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

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Surface mapping

High quality mappings between surface meshes
Why Surface Maps?

[Kim et al. 11]

[Symmetry Axis Curves]

[Liu et al. 12]

[Surface Correspondences]

[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 $f : S \rightarrow T$
  - 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

\[ f : S \rightarrow T \]
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 $L_\infty$
- 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 $\bar{S}$ and $\bar{T}$
Pipeline – Mapping

- $\overline{S}$ and $\overline{T}$ 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
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

\( \{v_t\} \) – vertices of target \( T \)
Qualitative Evaluation – Vertex Coloring

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

$\{v_t\}$ – vertices of target $T$
$\{\bar{v}_t\}$ – vertices of target with their mapped location on $\bar{S}$
Quantitative Evaluation: A numerical perspective

- A proposal for evaluation mapping numerically
- Finds semantic discrepancies
- Construction
  - Morph $T$ to $S$ as $\overline{T}$
  - Transfer isopoints $\{\text{iso}_s\}$ of $S$ to $\overline{T}$ as $\{\text{iso}_t\}$
  - Error calculation: $|| \{\text{iso}_s\} - \{\text{iso}_t\} ||$

$\{\text{iso}_s\}$ - isopoints on $S$
$\{\text{iso}_t\}$ - transferred isopoints from $S$ to $\overline{T}$
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
Discussion: Aircrafts class

$S$, $T_1$, $T_2$, $T_3$
Discussion: Insects class
Discussion: Fishes and Birds classes
Discussion: Coarse Humanoids class
Discussion: Busts class
Discussion: Detailed Humanoids class
Discussion: Pots class
Discussion: Different Genera
Discussion: Different Morphology
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