Aliez:06]
  - Solve (repeatedly) global linear system
- Overlapping domains [Guskov:00;Kraevoy & Sheffer:04;Kraevoy & Sheffer:05]
  - Group adjacent patches
    - map to convex domain
  - Iterate
    - Maintains validity
    - Fast







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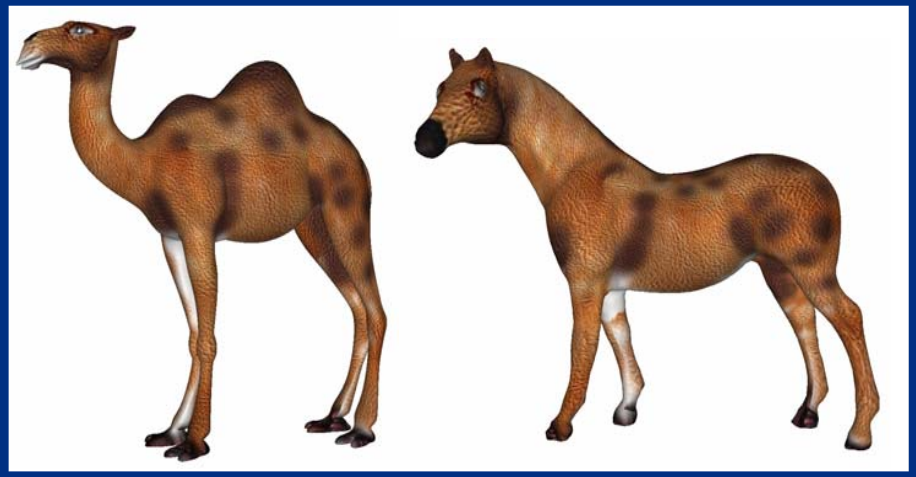
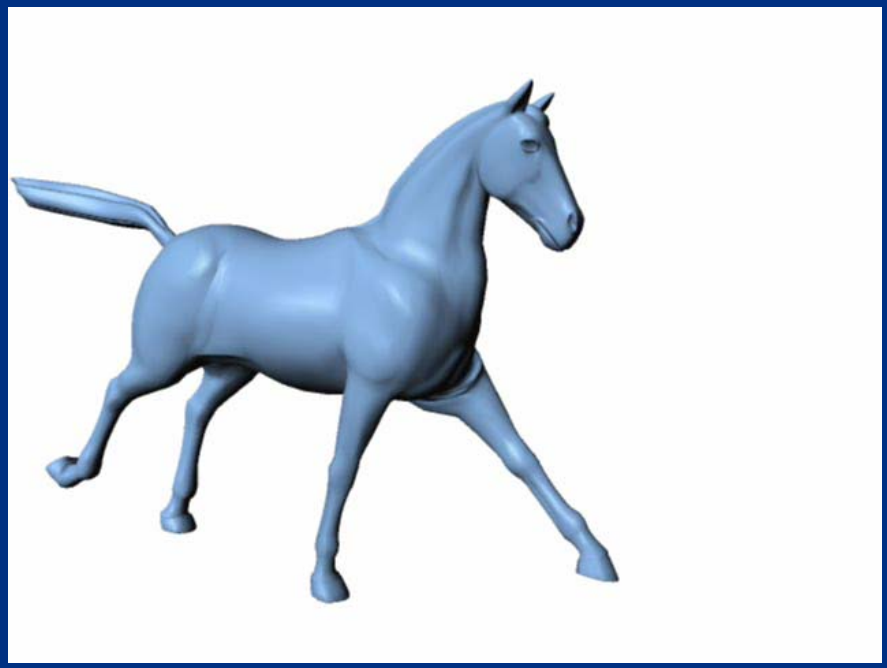
Application Examples



Texture transfer
80K/7K faces
56 sec



Motion transfer
[Sumner & Popovic 04]

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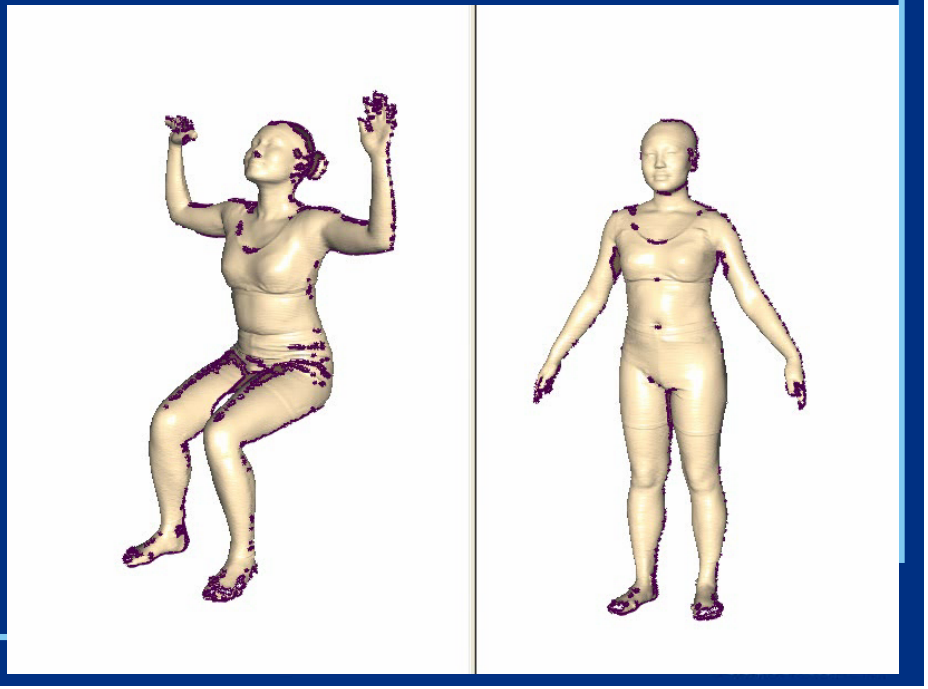
Mapping incomplete meshes – Base mesh approach [Kraevoy & Sheffer:05]

- Application: Mesh Completion
- Challenges
  - Compatible segmentation (multiple components)
  - *Parameterizing holes*



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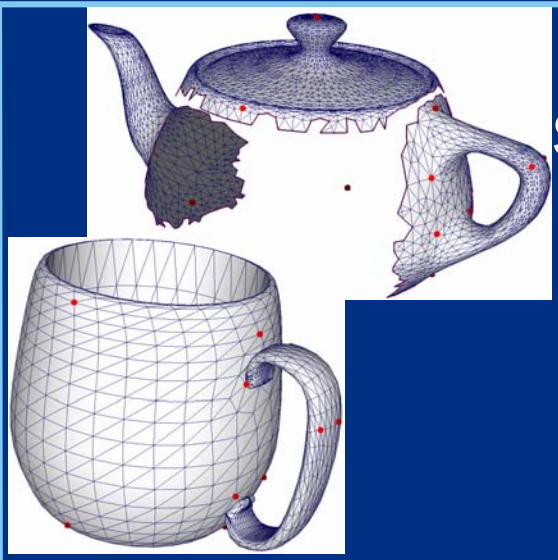
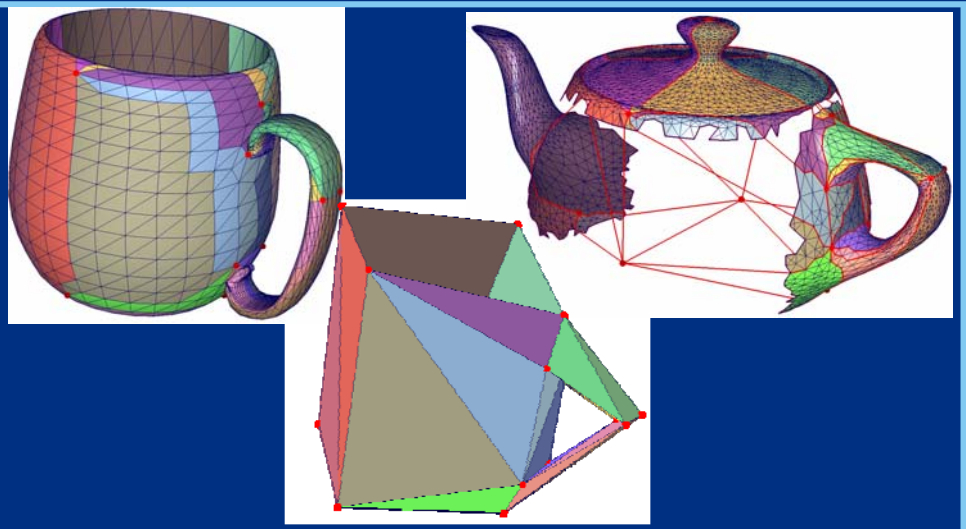
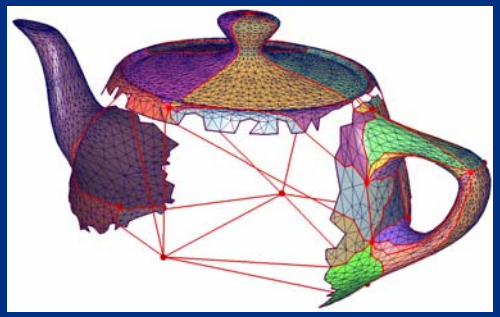
Base Parameterization with Holes/gaps



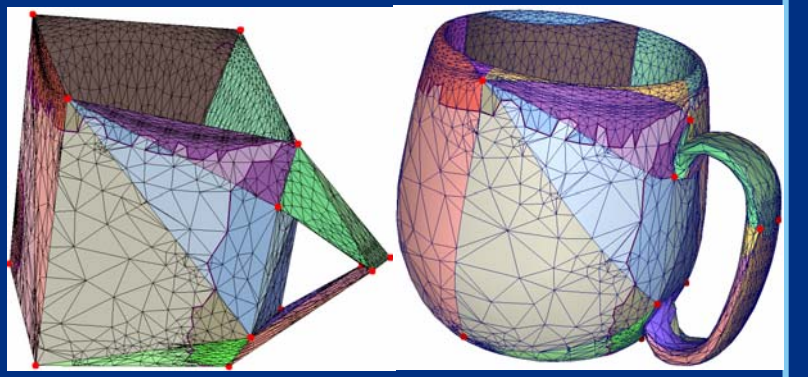
Segmentation





?

Parameterization



Idea: **triangulate holes (smartly)**

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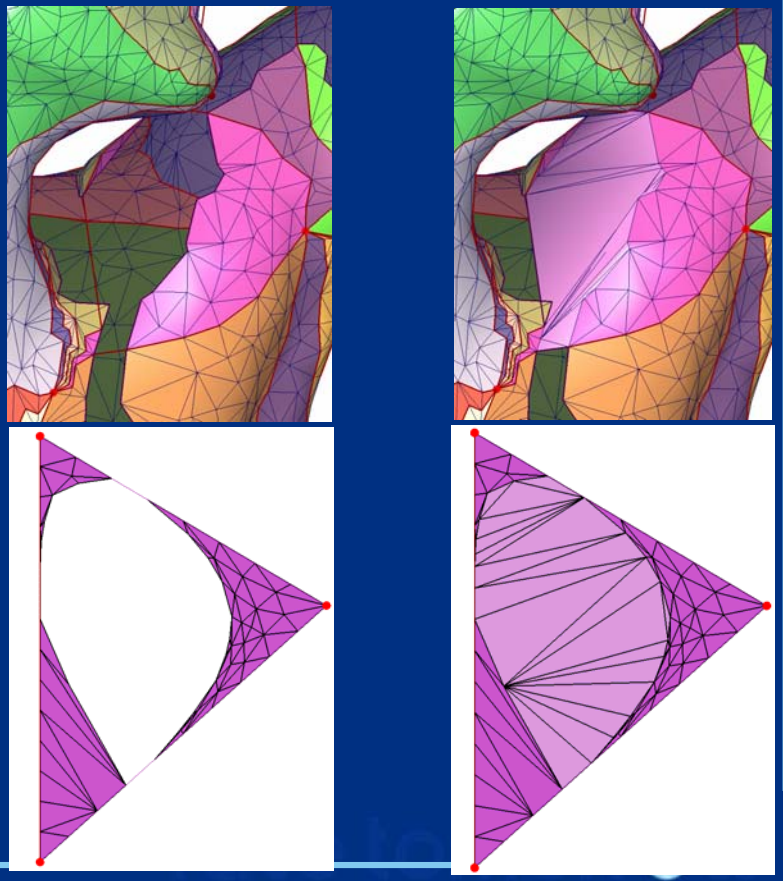
Initial Parameterization

- Map each patch to base triangle
  - Use uniform embedding [Tutte:63]
    - works for n-sided polygons
    - Bijective
- Triangulate holes



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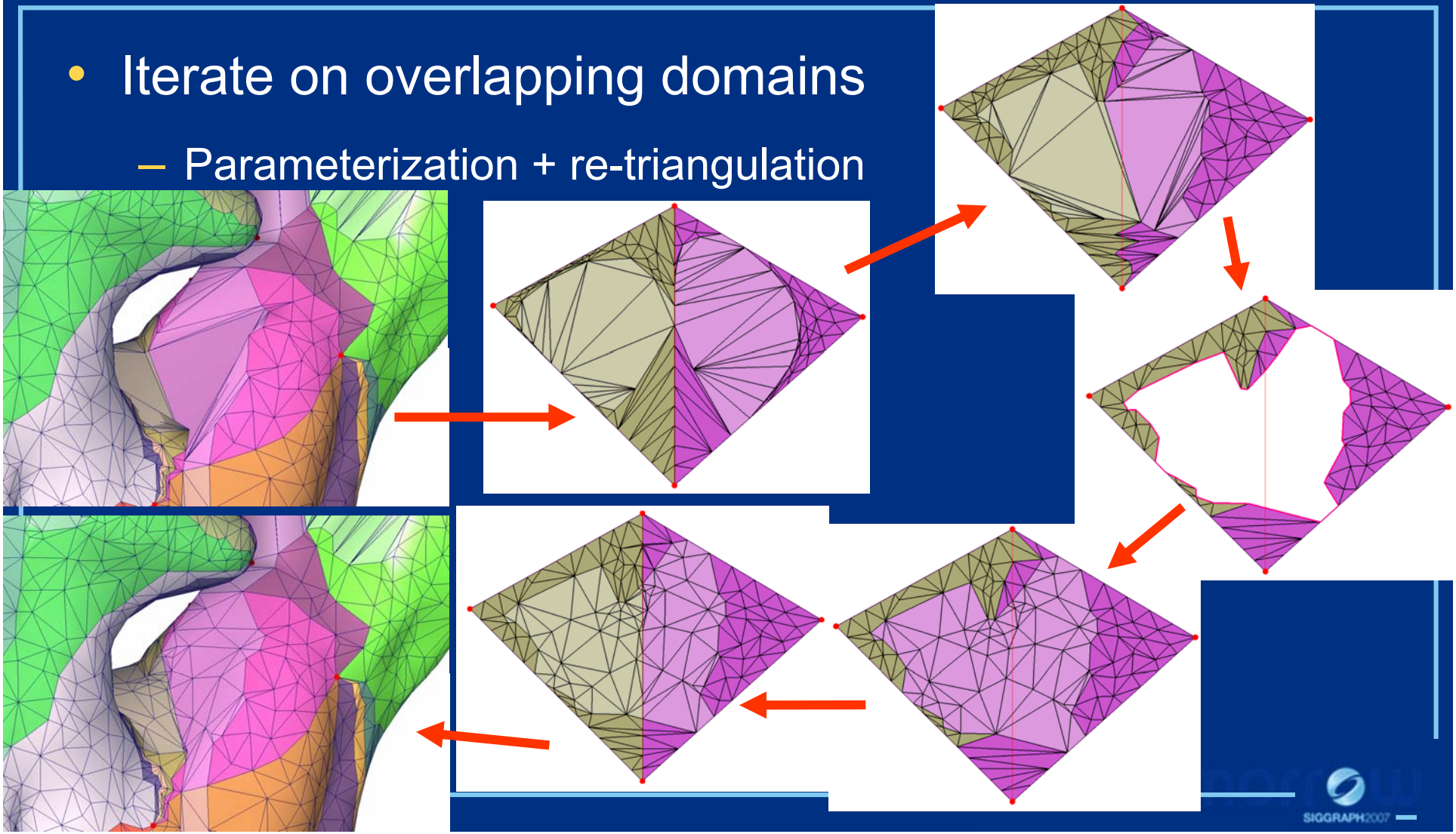
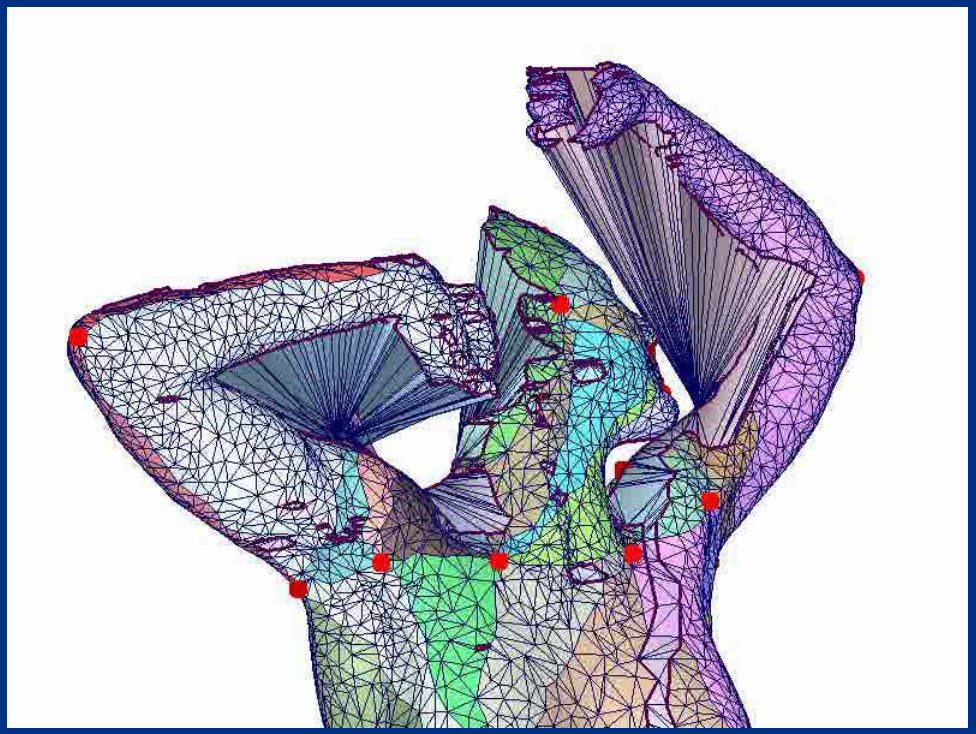
Improvement

- Iterate on overlapping domains
  - Parameterization + re-triangulation



Improvement



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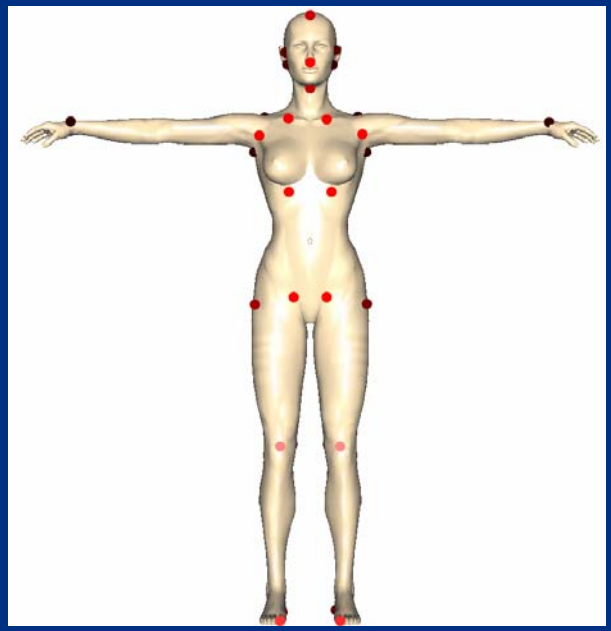
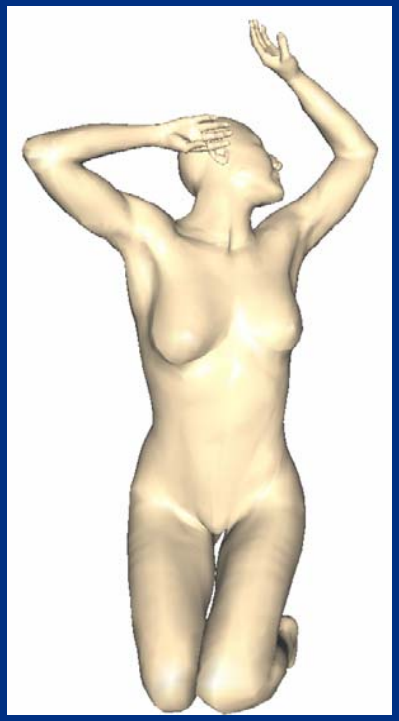
Completion Results





Sizes: 20455/27562	Markers: 39	Time 45s

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Global Approaches

- Energy Based [Allen:03]
  - Continuous setup
- Machine Learning [Anguelov:05]
  - Correspondence as discrete optimization
- Geodesic MDS [Bronstein:07]
  - No feature specification

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Energy Based Mapping [Allen:03]

- Pull one model towards the other - minimize

$$E = \alpha E_d + \beta E_s + \gamma E_m,$$

  - feature correspondence

$$E_d = \sum_{i=1}^{n} w_i \, \mathrm{dist}^2(\mathbf{T}_i \mathbf{v}_i, \mathcal{D})$$

  - attraction

$$E_m = \sum_{i=1}^{m} ||\mathbf{T}_{\kappa_i} \mathbf{v}_{\kappa_i} - \mathbf{m}_i||^2$$

  - shape preservation

$$E_s = \sum_{\{i,j|\{\mathbf{v}_i,\mathbf{v}_j\} \in edges(\mathcal{T})\}} ||\mathbf{T}_i - \mathbf{T}_j||_F^2$$

+ Oblivious to topological noise
– Robustness issues
  – Dense (74) markers
  – Similar pose

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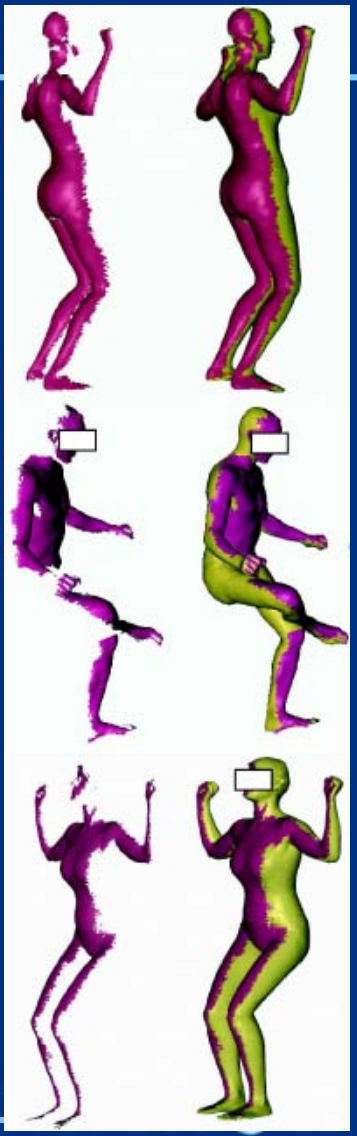
Correlated correspondence [Anguelov:05]

- Machine learning setup
  - *Correlated correspondence* (Loopy belief propagation)
    - Input: 4-10 markers
    - Output: 150-200 markers
  - Compute full registration
- Few markers
- Variety of poses/proportions
  - relies on shape similarity



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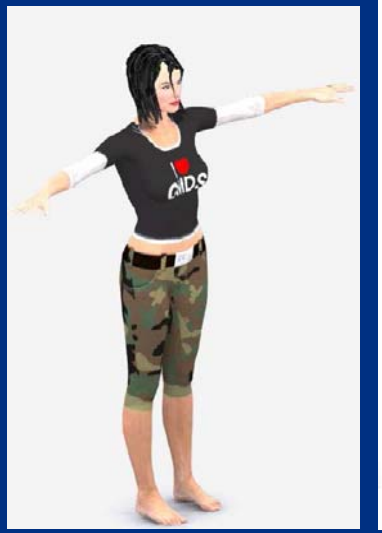
Generalized multidimensional scaling [Bronstein:07]

- Use MDS to match models in alternative space
  - use geodesics as pairwise point distances
- Assumes near-isomeric transformation



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Comparison

- Compatible Segmentation
  - Need “good” features
    - “bad” features cause distortion
  - Same genus
  - Validity guarantee
    - may be at expense of distortion
- Global
  - Recent methods require less (no) features
  - Topology oblivious (almost)
  - Can fail
    - small & large overlaps
    - similarity dependant

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External Material

- B. Allen, B. Curless, and Z. Popovic, *The space of human body shapes: Reconstruction and parameterization from range scans*, SIGGRAPH 2003
- D. Anguelov, P. Srinivasan, D. Koller, S. Thrun, J. Rodgers, and J. Davis, *SCAPE: Shape completion and animation of people*, SIGGRAPH 2005.
- A. M. Bronstein, M. M. Bronstein R. Kimmel, *Calculus of non-rigid surfaces for geometry and texture manipulation*, IEEE TVCG 2007.
- V. Kraevoy and A. Sheffer, *Cross-parameterization and compatible remeshing of 3D models*, SIGGRAPH 2004.
- V. Kraevoy and A. Sheffer, *Template based mesh completion*, SGP 2005.
- J. Schreiner, A. Asirvatham, E. Praun, and H. Hoppe, *Inter-surface mapping*, SIGGRAPH 2004.

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