Recognition of Shapes by Editing Shock Graphs

(Sebastian, Klein & Kimia)

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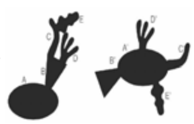
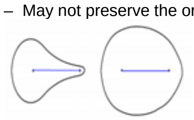
Introduction

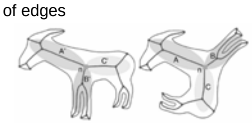
- Objective
  – To operationalize the notion of shape similarity, and use it as a basis for categroty-level recognition
- Motivation
  – Shape is an important cue for recognition, but it is difficult to extract, characterize and represent

Related Work

- Shape is represented by point sets
  – May not capture the global measure
  – May be alleviated by using a global shape context, but is still sensitive to partial occlusion and part articulation
- Shape is represented by curve
  – Sensitive to articulations and deformations
- Shape is represented by medial axis
  – Some obvious shape deformations cannot be captured
  – May not preserve the ordering of edges

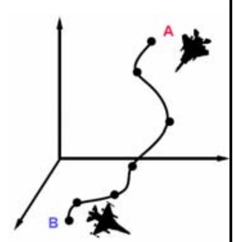






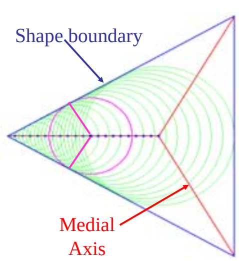
Overview

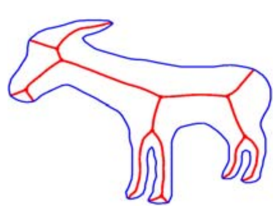
1. Use shock graphs to represent shapes
2. Partition shape space by defining an equivalence class of shapes
3. Discretize deformation space by defining an equivalence class of deformation paths
4. Employ an edit-distance algorithm to find the optimal deformation path



Shock Graphs

- **Medial Axis**
  - locus of centers of maximal circles that are bitangent to shape boundary

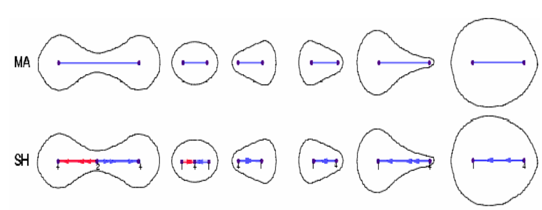




Real Example

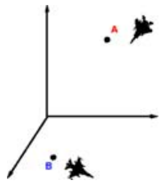
Shock Graphs (2)

- **Shock Graph**
  - A dynamic interpretation of the medial axis
  - With associated direction of flow



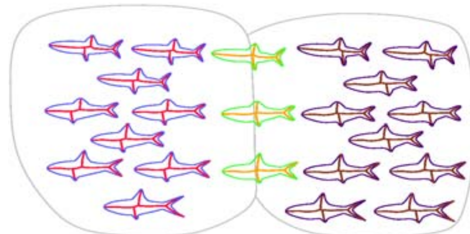
Partition the shape space

- Shape space
  - Shape is a point
  - Shape deformation sequence is a path
- Shape cell
  - A collection of shapes that have the same shock graph topology



Partition the shape space (2)

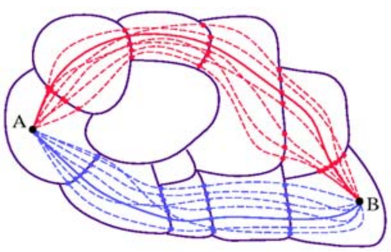
- Transition shapes
  - form the boundary between shape cells



Shape cell 1 **Shape cell 2**

Discretize the deformation space

- The number of deformation paths between two shapes is infinite
- Finding the optimal deformation path is intractable

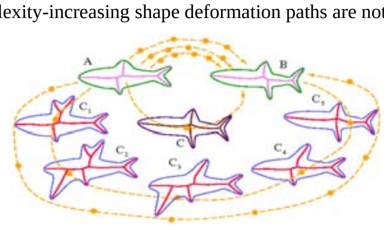


Discretize the deformation space (2)

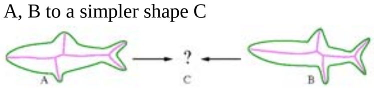
- Two deformation paths are equivalent if they pass through the same sequence of shock graph transitions

Avoid Complexity-Increasing Paths

- Complexity-increasing shape deformation paths are not optimal

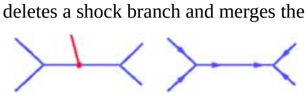


- Represent a deformation path by a pair of **simplifying deformation paths** from A, B to a simpler shape C

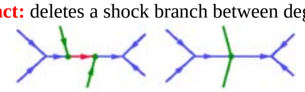


Edit Operations for Shock Graphs

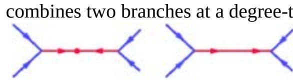
- Four edit operations are needed for shock graphs
  - **Splice:** deletes a shock branch and merges the remaining two



  - **Contract:** deletes a shock branch between degree-three nodes



  - **Merge:** combines two branches at a degree-two node



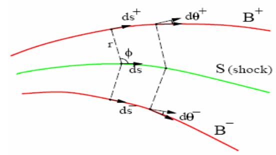
  - **Deform:** changes the attributes of a shock branch

Assign Costs to Edit Operations

- Derive the cost of the deform edit:
  - Sum over local shape differences between matching shock segments
- Derive the cost of other edits:
  - The limit of the deform cost as the shape moves to the boundary of the shape cell

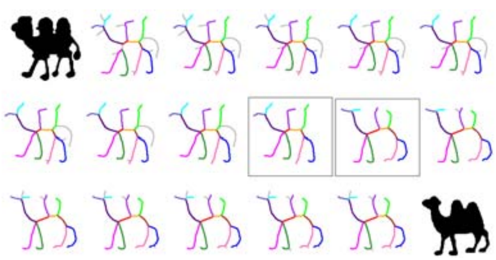
Deform Cost between Shock Edges

- Deform cost between shock edges consists of
  - Length differences of shock segments
  - Curvature differences of shock segments
  - Length differences of the boundary segments
  - Curvature differences of boundary segments
  - Difference in width of shape
  - Difference in relative orientation of boundary segments



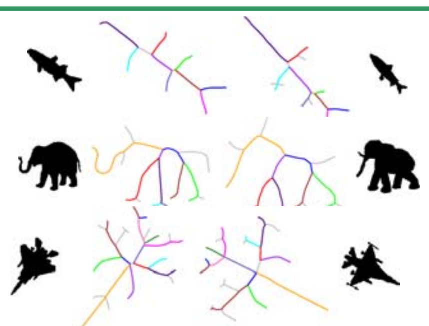
Edit Distance between Shapes

- Edit-distance is defined as the **sum of the cost of edits** in optimal edit sequence



Experiment Results

Matching Results

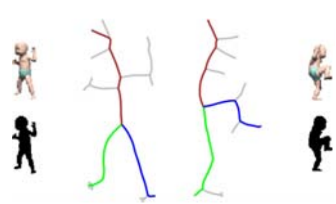


Edit-distance algorithm gives intuitive results

* Same colors indicate matching edges; gray-colored edges are pruned

Articulations

- Shock graphs represents object parts and part hierarchy

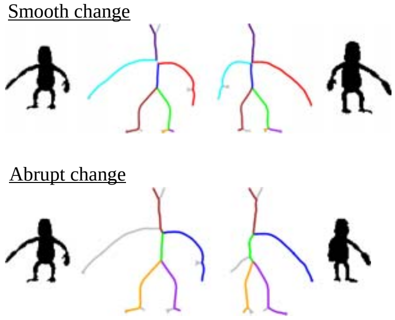


Edit-distance is robust in presence of part-based changes

View-point changes

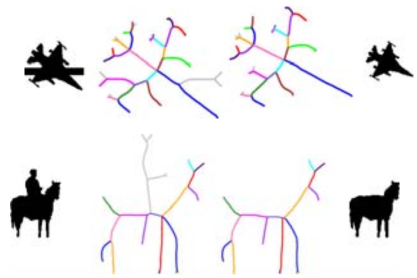
Smooth change

Abrupt change



- Deform edit handles smooth changes
- Splice and contract edits handle abrupt changes

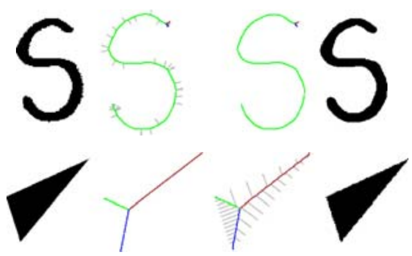
Partial Occlustions



Edit-distance is robust to partial occlusion

Boundary noises

- Shock graphs are sensitive to boundary noise



In optimal edit sequence “noisy” branches are pruned

Conclusions

- Strengths
  - Planar ordered shock graph representation
  - Discretization of shape space and deformation space, which makes the problem of finding an optimal deformation path practical
  - Incorporation of edit-distance algorithm that finds the optimal path in polynomial time
  - Robustness to various visual transformations

Conclusions (2)

- Weaknesses
  - Good segmentation is required
  - Edit operations are sensitive to noises
  - Edit operations are sensitive to scale
  - Exhaustively searching of optimal deformation path still needs expensive computation
  - It doesn’t capture any features within the boundary
  - The shape representation is not a statistical model and is not yet suitable for learning of object classes

Thank you!