Joint planar parameterization of segmented parts and cage deformation for dense correspondence

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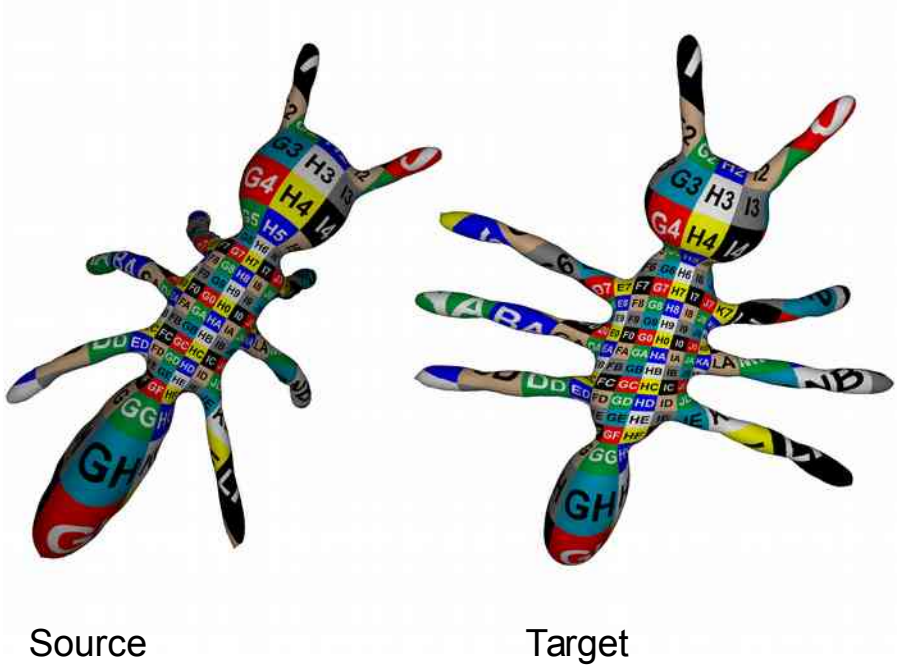
Shape Modelling International - 2018

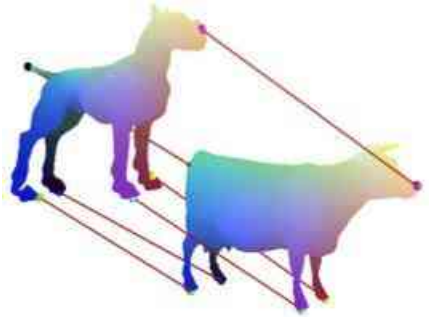
Surface mapping

High quality mappings between surface meshes

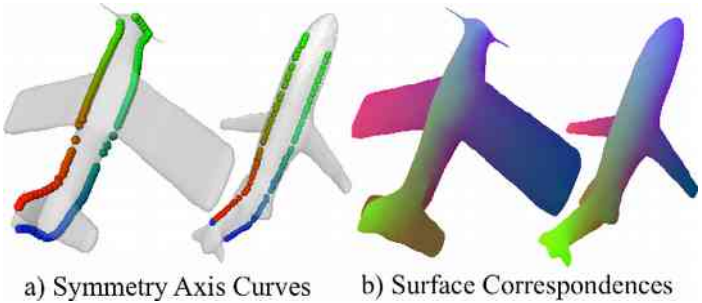


Source Target

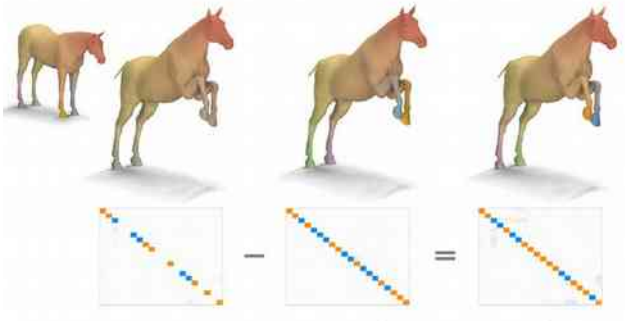
Why Surface Maps?



[Kim et al. 11]

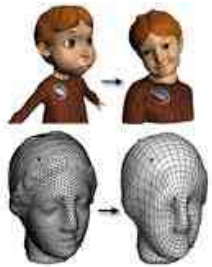


[Liu et al. 12]



[Ovsjanikov et al. 12]

[Zell et al. 13]



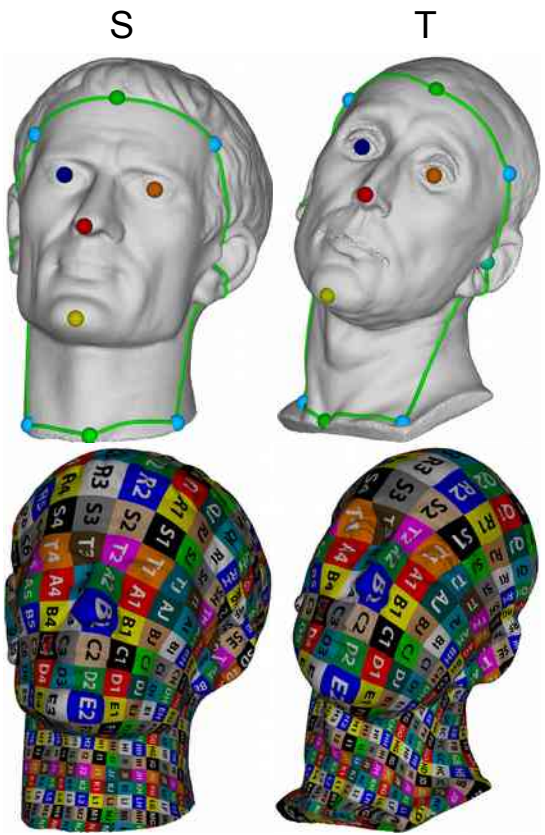
[Panozzo et al. 13]

[Aigerman et al. 15]

[Aigerman et al. 15]

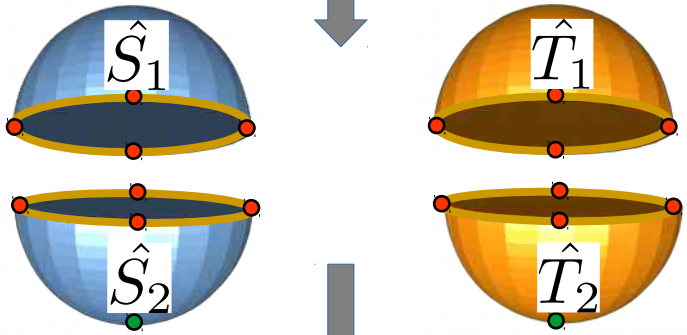
Objective!

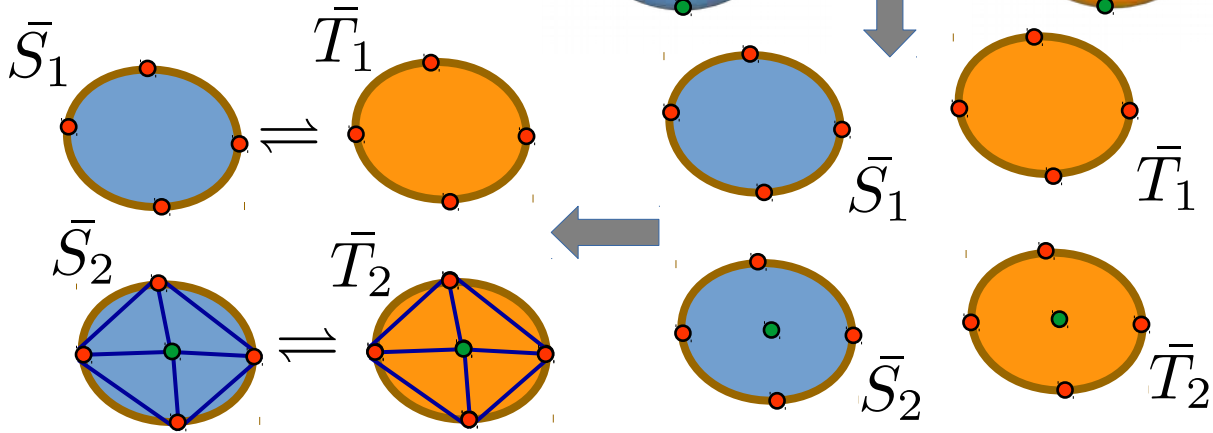
- Input
  - Two surface meshes S, T
  - Coarse set of corresponding landmarks
  - Closed paths connecting some of the landmarks
- Output: a map $f : S \to T$
  - High quality (Low distortion)
  - Maps semantic areas correctly
  - Bijective



Pipeline

1. Segmentation using closed paths
2. Planar parametrization of segmented parts
3. Cage deformation
4. Mapping extraction

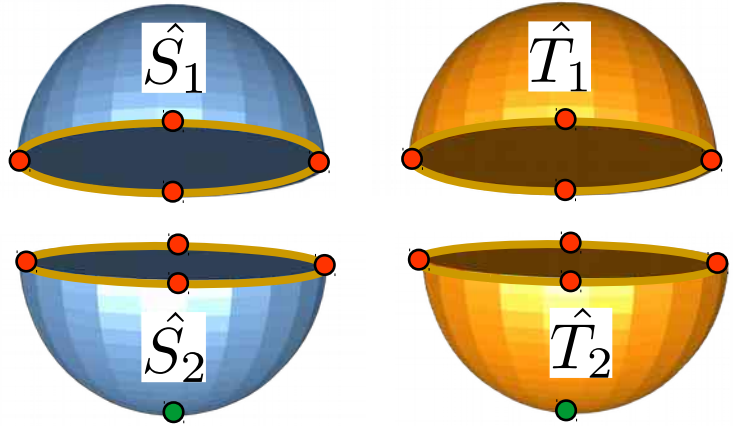




$f : S \to T$

Pipeline – Segmentation using closed paths

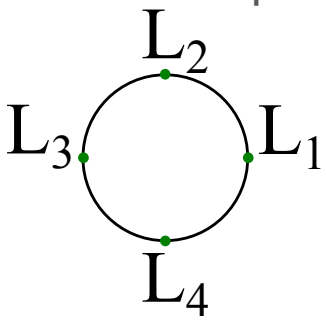
1. Two types of landmarks
   - Exterior landmarks for closed paths
   - Interiors at important features
2. Cut along closed paths
3. Segment meshes to be homeomorphic to a disk
4. Match segmented parts based on transferred landmarks

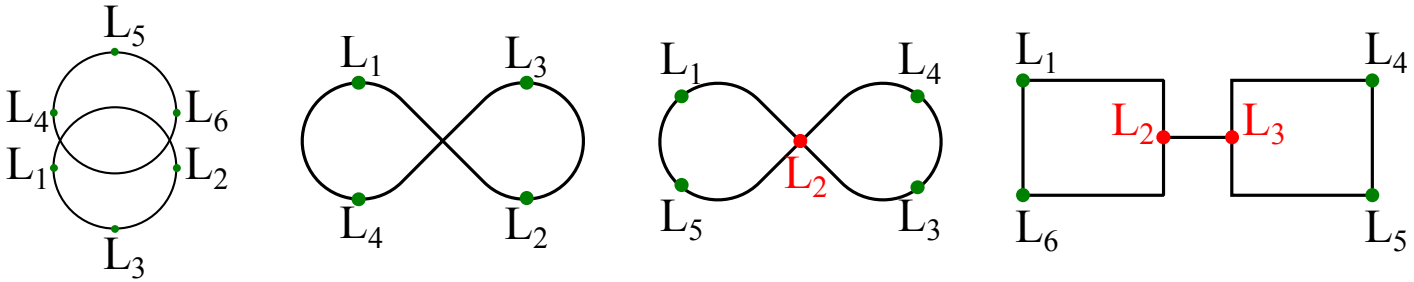


Pipeline – Segmentation using closed paths

Valid and Invalid closed paths

Valid closed path

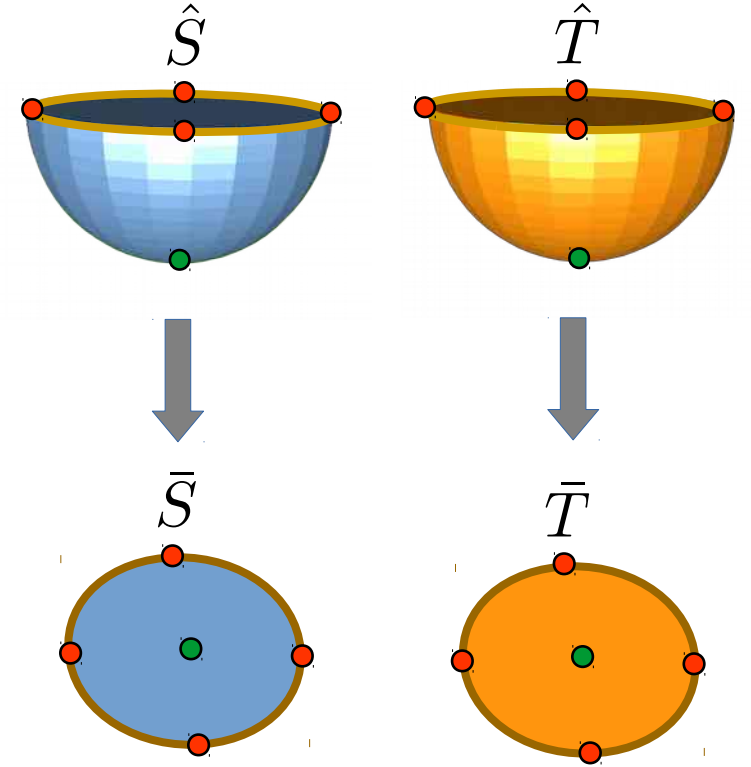




Invalid closed path types

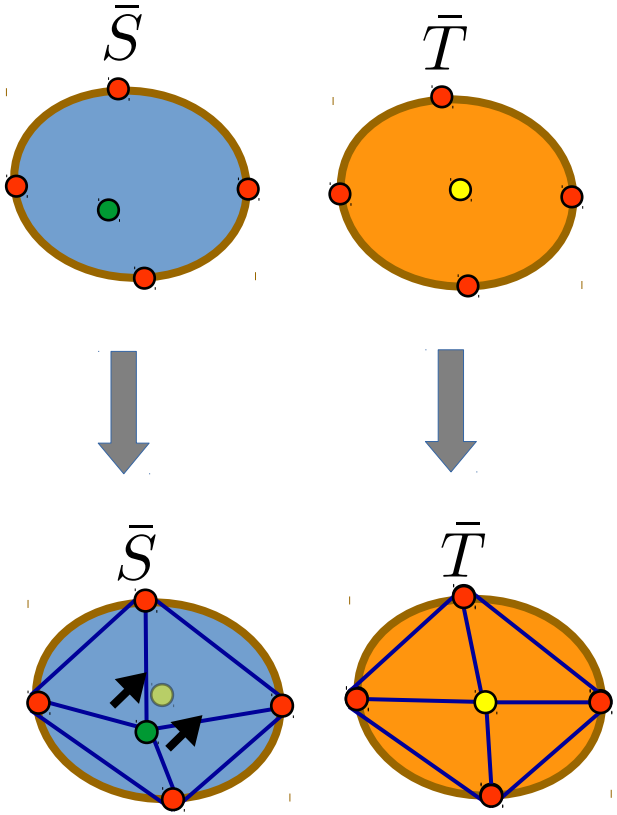
Pipeline – Planar parametrization of segments

- Flatten selected mesh using ABF++
- Choose a mesh flattening with lower L_2 and L_∞
- Align boundary of the second mesh and flatten



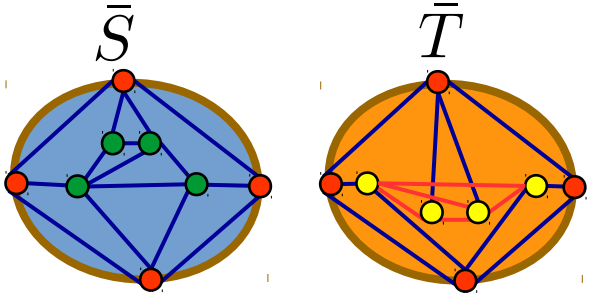
Pipeline – Cage Deformation

- Boundary landmarks are aligned
- But internal landmarks are not aligned
- Construct cage using Delaunay on 2d landmarks on $\bar{S}$
- Transfer cage to $\bar{T}$
- Map vertices of $\bar{S}$ and $\bar{T}$ to a cage triangle
- Align the cages and move vertices of $\bar{S}$

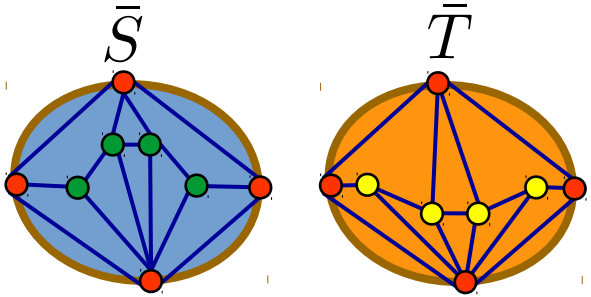


Pipeline – Cage Deformation: Ambiguous cages

- Rarely landmarks cross an edge
- Creates overlapping cage triangles
- Apply Delaunay to overlapping its connected triangles
- Use the new cage triangulation for both $\overline{S}$ and $\overline{T}$



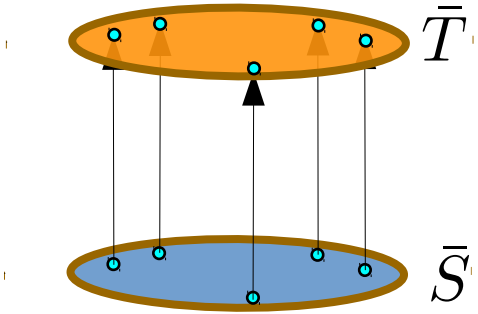
Ambiguous cages



Resolved cages

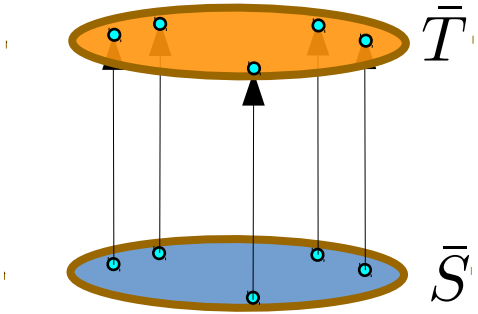
Pipeline – Mapping

- $\bar{S}$ and $\bar{T}$ are both aligned with boundary and interiors
- We use KD-tree to establish mapping
- Mapping is between a vertex to a location
- Expressed as a barycentric location based on vertices and a triangle



Pipeline – Mapping

- $\bar{S}$ and $\bar{T}$ are both aligned with boundary and interiors
- We use KD-tree to establish mapping
- Mapping is between a vertex to a location
- Expressed as a barycentric location based on vertices and a triangle
- Transfer mapping to original S and T

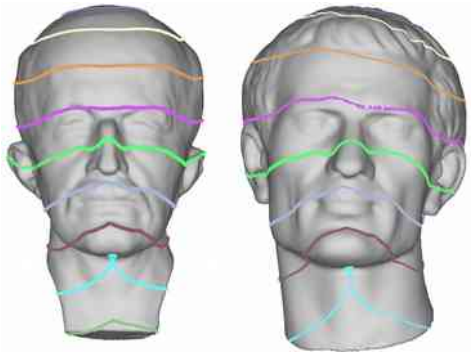


Results And Evaluation

- Qualitative
  - Smoothness and distortion
  - Three type of techniques
- Quantitative
  - Measure bijectivity
  - Linking of related regions

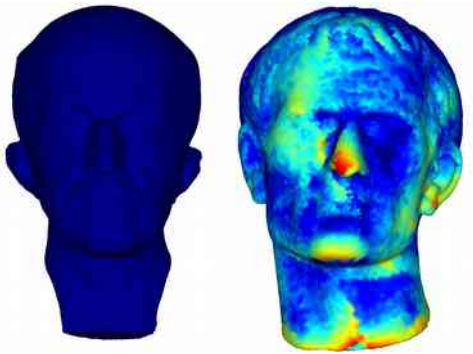
Qualitative Evaluation

- Isopoints
- Grid texture
- Vertex coloring



Isopoints

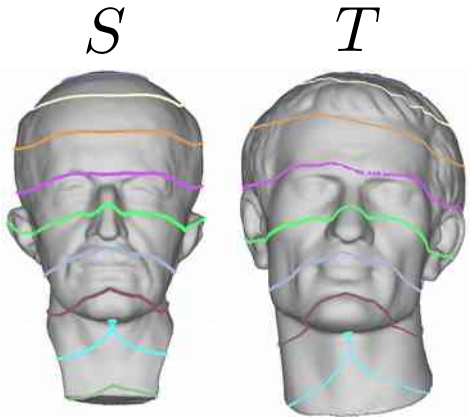
Grid textures



Vertex coloring

Qualitative Evaluation – Isopoints

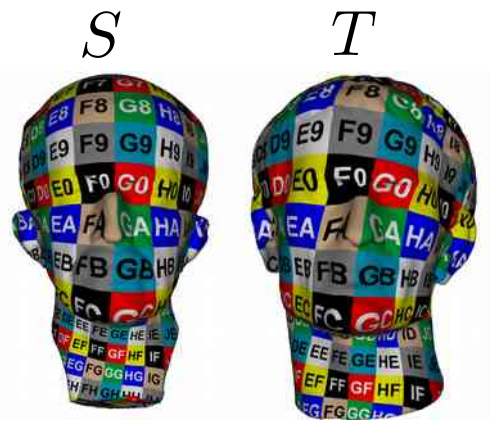
- Constructing isocurves
  - Calculate geodesic distances on source **S**
  - Color each isocurve differently
  - Transfer the isocurves using the mapping to the target **T**
- Helps with identifying
  - Areas with too much clutter
  - Missing isopoints at expected regions
  - Zig-zagging: Smoothness issues



Isopoints visualization

Qualitative Evaluation – Grid texture

- Constructing grid textures
  - Create UV map with grid texture on source **S**
  - Transfer UV map to $\{v_t\}$
- Helps with identifying
  - Magnitude of distortion in triangles
  - Semantic mismatches are explicitly visible

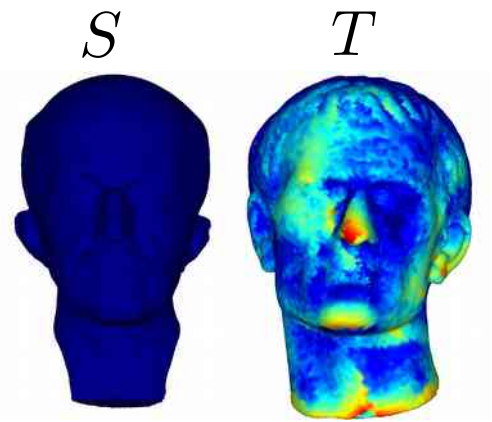


Grid textures

$\{v_t\}$ – vertices of target **T**

Qualitative Evaluation – Vertex Coloring

- Constructing vertex coloring
  - Morph **S** to **T** as $\overline{\mathbf{S}}$
  - For each $\{v_t\}$ find the location on $\overline{\mathbf{S}}$ as $\{\bar{v}_t\}$
  - Color $\{v_t\}$ based on $\| \{v_t\} - \{\bar{v}_t\} \|$
- High displacements – higher errors

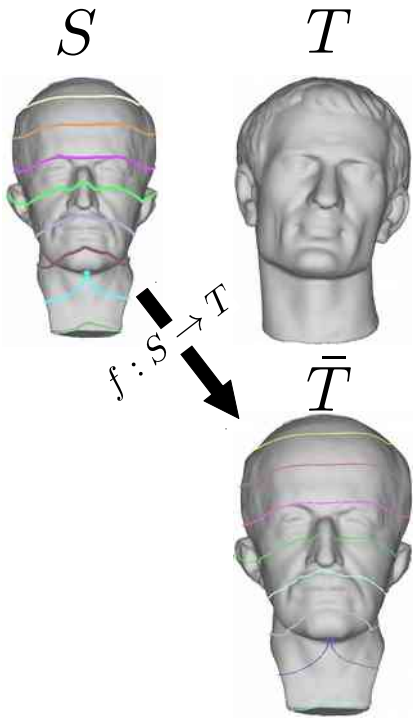


Vertex coloring

$\{v_t\}$ – vertices of target **T**
$\{\bar{v}_t\}$ – vertices of target with their mapped location on $\overline{\mathbf{S}}$

Quantitative Evaluation : A numerical perspective

- A proposal for evaluation mapping numerically
- Finds semantic discrepancies
- Construction
  - Morph **T** to **S** as $\overline{\mathbf{T}}$
  - Transfer isopoints $\{iso_s\}$ of **S** to $\overline{\mathbf{T}}$ as $\{\overline{iso_t}\}$
  - Error calculation: $|| \{\{iso_s\} - \overline{iso_t}\} ||$



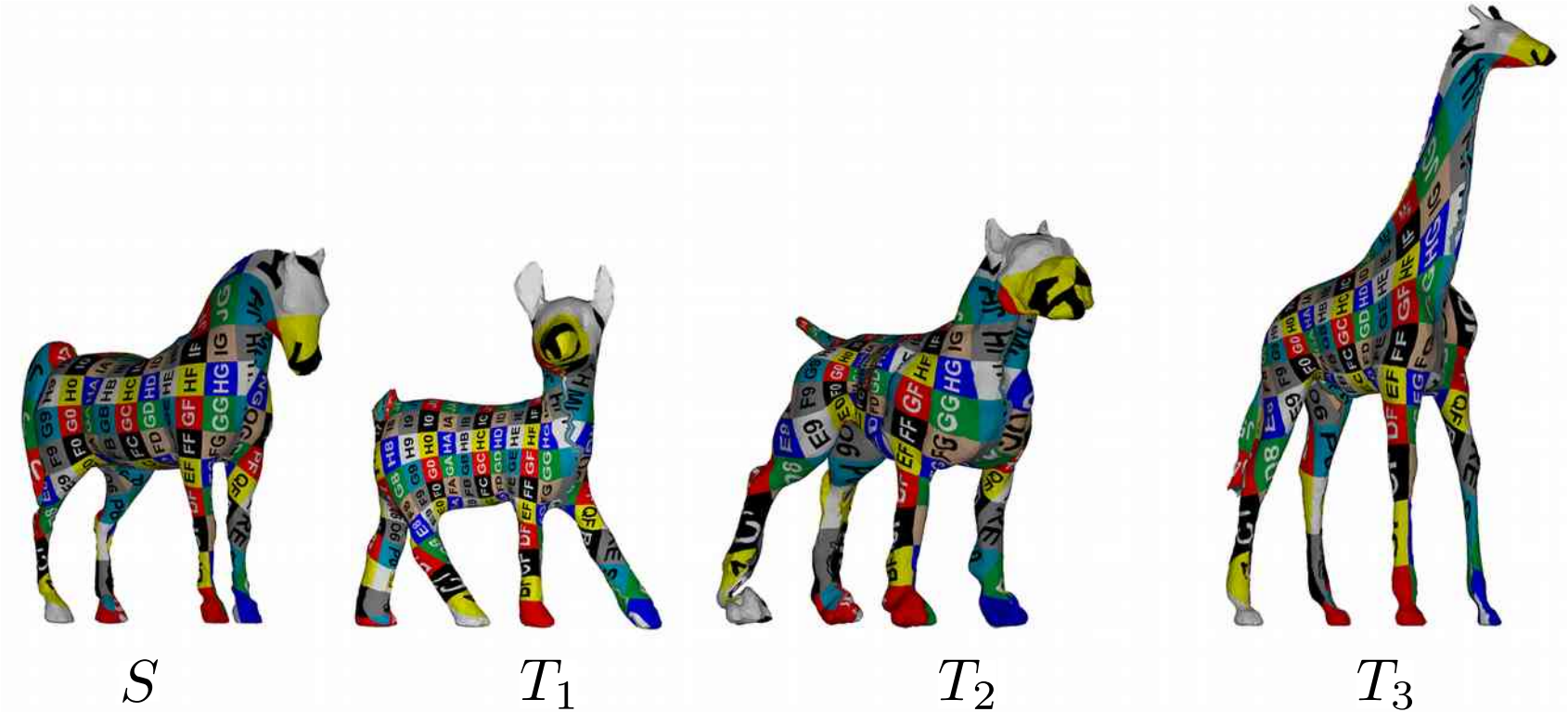
Isopoints transferred to $\overline{\mathbf{T}}$

$\{iso_s\}$ – isopoints on **S**
$\{\overline{iso_t}\}$ – transferred isopoints from **S** to $\overline{\mathbf{T}}$

Discussion

- Datasets
  - SCAPE
  - SHREC Watertight
  - Artists and MakeHuman generated
- Class-wise: A single source mapped to multiple targets
- Genus 0: one closed path
- Higher Genus: 4 closed paths

Discussion: Quadrupeds class



S T_1 T_2 T_3

Discussion: Aircrafts class

S T_1 T_2 T_3

Discussion: Insects class

S T_1 T_2 T_3

Discussion: Fishes and Birds classes

S T_1 T_2 T_3

Discussion: Coarse Humanoids class

S

T_1

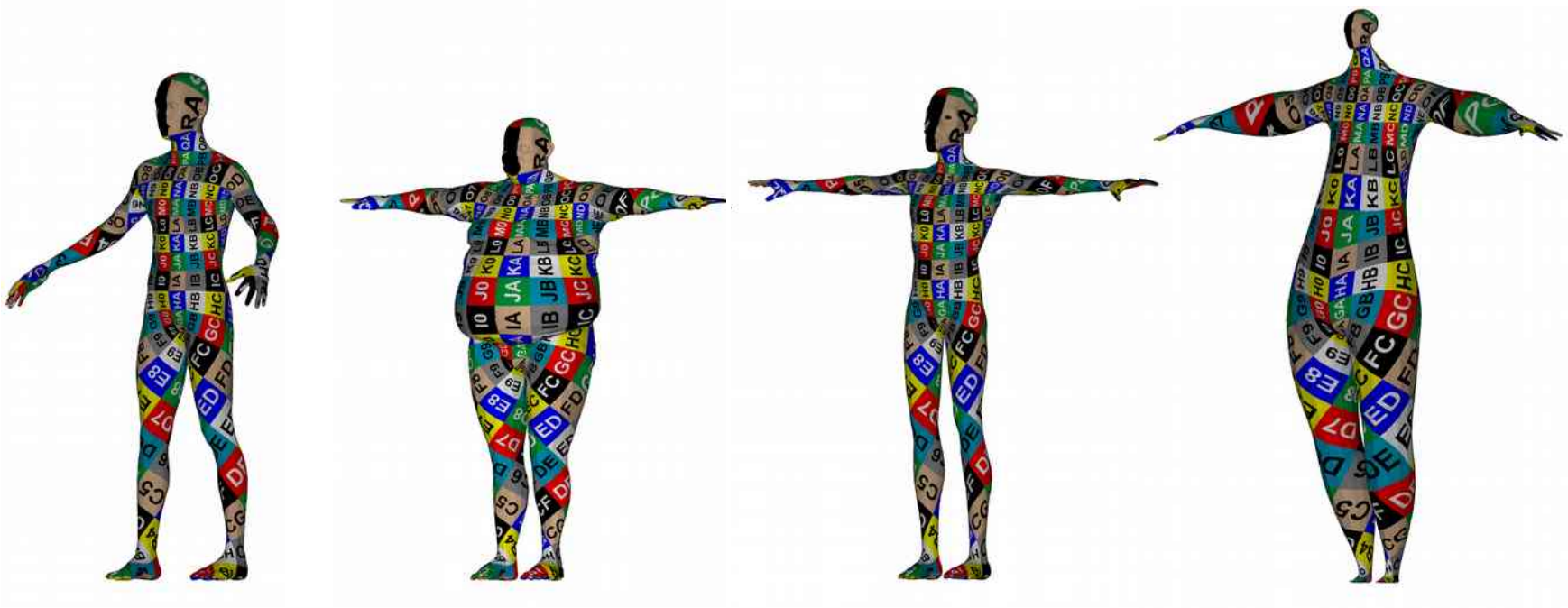
T_2

T_3

Discussion: Busts class

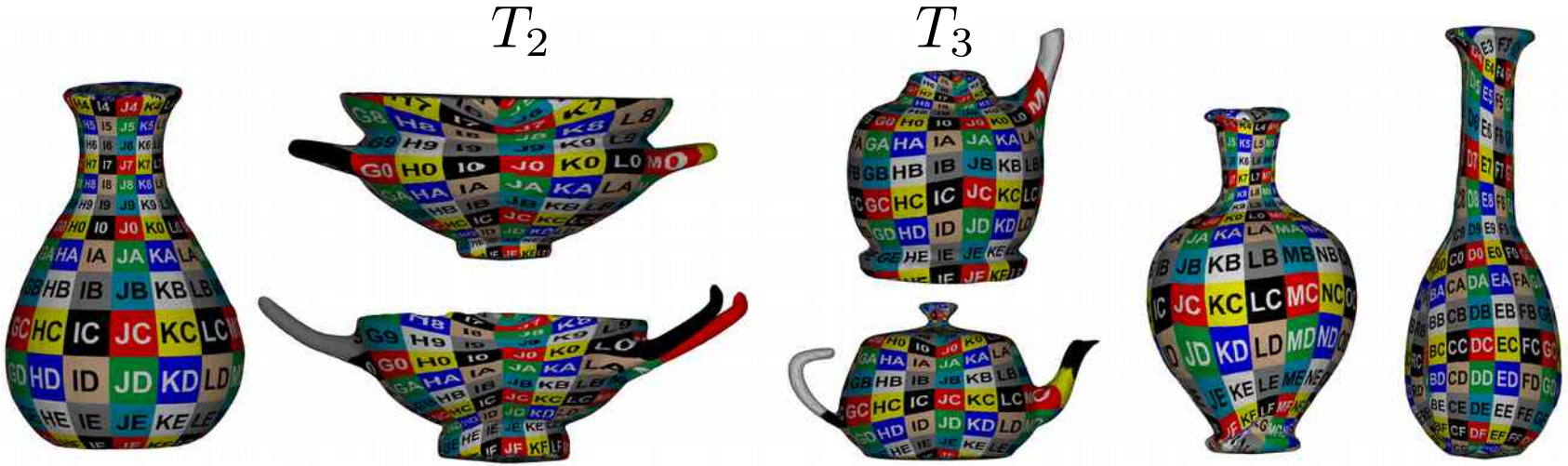
S T_1 T_2 T_3

Discussion: Detailed Humanoids class

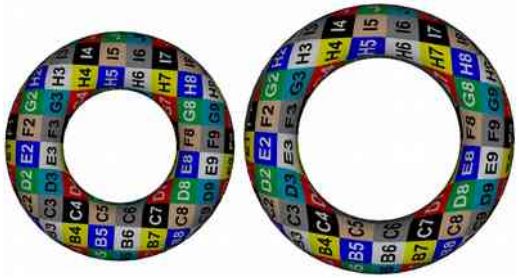


S T_1 T_2 T_3

Discussion: Pots class



Discussion: Different Generas



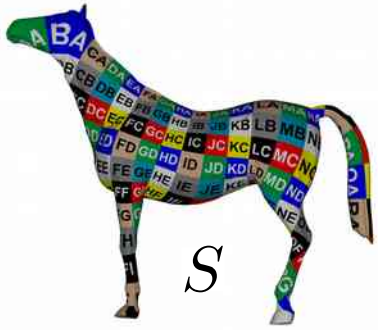
S T

S T

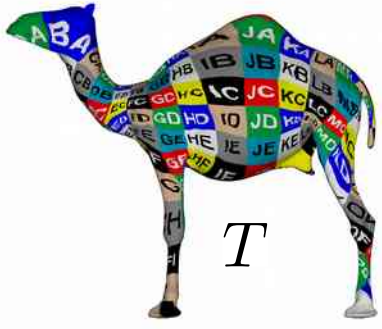
S T

S T

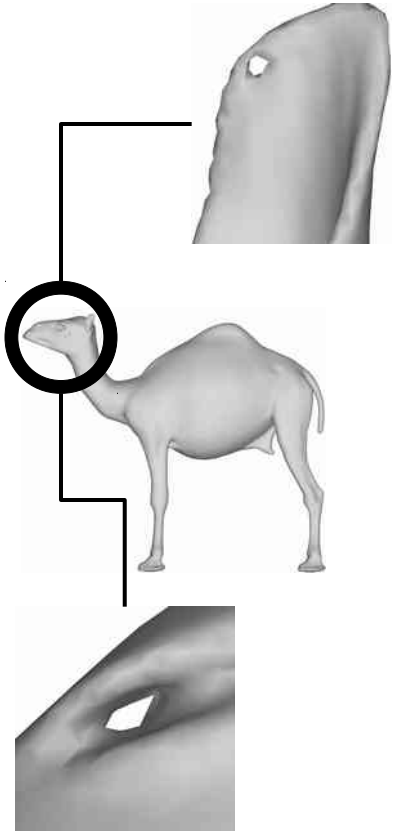
S T



S



T



Discussion: Different Morphology

S T

Conclusion – A Mapping Approach

- Sparse inputs for landmarks and closed paths
- Free of high distortions and handles small features
- Robust to different genera and isometries

Conclusion – Limitations And Future works

- Limitations
  - Input for closed paths can be taxing
  - Bijectivity depends on the flattening mechanism
  - Cage mesh can be flipped if landmark correspondences are flipped
- Future directions
  - Automatic landmarks and closed paths
  - Cage deformation optimized along with weights of the mesh