Blended Intrinsic Maps

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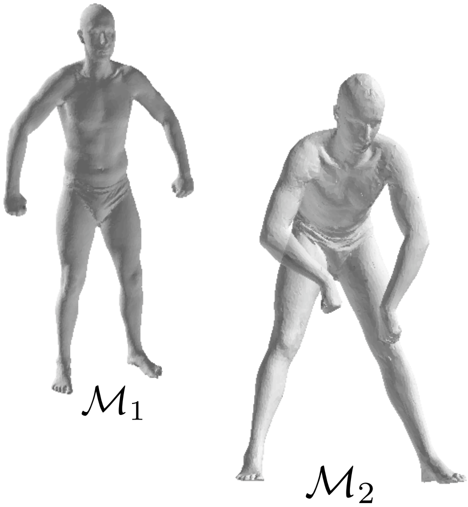
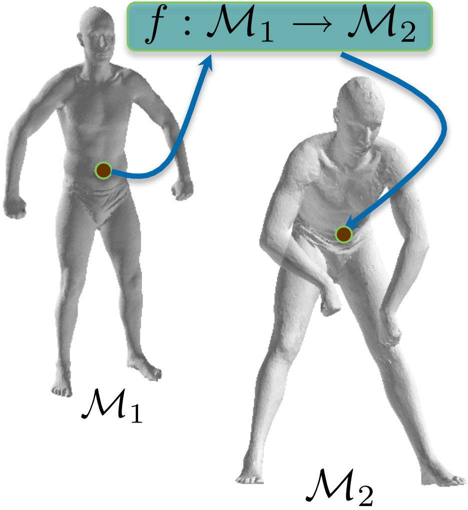
SIGGRAPH2011

Goal: Find a map between surfaces



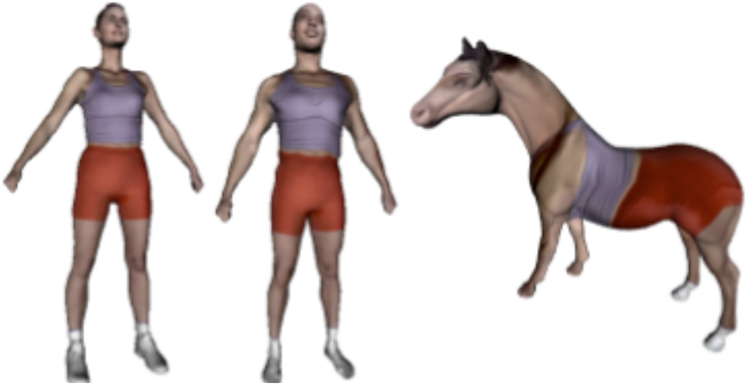
Goal: Find a map between surfaces

- Automatic
- Efficient to compute
- Smooth
- Low-distortion
- Defined for every point
- Aligns semantic features



Applications

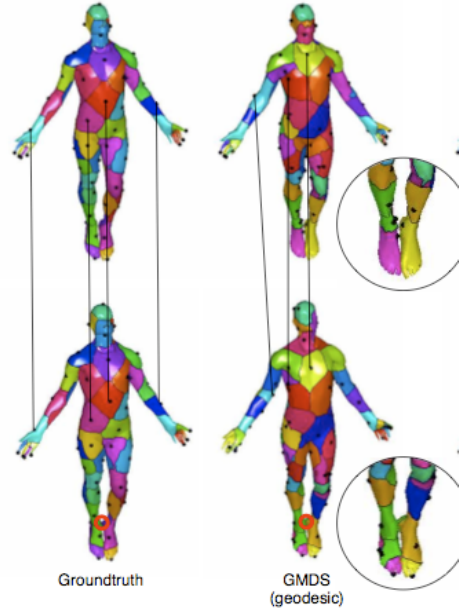
- Graphics
  - Texture transfer
  - Morphing
  - Parametric shape space
- Other disciplines
  - Paleontology
  - Medicine



Praun et al. 2001

Related Work

- **Gromov-Hausdorff**
- Surface Embedding
- Möbius Transformations



Bronstein et al., 2006

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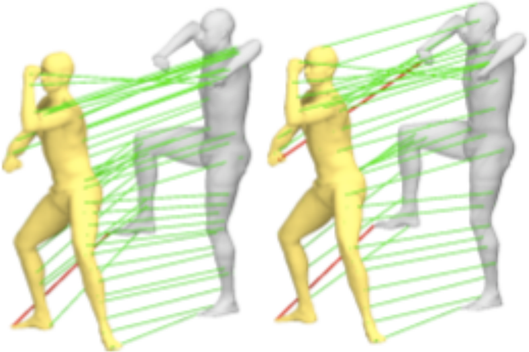

Ovsjanikov et al., 2010

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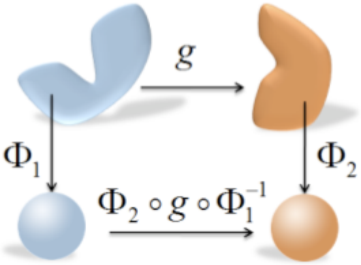

Lipman and Funkhouser. 2009

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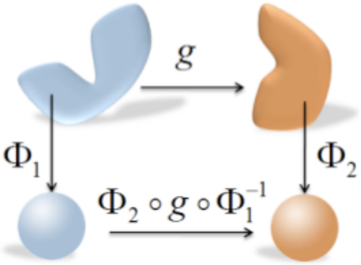
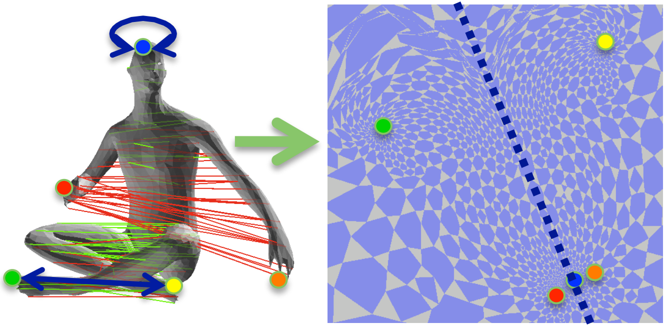


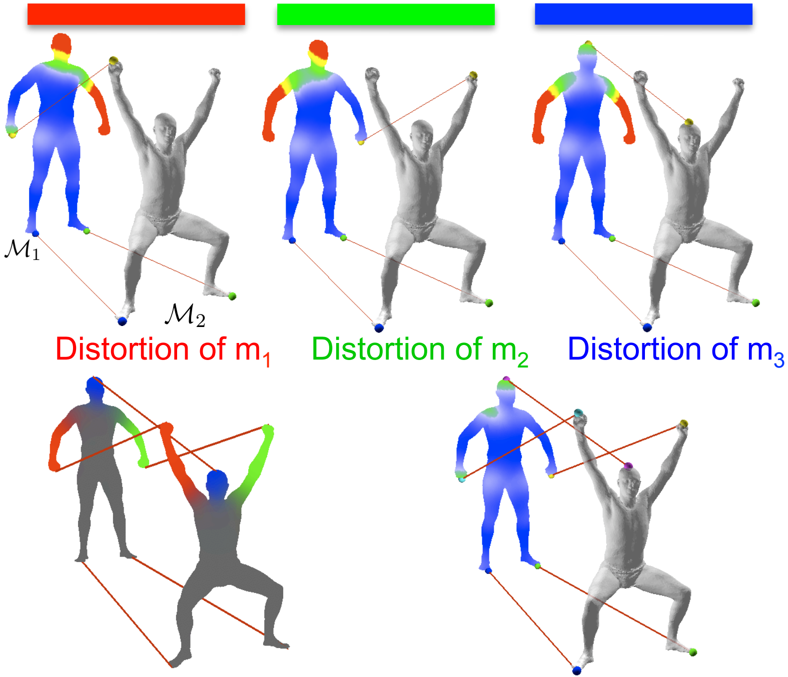


Kim et al. 2010

Lipman and Funkhouser. 2009

Our Approach

- **Blended Intrinsic Maps**
  - Weighted combination of intrinsic maps

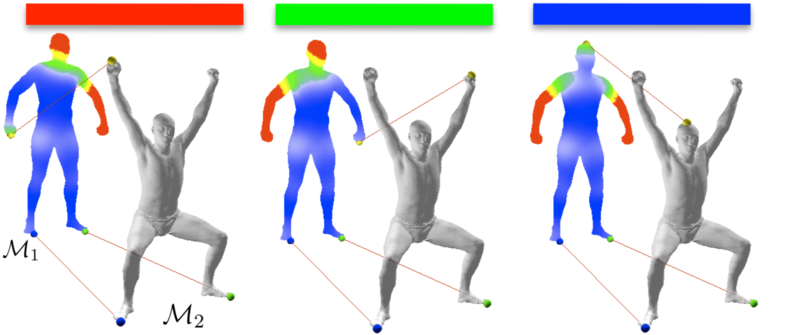


Distortion of m_1 Distortion of m_2 Distortion of m_3

Blending Weights for m_1, m_2, and m_3 Distortion of the Blended Map

Our Approach

- **Blended Intrinsic Maps**
  - Weighted combination of intrinsic maps



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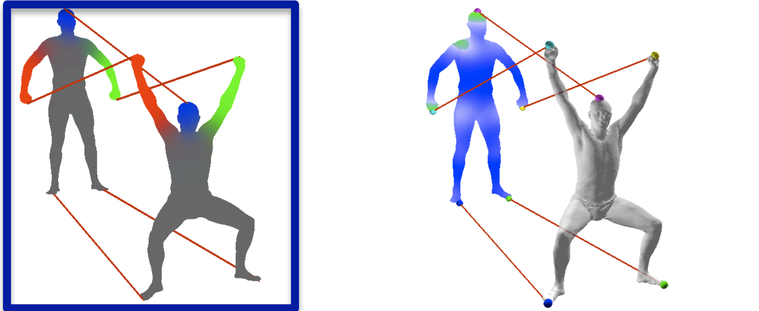

Blending Weights for m_1, m_2, and m_3 Distortion of the Blended Map

Our Approach

- **Blended Intrinsic Maps**
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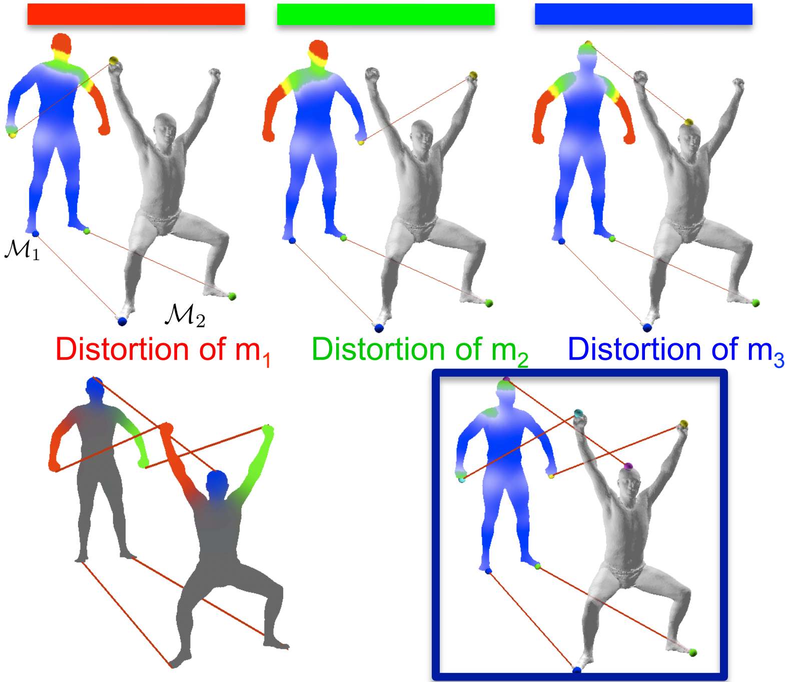
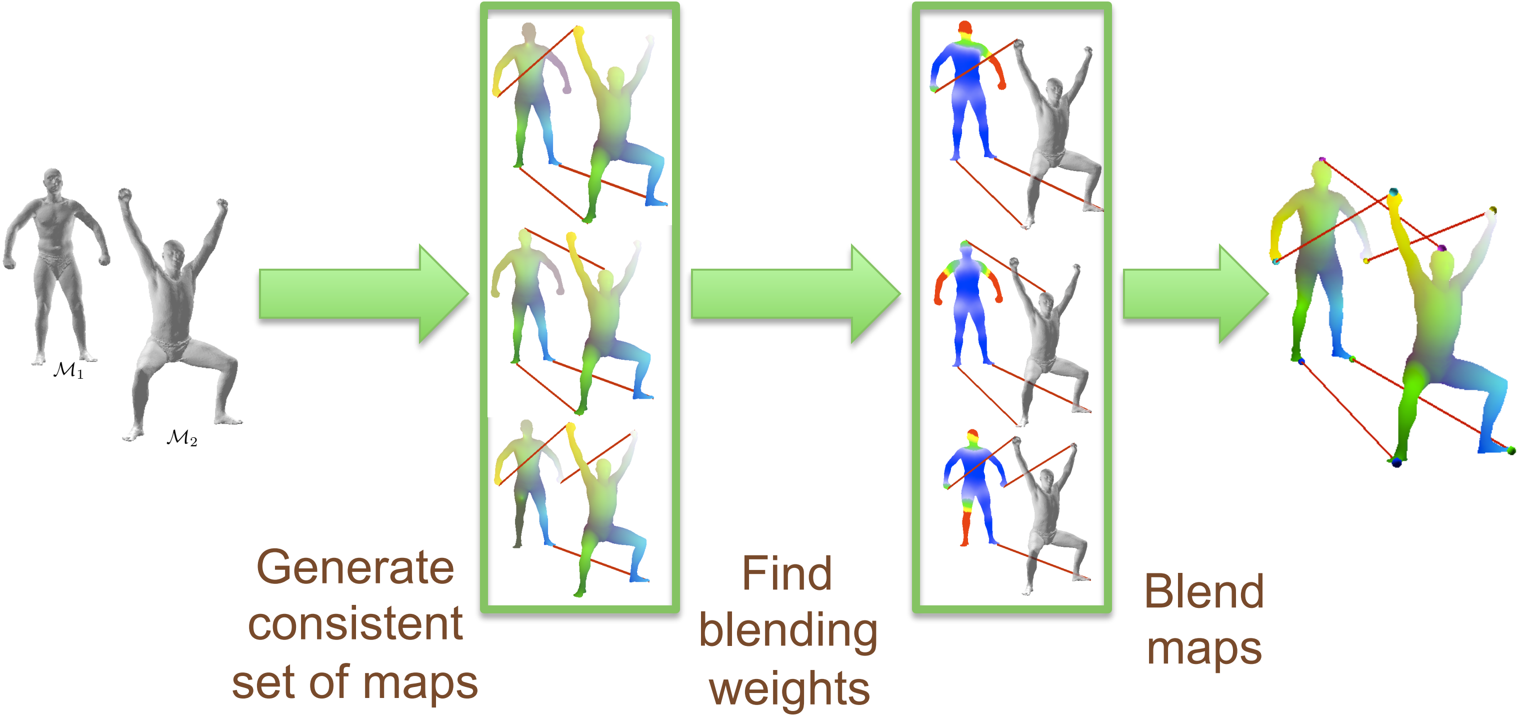


Distortion of m$_1$ Distortion of m$_2$ Distortion of m$_3$

Blending Weights for m$_1$, m$_2$, and m$_3$ Distortion of the Blended Map

The Computational Pipeline

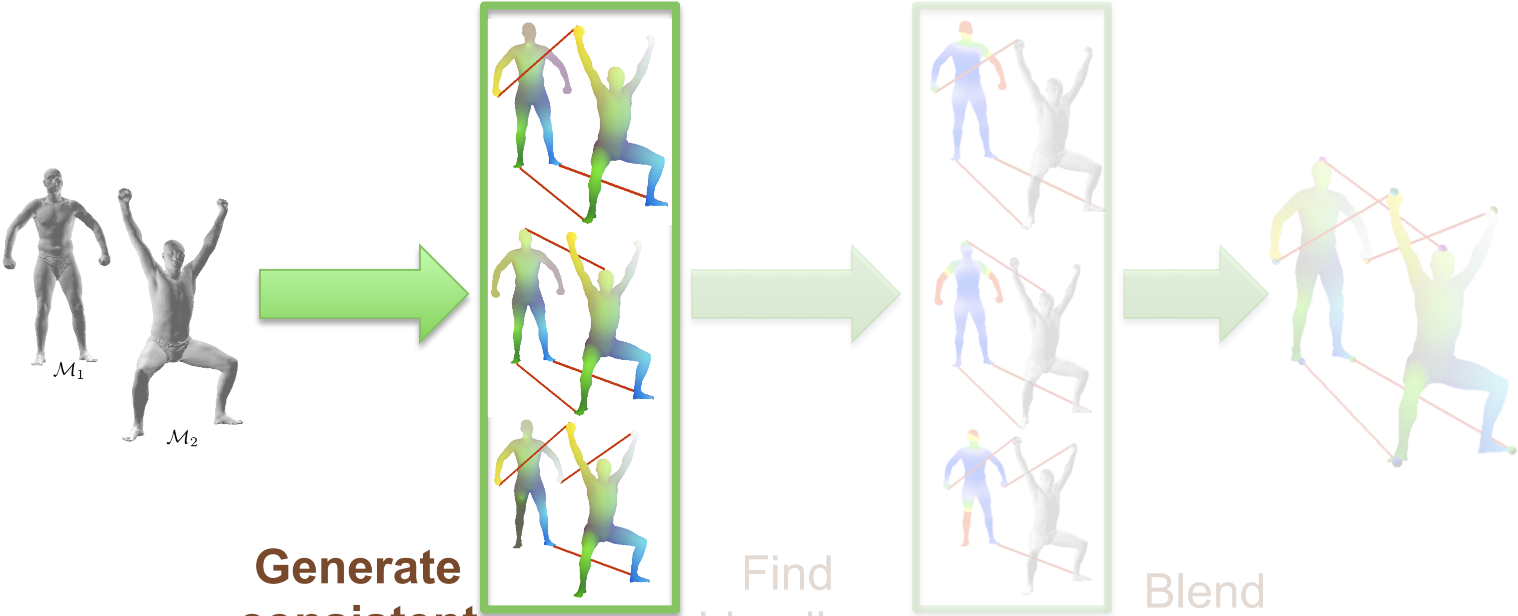


Generate consistent set of maps

Find blending weights

Blend maps

The Computational Pipeline



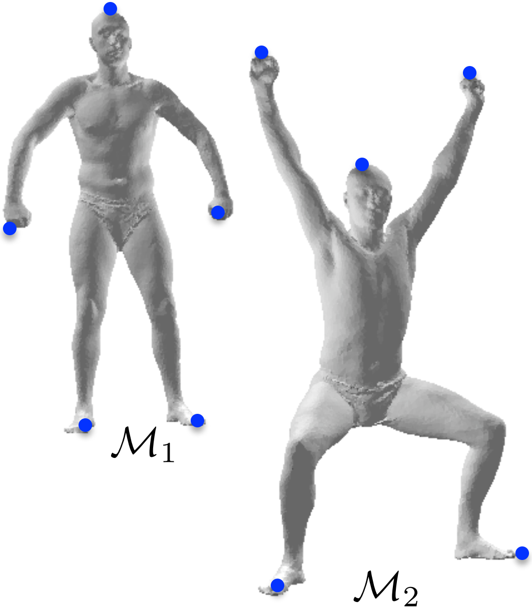
Generate consistent set of maps

Find blending weights

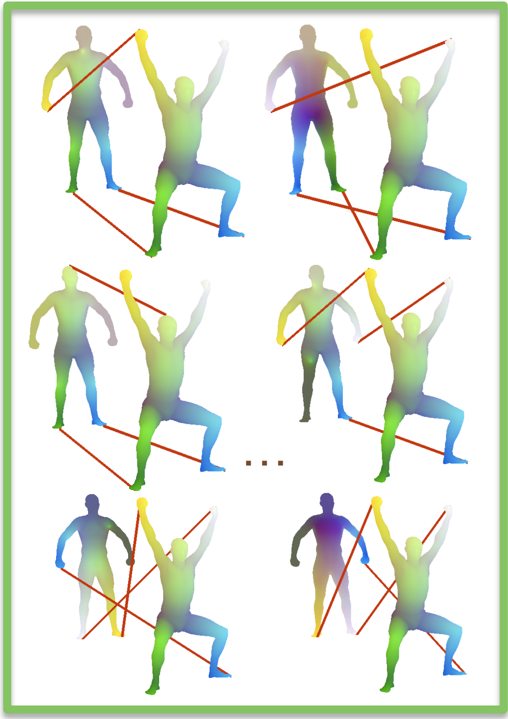
Blend maps

Generating Consistent Maps

Generate a set of candidate conformal maps by enumerating triplets of feature points

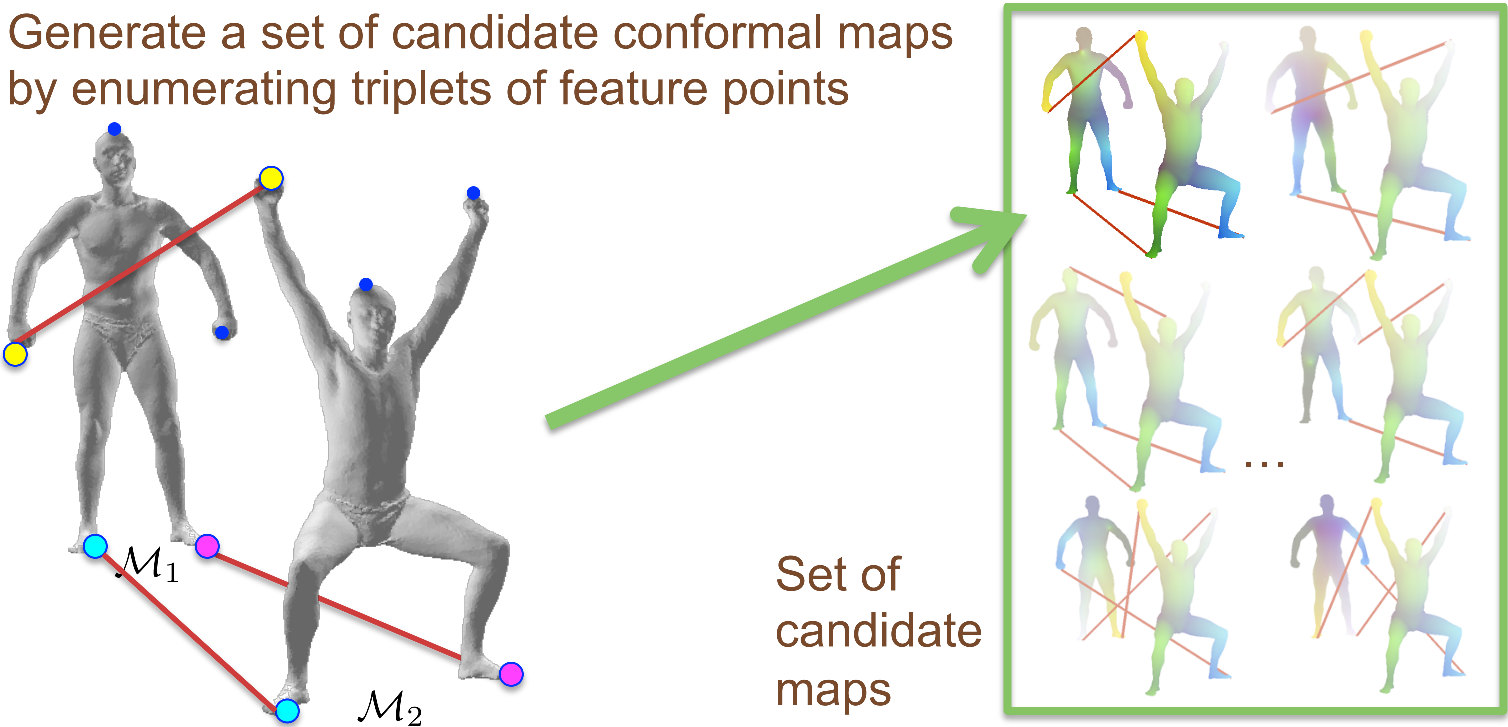


Set of candidate maps



Generating Consistent Maps

Generate a set of candidate conformal maps by enumerating triplets of feature points



Set of candidate maps

Generating Consistent Maps

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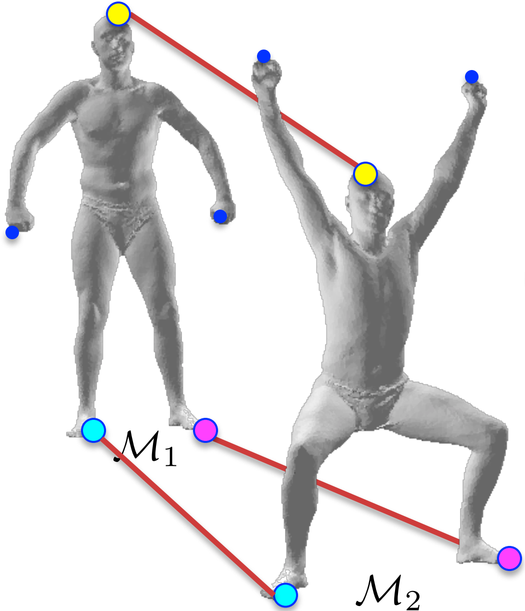

Set of candidate maps

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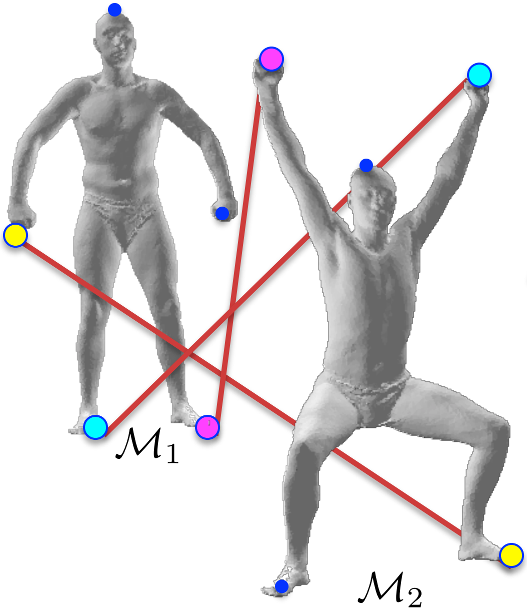
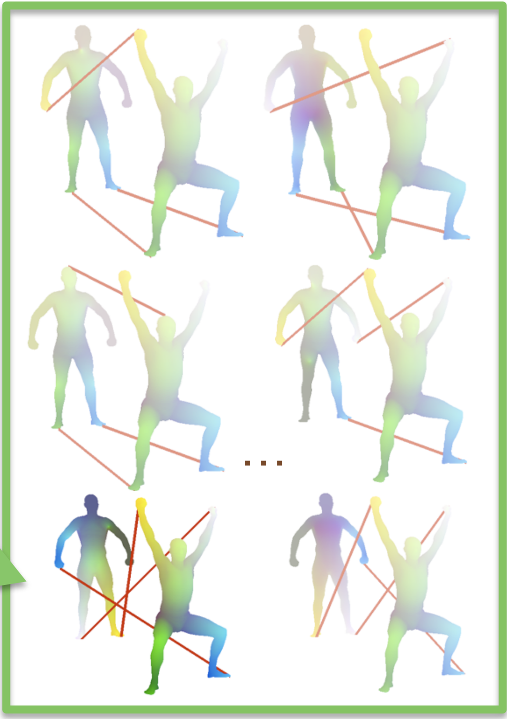


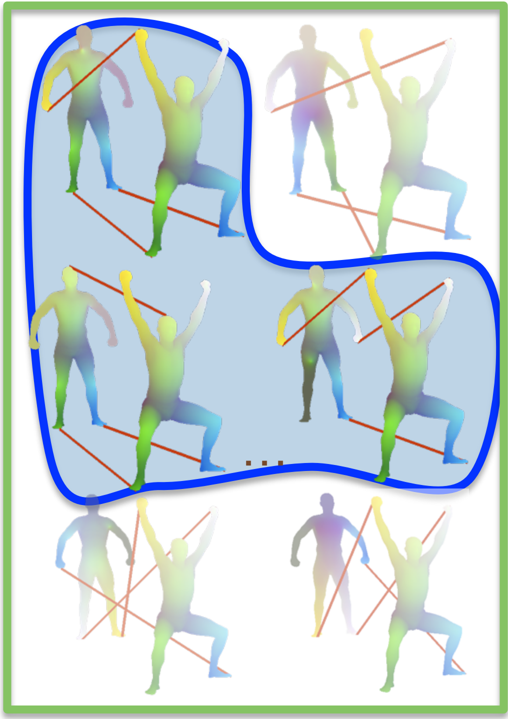
Set of candidate maps



Generating Consistent Maps

Find consistent set(s) of candidate maps

$\mathcal{M}_1$
$\mathcal{M}_2$

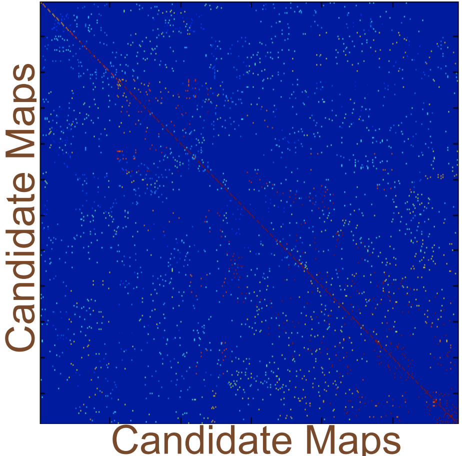


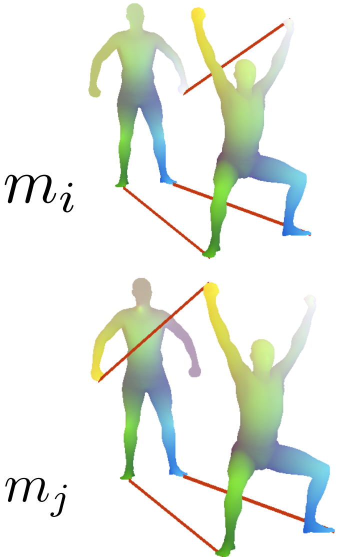
Set of consistent candidate maps

Generating Consistent Maps

Define a matrix **B** where every entry (i,j) indicates the distortion of m_i and m_j and their pairwise similarity $S_{i,j}$

$$\mathbf{B}_{i,j} = \int_{M_1} c_i(p) c_j(p) S_{i,j}(p) dA(p)$$



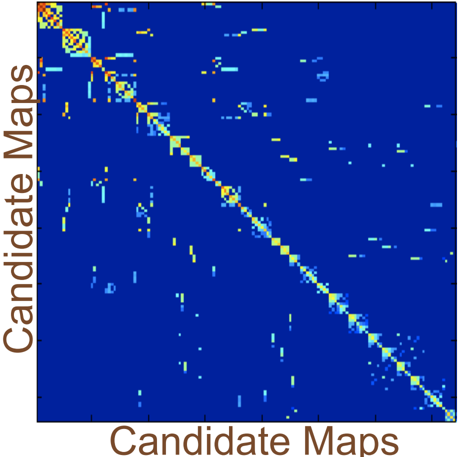


Generating Consistent Maps

Find blocks of low-distortion and mutually similar maps

$$E_{\mathcal{M}}(\vec{w}) = \vec{w}^T \mathbf{S} \vec{w}$$

$$\|\vec{w}\|_2 = 1$$



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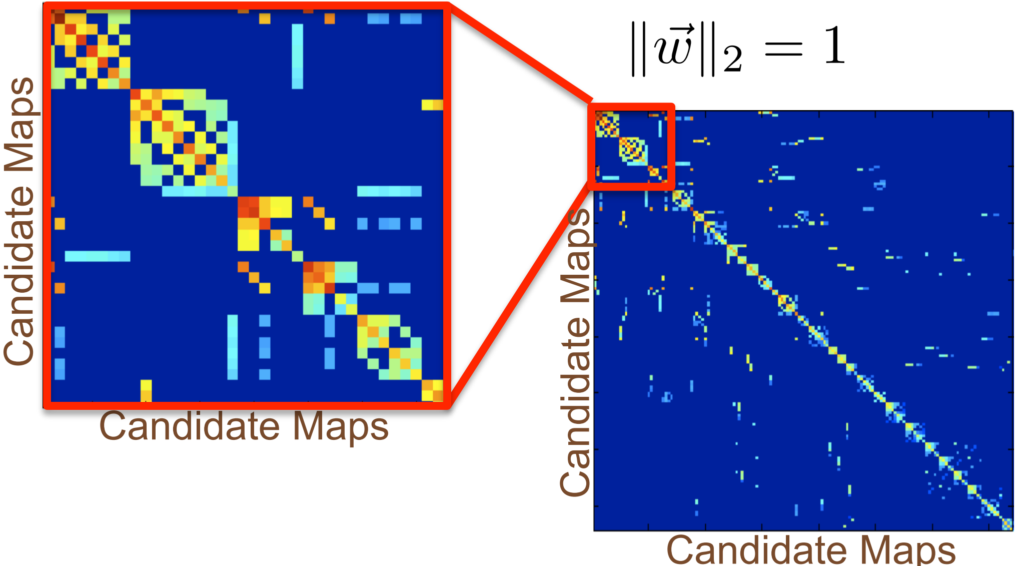
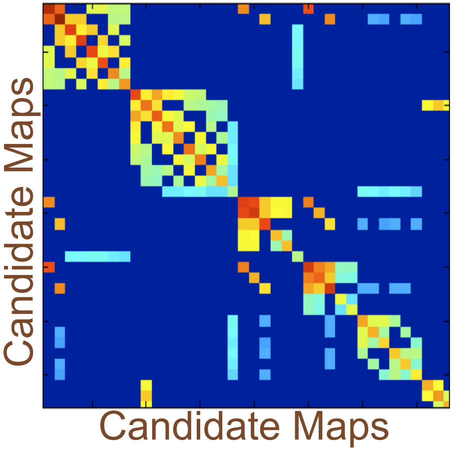
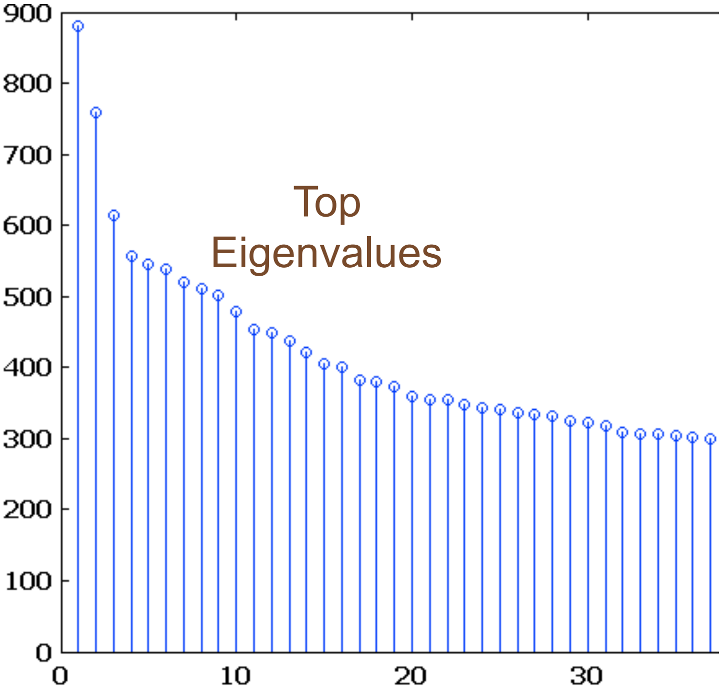


Generating Consistent Maps

Eigenanalysis

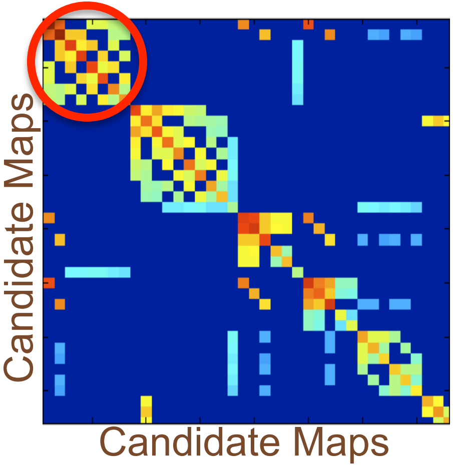


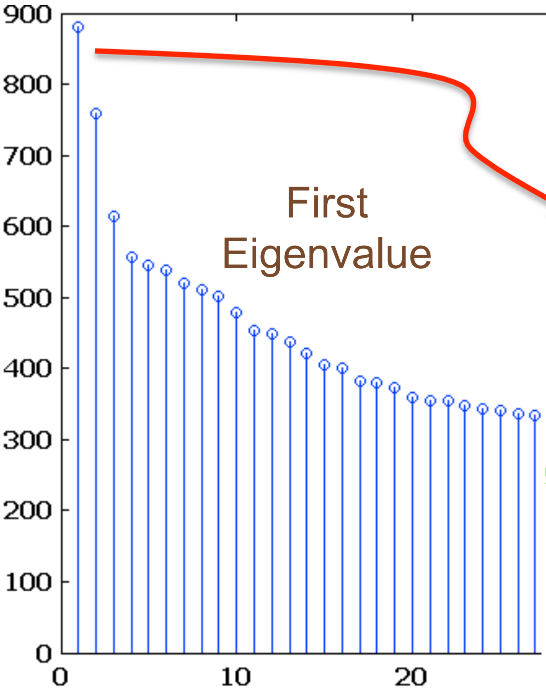


Top Eigenvalues

Generating Consistent Maps

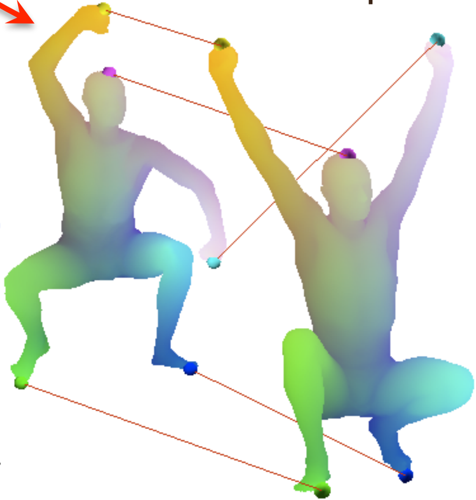
Eigenanalysis





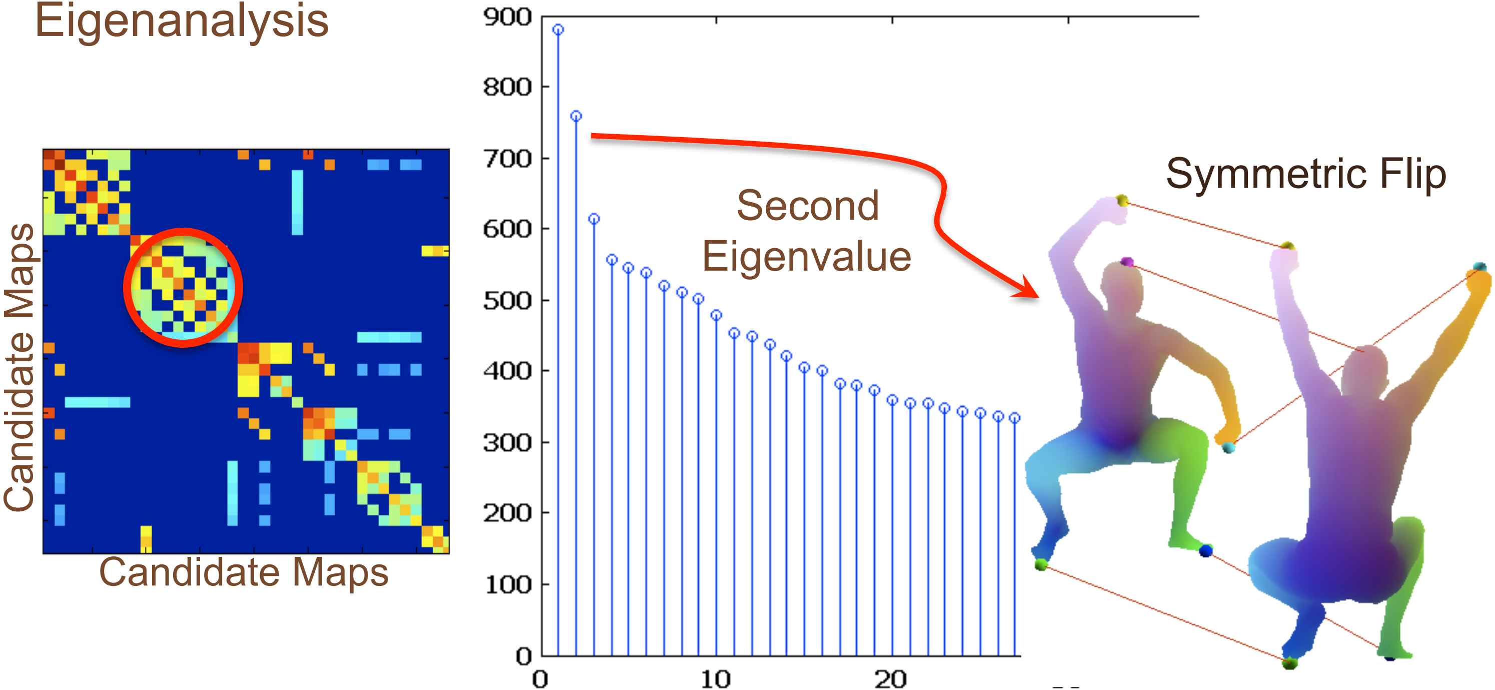
First Eigenvalue

Correct Maps



Generating Consistent Maps

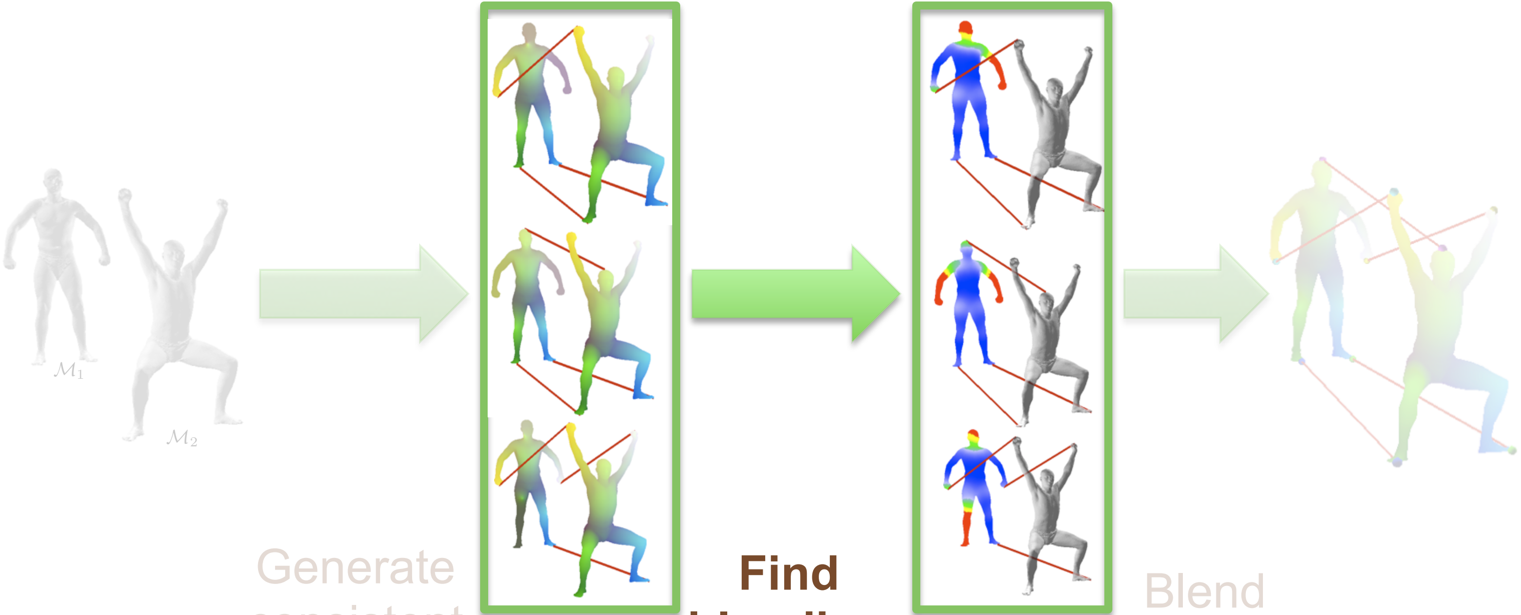
Eigenanalysis



Second Eigenvalue

Symmetric Flip

The Computational Pipeline



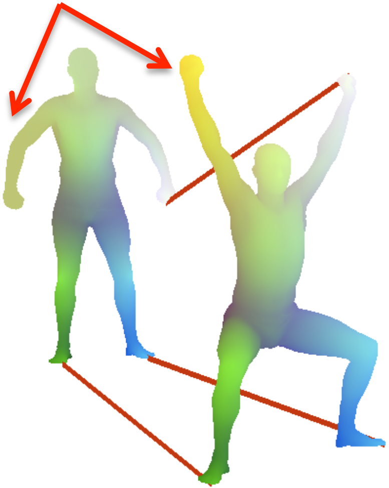
Generate consistent set of maps

Find blending weights

Blend maps

Finding Blending Weights

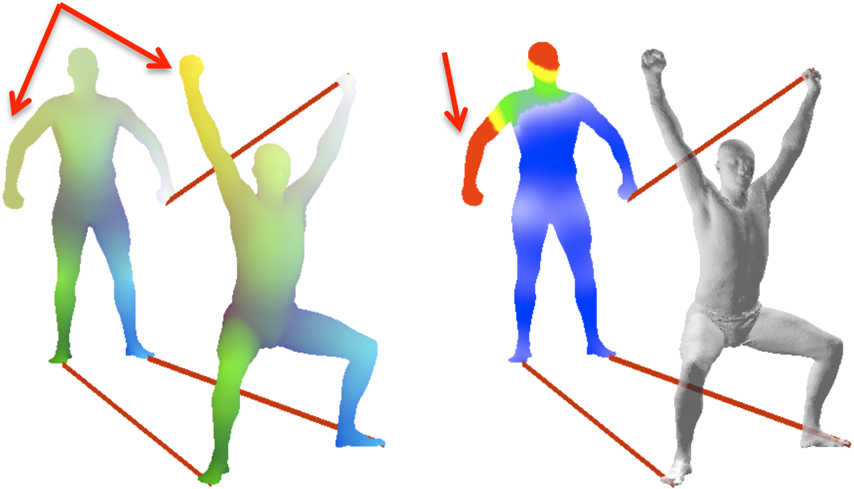
- For every **point** p
  - Compute a weight of each map m_i at p



Candidate Map

Finding Blending Weights

- For every **point** p
  - Compute a weight of each map m_i at p
- We model the weight with deviation from isometry
  - Area distortion for conformal maps



Candidate Map

Blending Weight $c_i(p)$

The Computational Pipeline

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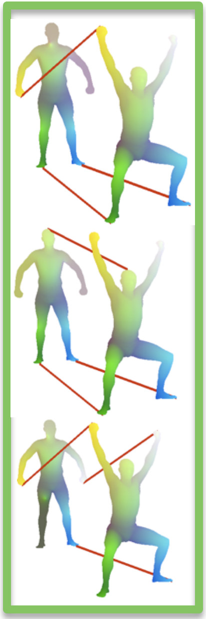
Generate consistent set of maps



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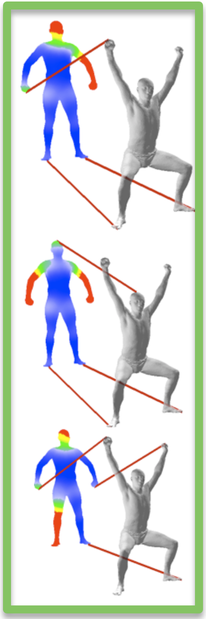

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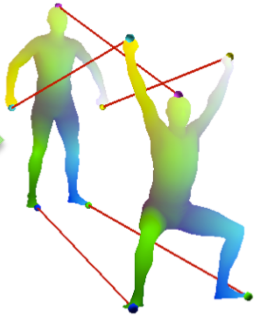
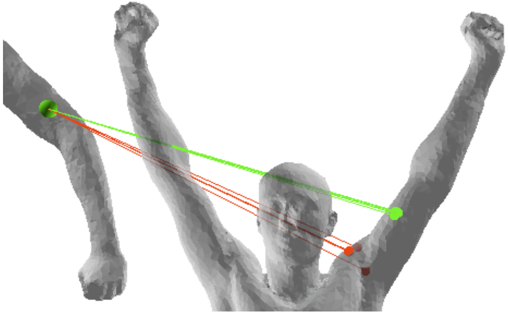


Blending Maps

- Input for each point p:
  - An image $m_i(p)$ after applying each map m_i
  - A blending weight for each map
- Output for each point:
  - Weighted geodesic centroid of $\{ m_i(p) \}$



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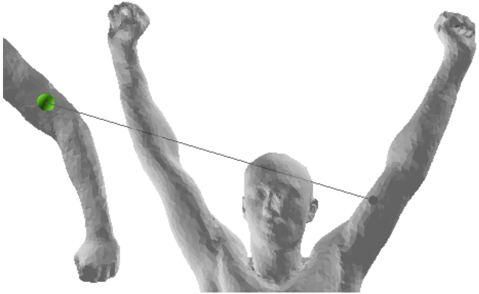

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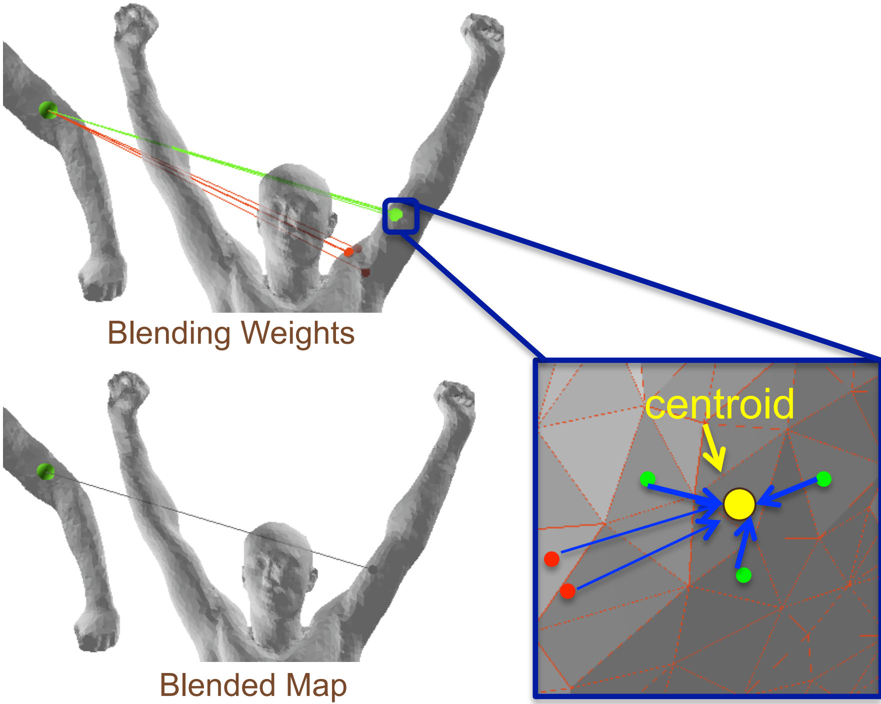
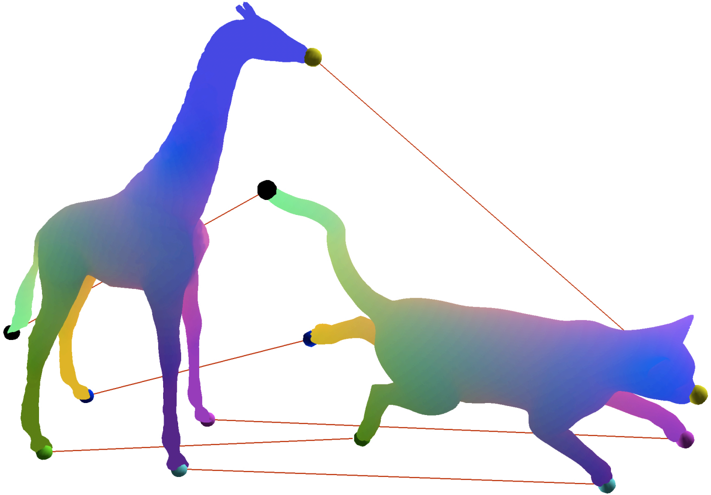

Blending Weights

Blended Map

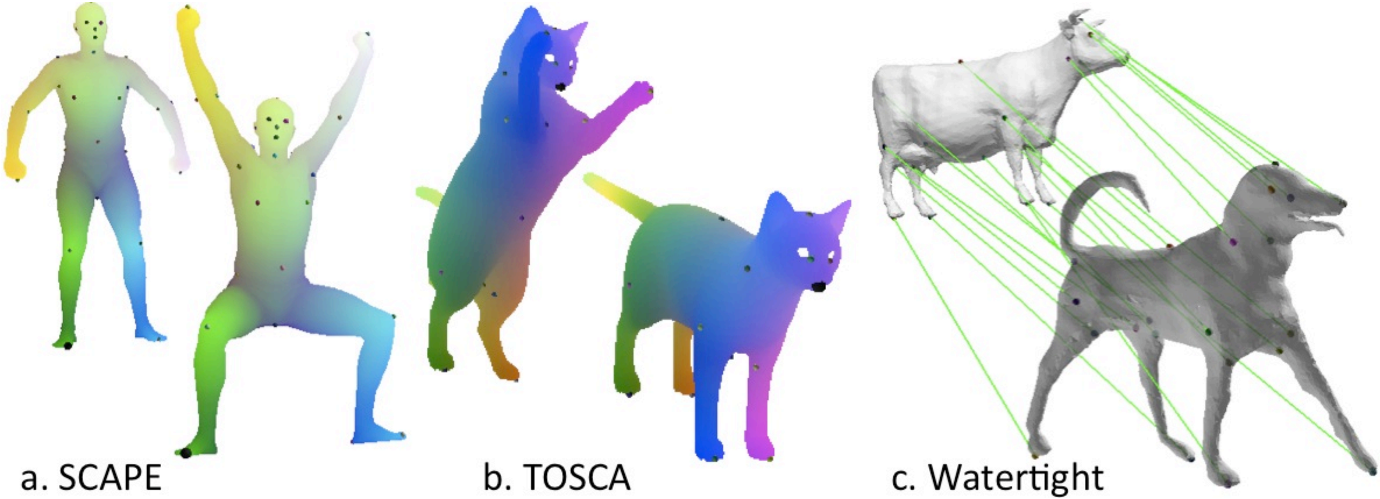
Results

- **Dataset**
- Examples
- Evaluation Metric
- Comparison



Dataset

- 371 meshes
- Ground Truth:



a. SCAPE

b. TOSCA

c. Watertight

Results

- Dataset
- **Examples**
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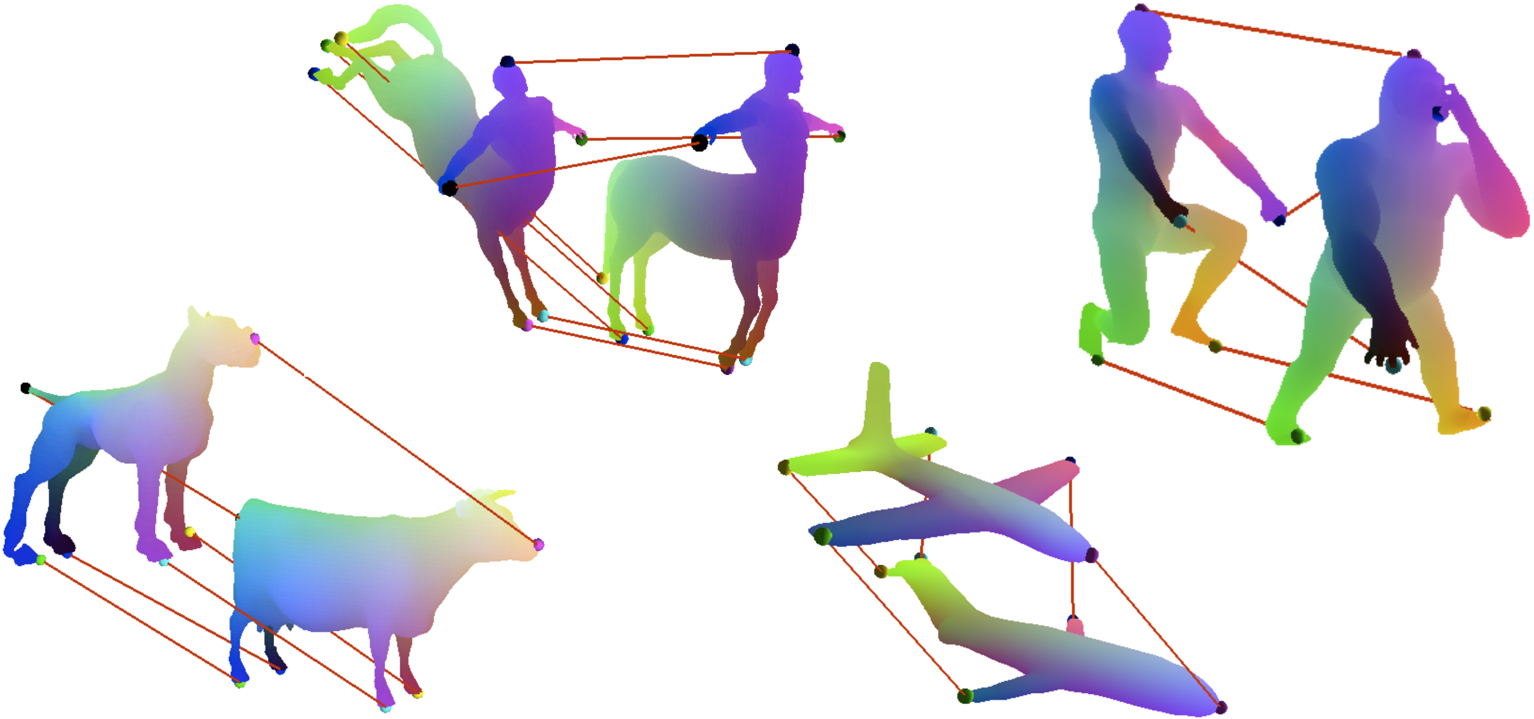
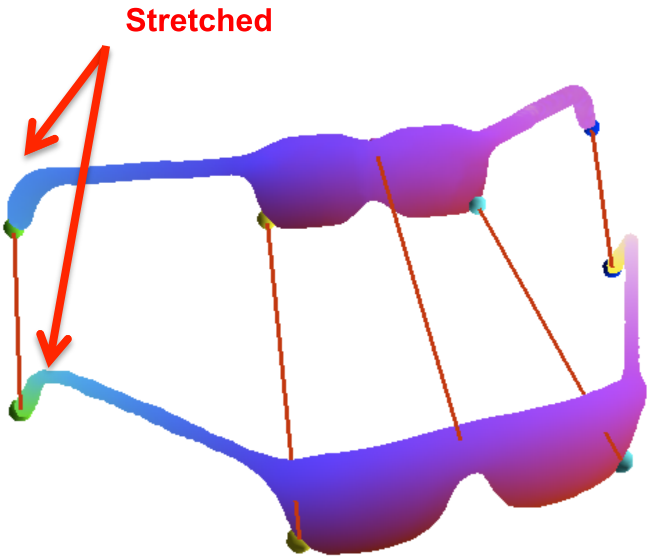
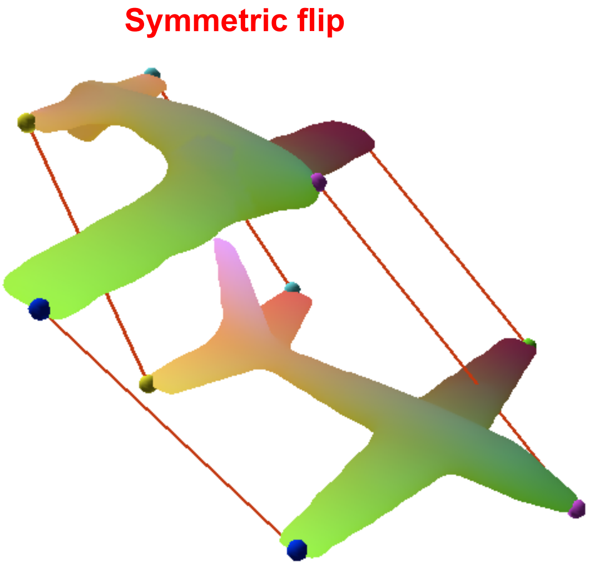
- Comparison

Examples



Failures





Results

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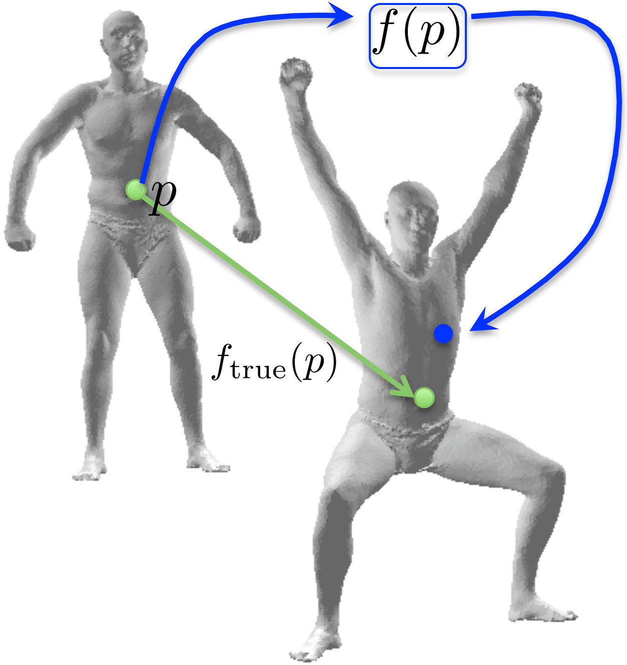
- Examples
- **Evaluation Metric**
- Comparison

Evaluation Metric

- Predict the map for every point with a ground truth correspondence



Evaluation Metric

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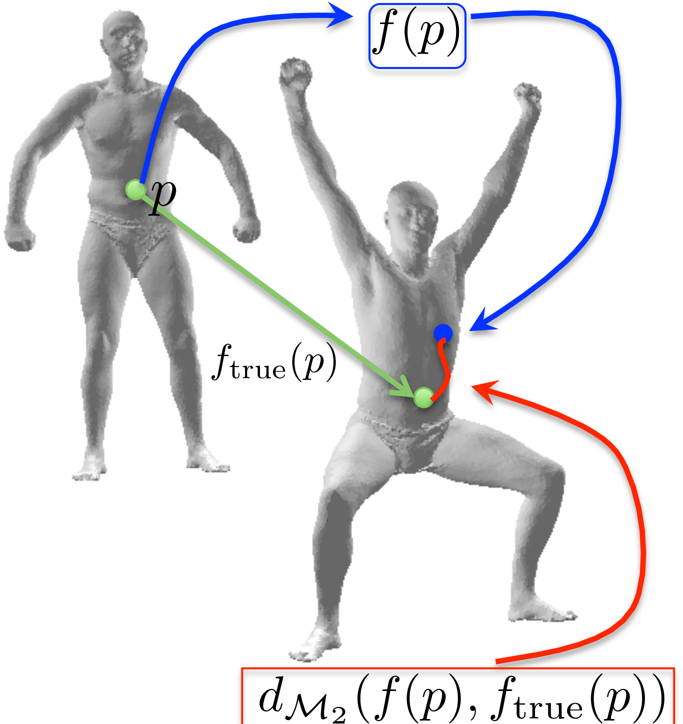
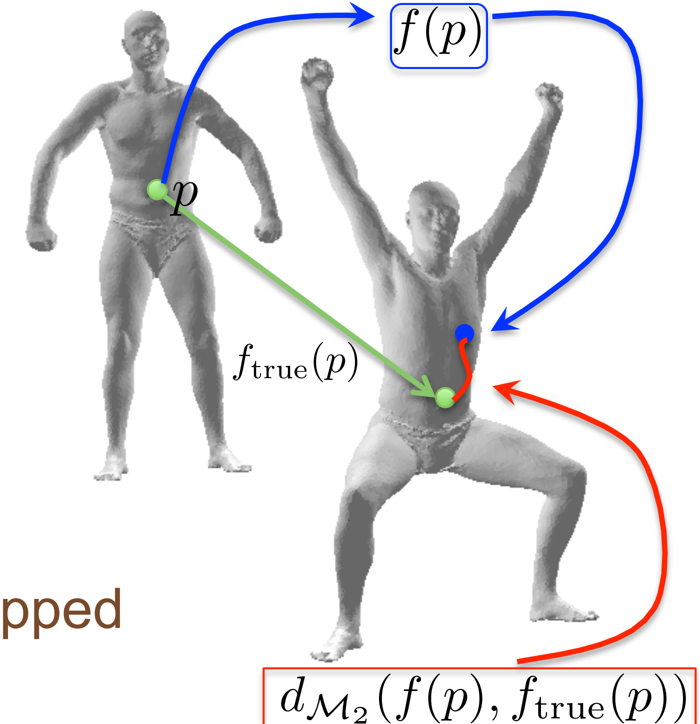
- Predict the map for every point with a ground truth correspondence
- Measure geodesic distance between prediction and the ground truth

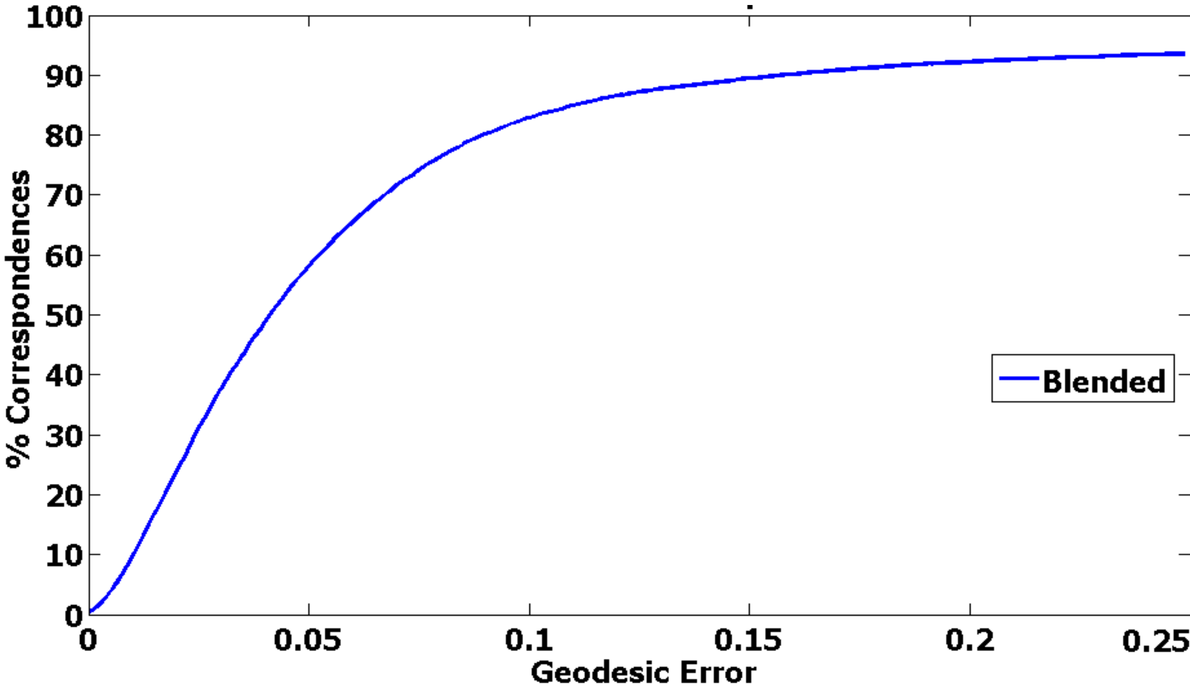


Evaluation Metric

- Predict the map for every point with a ground truth correspondence
- Measure geodesic distance between prediction and the ground truth
- Record fraction of points mapped within geodesic error



Correspondence Rate Plot



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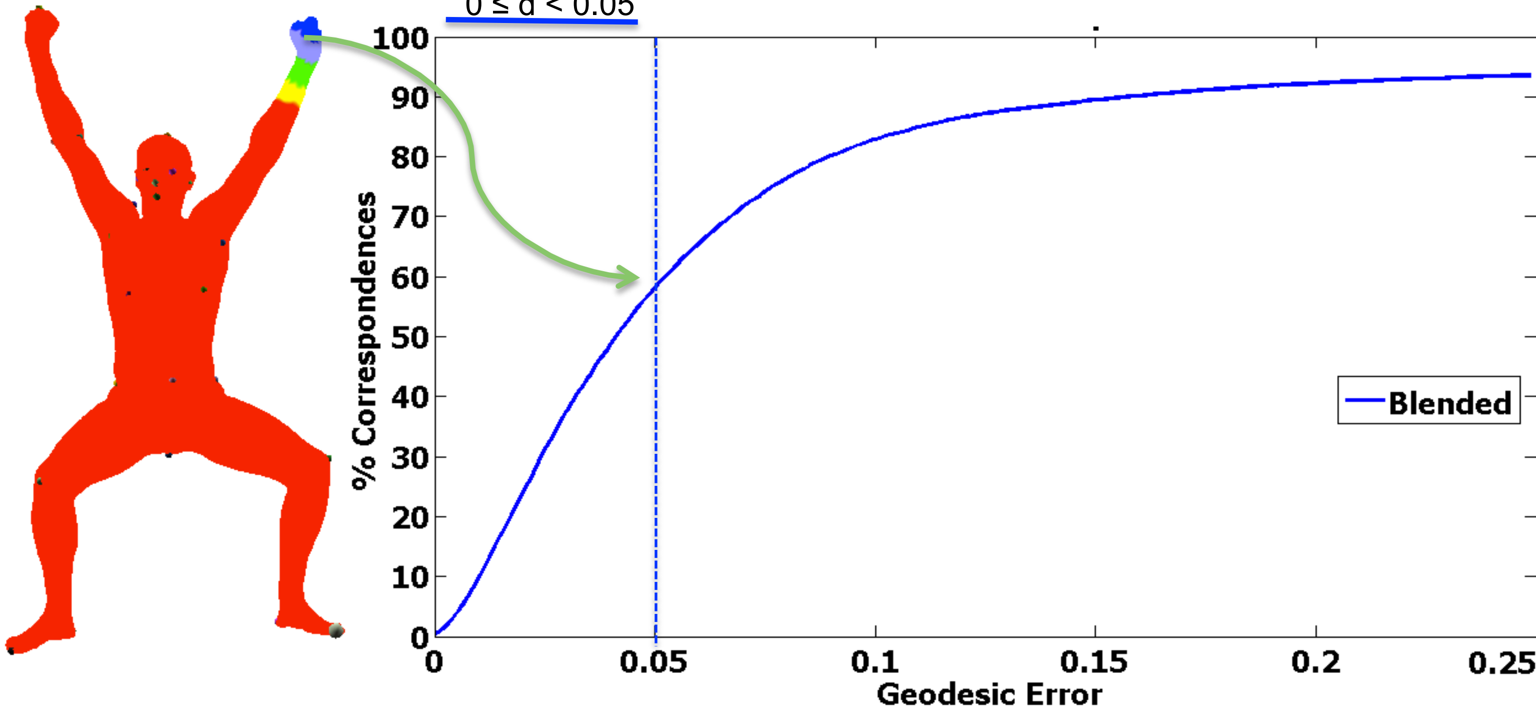
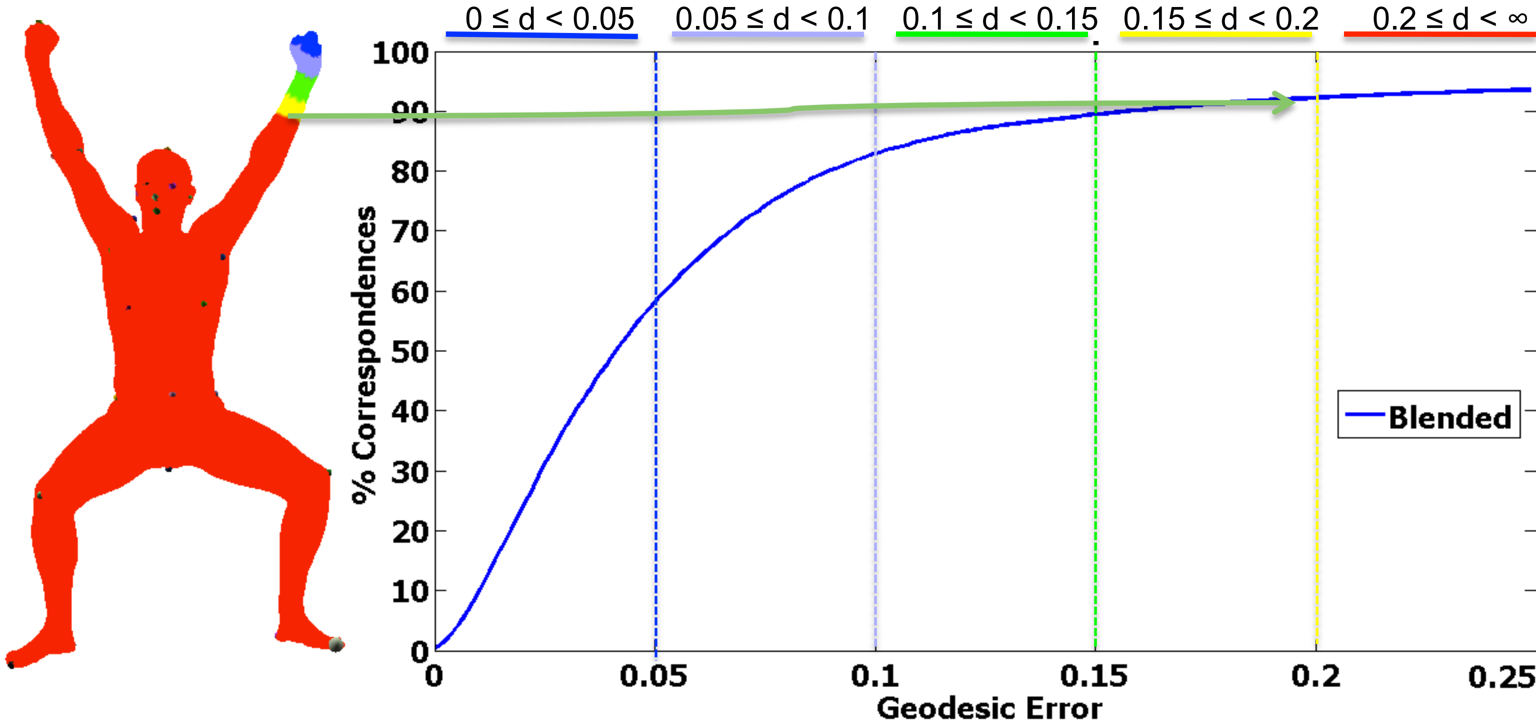


$0 \leq d < 0.05$

Correspondence Rate Plot

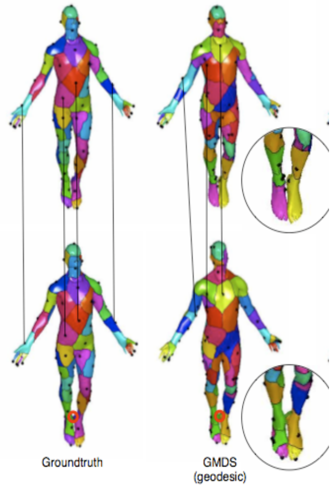


Results

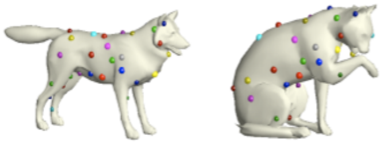
- Dataset
- Examples
- Evaluation Metric
- **Comparison**

Comparison

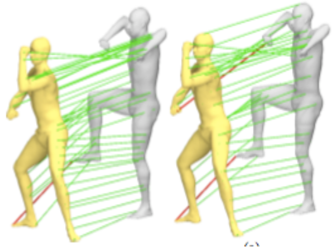
- Gromov-Hausdorf
- Heat Kernel Maps
    - 1 Correspondence
    - 2 Correspondences
- Möbius Voting



GMDS
Bronstein et al. 2006

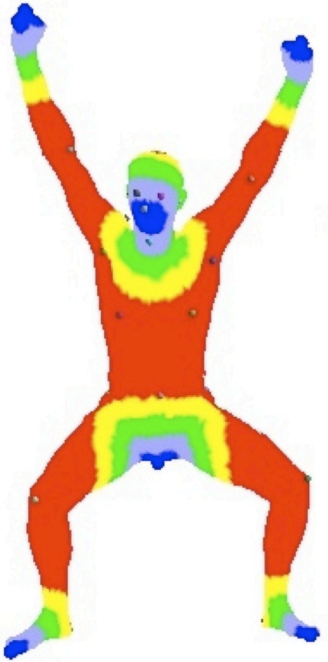


Mobius Voting
Lipman and Funkhouser. 2009

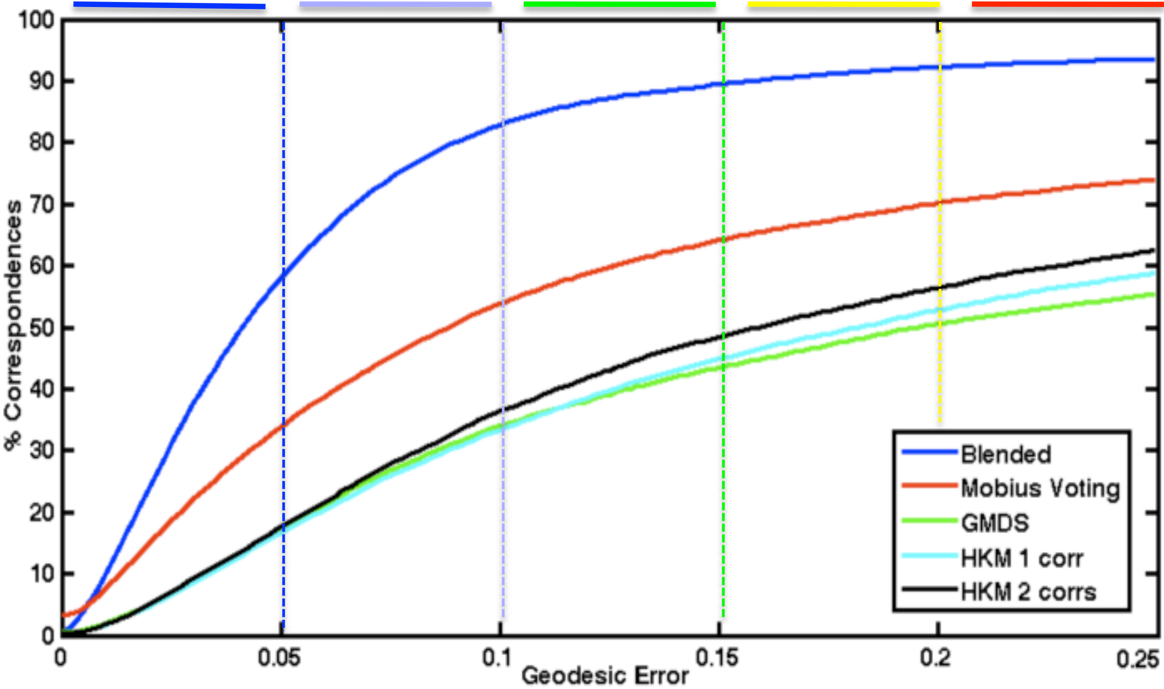


HKM 1 HKM 2
Ovsjannikov et al. 2010

Comparison Correspondence Plot



$0 \leq d < 0.05$ $0.05 \leq d < 0.1$ $0.1 \leq d < 0.15$ $0.15 \leq d < 0.2$ $0.2 \leq d < \infty$



Conclusion

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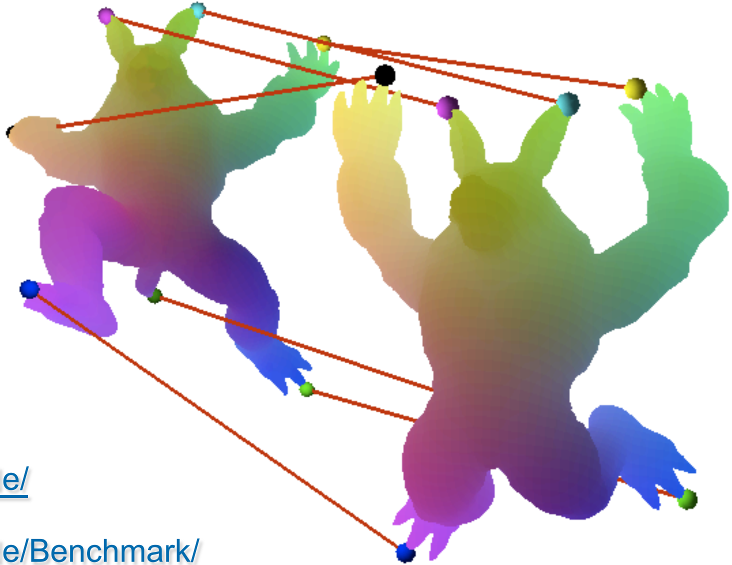
- Blending Intrinsic Maps
  - Smooth
  - Efficient to compute
  - Outperforms other methods on benchmark dataset
- Code and Data:
  - http://www.cs.princeton.edu/~vk/CorrsCode/
  - http://www.cs.princeton.edu/~vk/CorrsCode/Benchmark/



Future work

- Other (non-conformal) intrinsic maps:
  - Partial maps
  - Arbitrary genus surfaces
- Space of maps between surfaces
  - Maps consistent across multiple surfaces
  - Metric for comparing surfaces

Acknowledgments

- Data
  - Giorgi et al.: SHREC 2007 Watertight
  - Anguelov et al.: SCAPE
  - Bronstein et al.: TOSCA
- Code:
  - Ovsjanikov et al.: Heat Kernel Map
  - Bronstein et al.: GMDS
- Funding:
  - NSERC, NSF, AFOSR
  - Intel, Adobe, Google

Thank you!