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Shape Modeling for ~~Dummies~~ Non-Experts

(Modeling with Interchangeable Parts)

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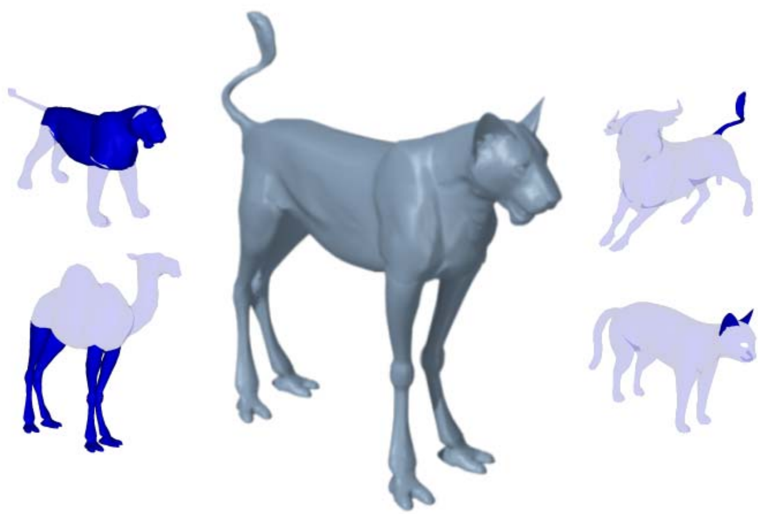
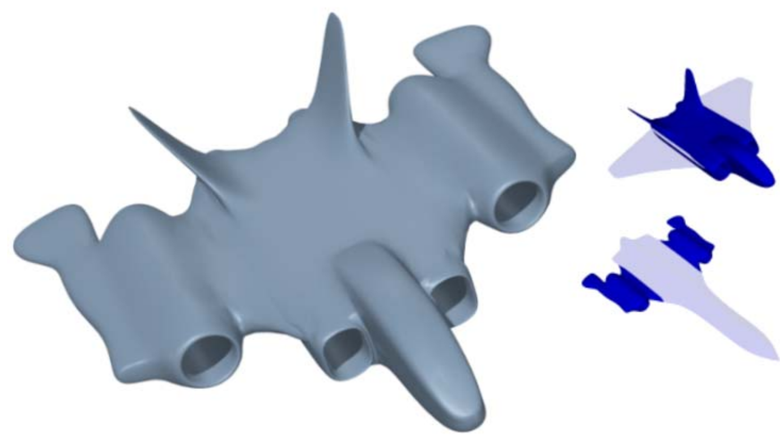
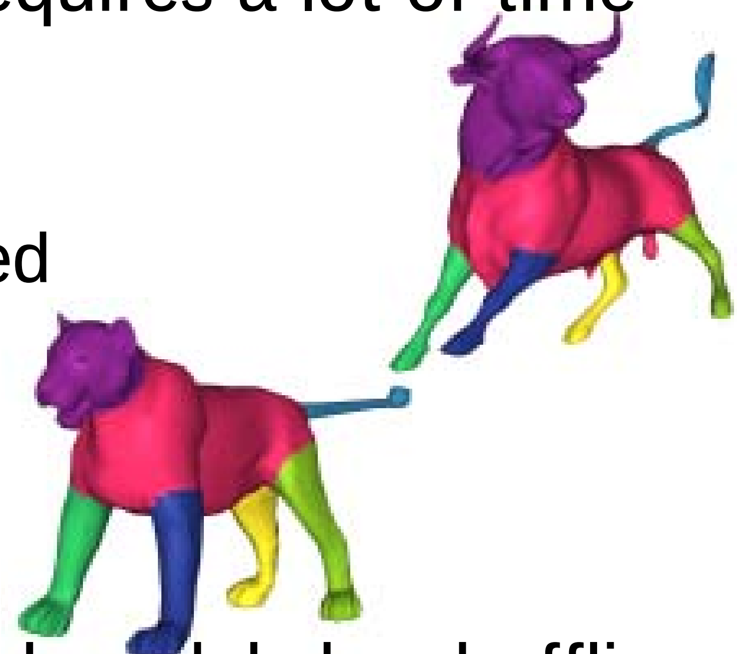
(joint work with Vladislav Kraevov & Dan Julius)





Motivation - Easy creation of 3D Content

- Currently 3D modeling requires a lot of time & expertise
- Observations:
  - Practical modeling limited to small set of classes
  - Models have intuitive breakdown into interchangeable parts



- Can create rich & detailed models by shuffling parts
  - n models with m parts $\rightarrow$ n^m new models

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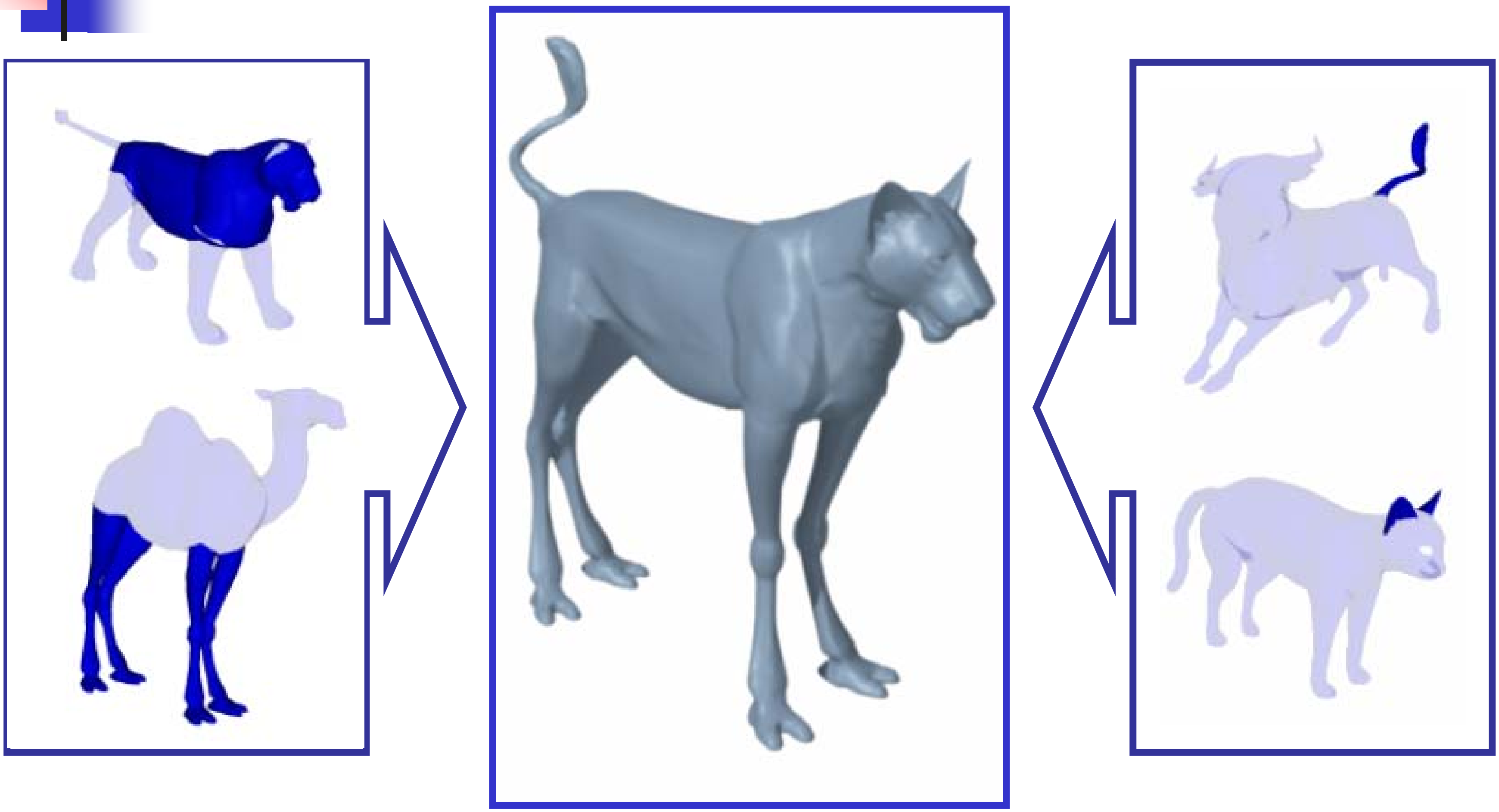
Shuffler Modeling System



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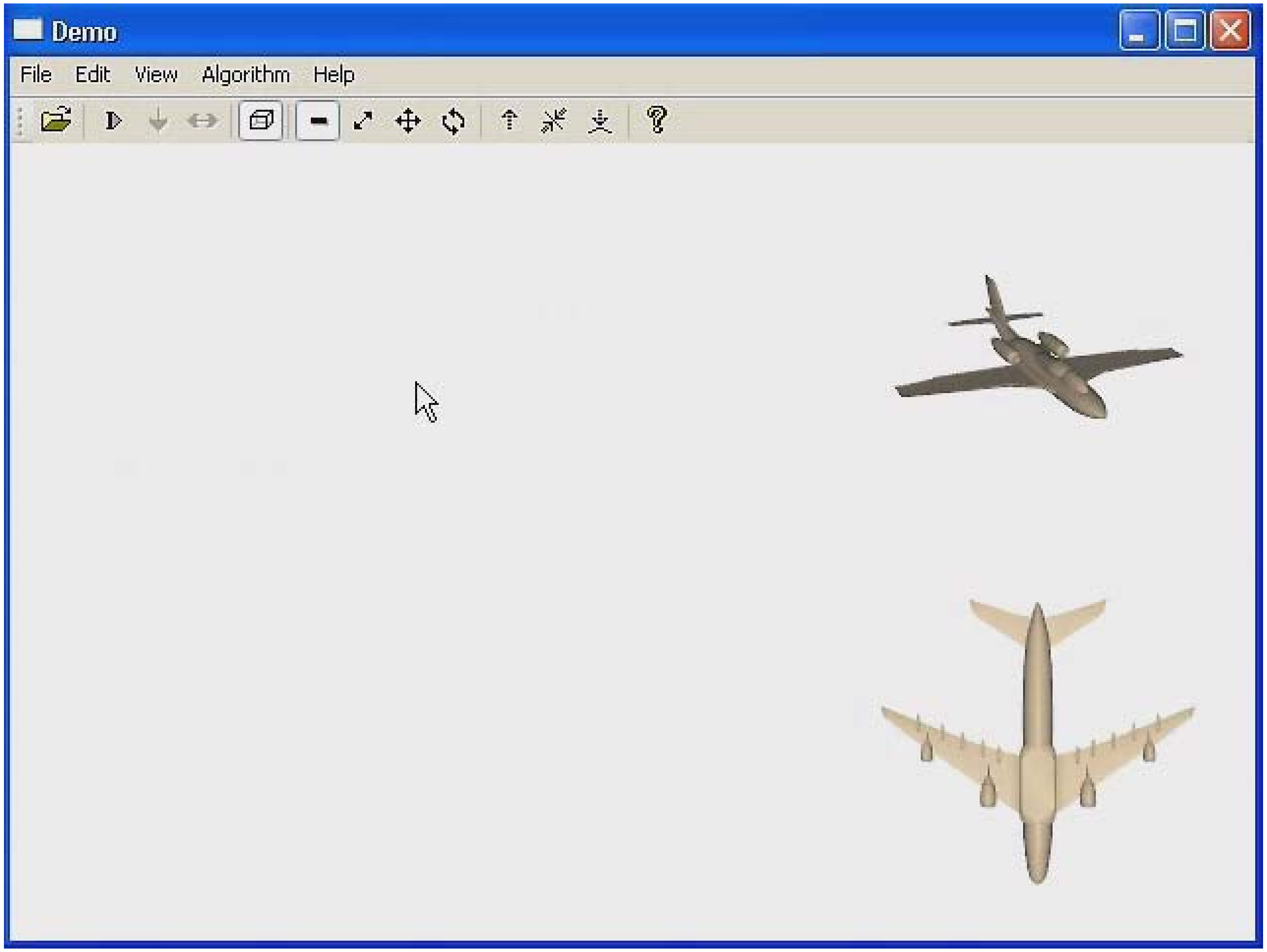
Modeling System



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Shuffler

- Fast & Trivial to use
  - Mouse click based
  - No geometric input from user
  - No user parameters
- Operates on models of generic topology
  - multiple components, any genus, boundaries, non-manifold

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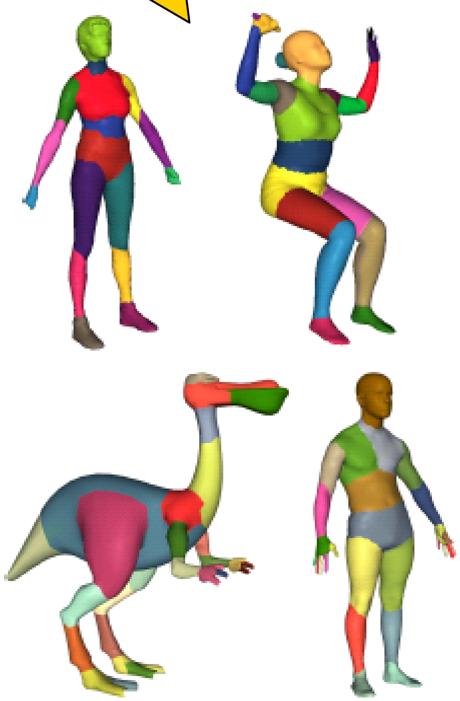
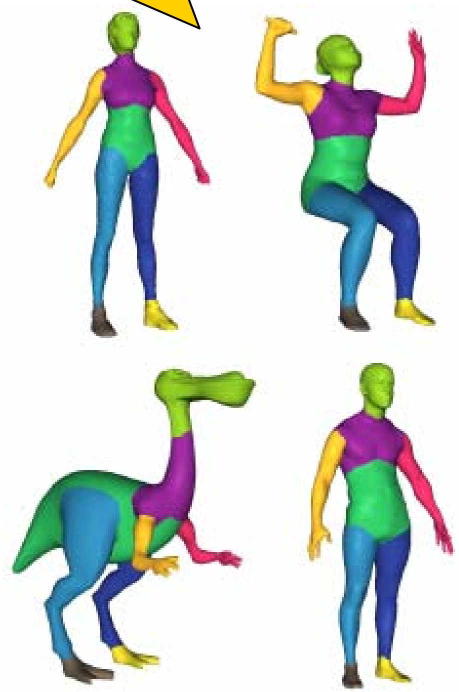
Under the hood...

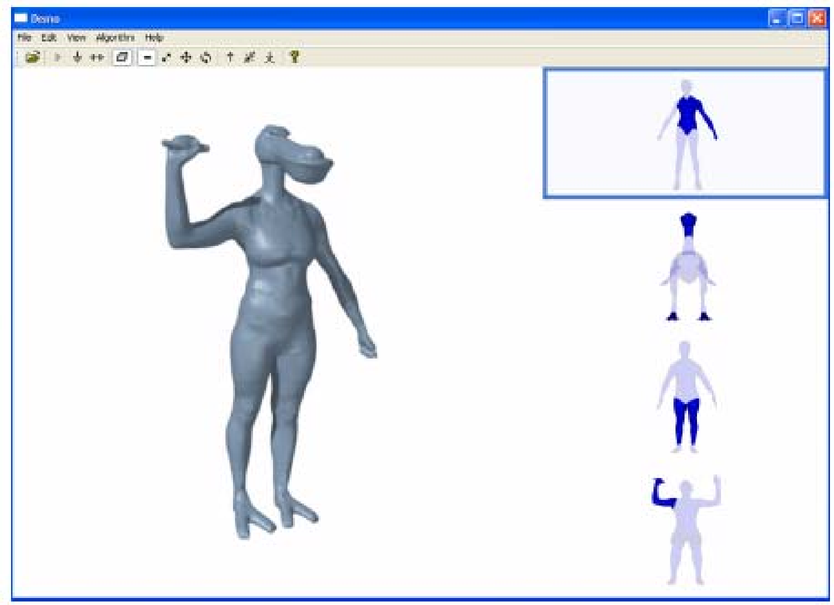
I. Meaningful Segmentation



II. Part Correspondence



III. Shuffling: alignment & blending



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Previous Work – Modeling

- From scratch
  - Traditional Tools [Maya, 3DMax]
    - + Create rich & complex models
    - – time consuming, requires expertise
  - Sketching [Igarashi'99]
    - + Fast & easy
    - – Good for simple models

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Previous Work – Modeling

- Reuse
  - \+ Create complex models
  - Blending [Allen'03, Schreiner'04, Kraevoy'04]
    - – Users must specify feature correspondences
  - Composition [Yu'04, Sorkine'04]
    - – Users must cut & position parts
  - Modeling by Example [Funkhouser'04]
    - \+ Find & position parts based on similarity
    - – Users must cut models

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Previous Work - Segmentation

- Meaningful ≈ convex
  [Hoffman & Richards'84]
- Exact convex [Chazelle'95]
  – oversegments
- Parts from farthest points
  [Katz'03,Zhang'05,Katz'05]

- Feature characteristics
  [Mortara'04, Attene'06]

- Distance to convex-hull
  [Lien'06]

- Typically require per model parameter fine-tuning

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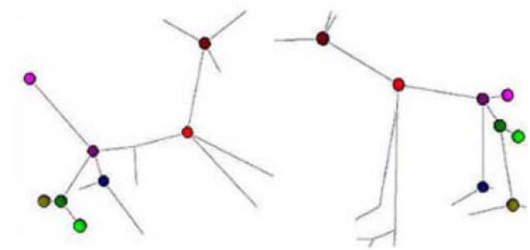
Previous work - Correspondences

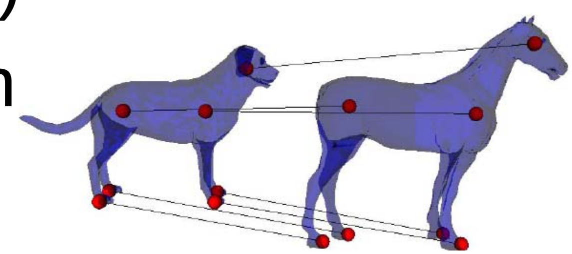
- Use for "matching score" [Cornea'05, Sundar'03]
  - Do not disambiguate symmetries
  - Incomplete matches

[Cornea'05]

[Sundar'03]



  - Topology restrictions (genus 0)
  - Some assume rigid registration
- Partial matching [Funkhouser'04]
  - single part



[Novotni'06]

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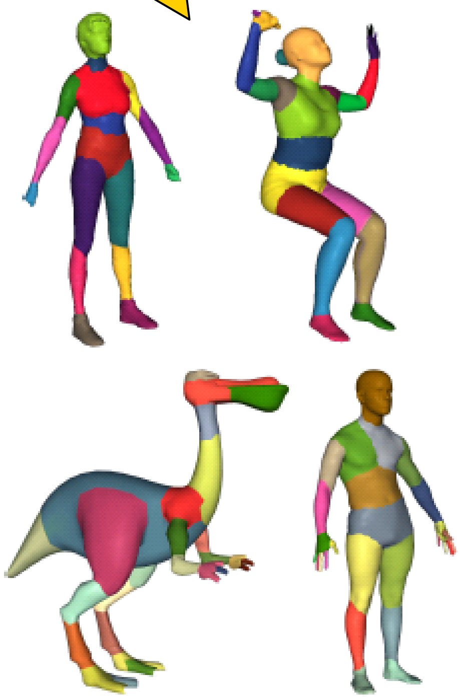
Segmentation

I. Meaningful Segmentation



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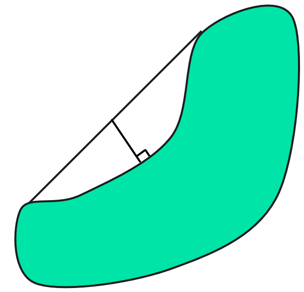
Metrics

Segmentation quality

1. Convexity

$$dist(P, C(P)) = \frac{\sum_{t \in P} dist(t, C(P)) \cdot area(t)}{\sum_{t \in P} area(t)},$$



2. Compactness

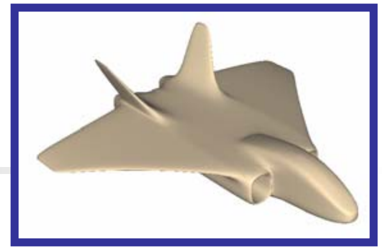
$$comp(C) = \frac{area(C)}{volume(C)^{2/3}}$$

3. Cost

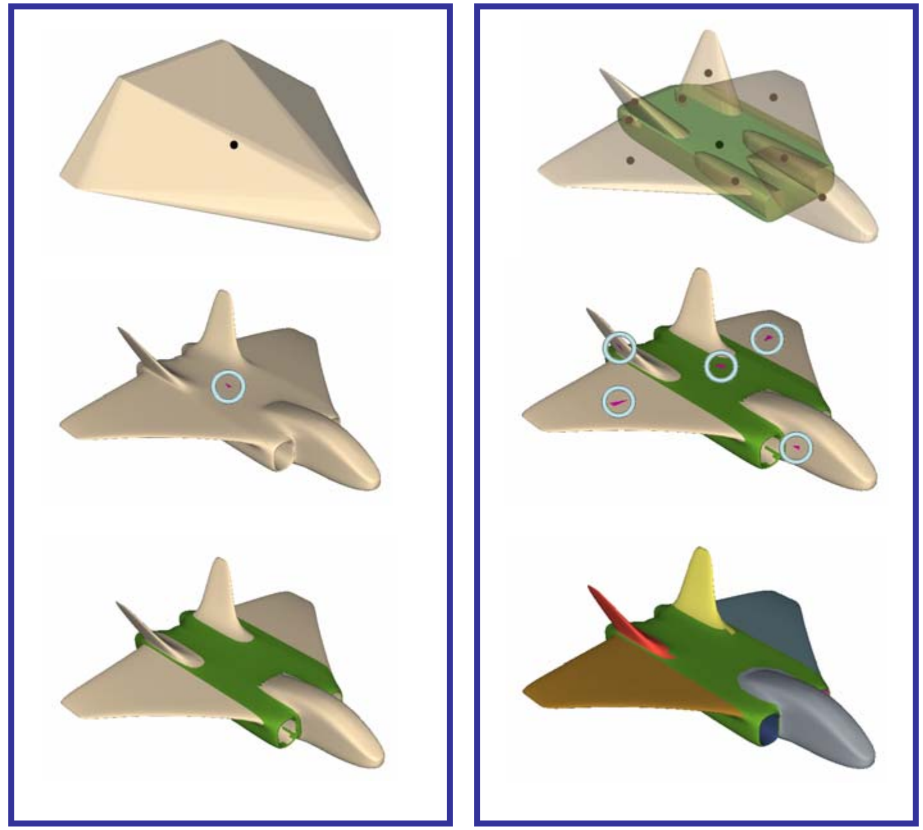
$$cost(P) = (1 + dist(P, C(P))) \cdot (1 + comp(C(P)))^{\alpha},$$

(α – the same for all models)

Algorithm



1. Patch generation – "hole filling"
2. Seed generation
3. Patch growing & reseeding
   - Use convexity bound
4. Repeat till no "holes" left



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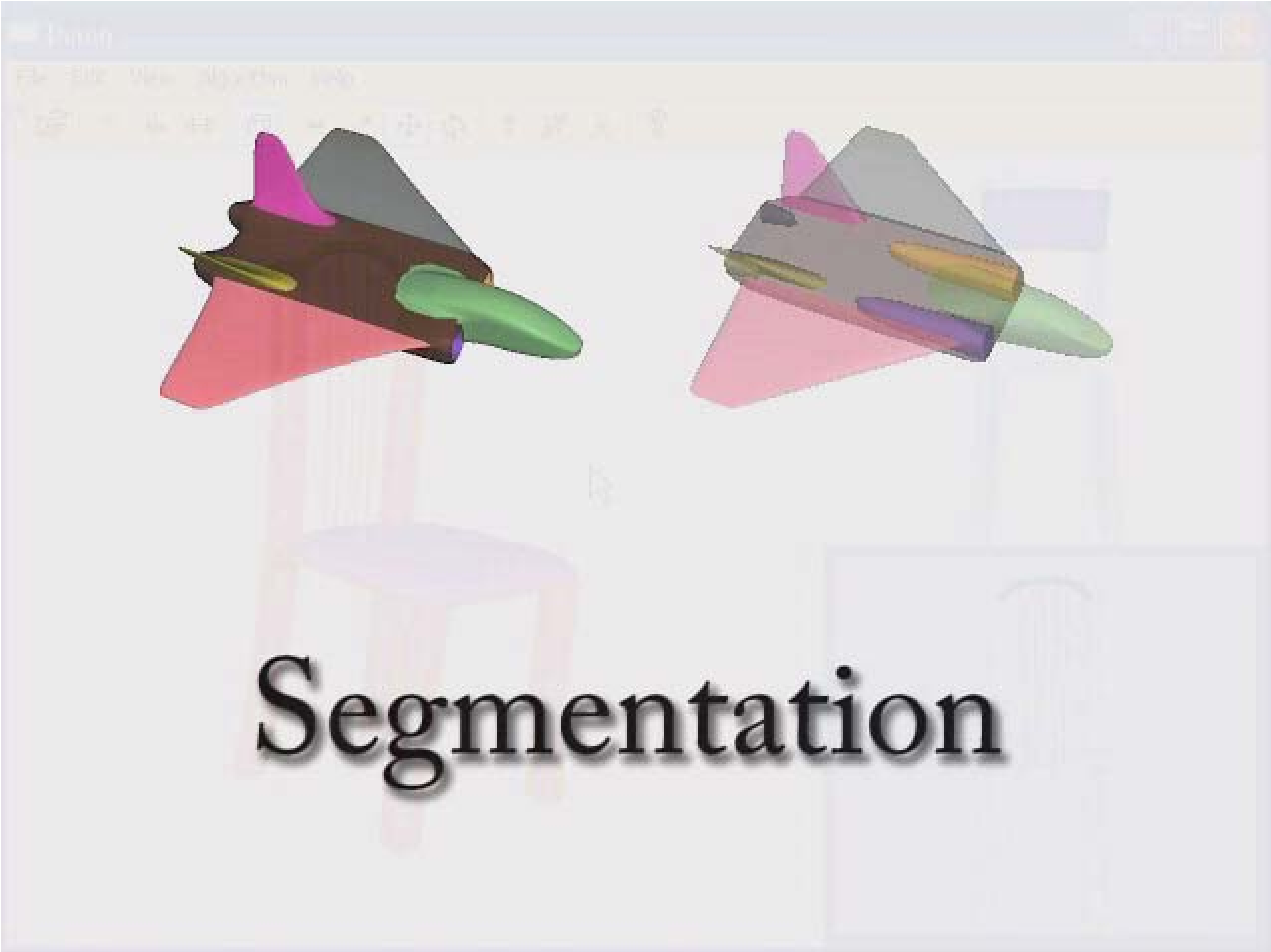
Segmentation



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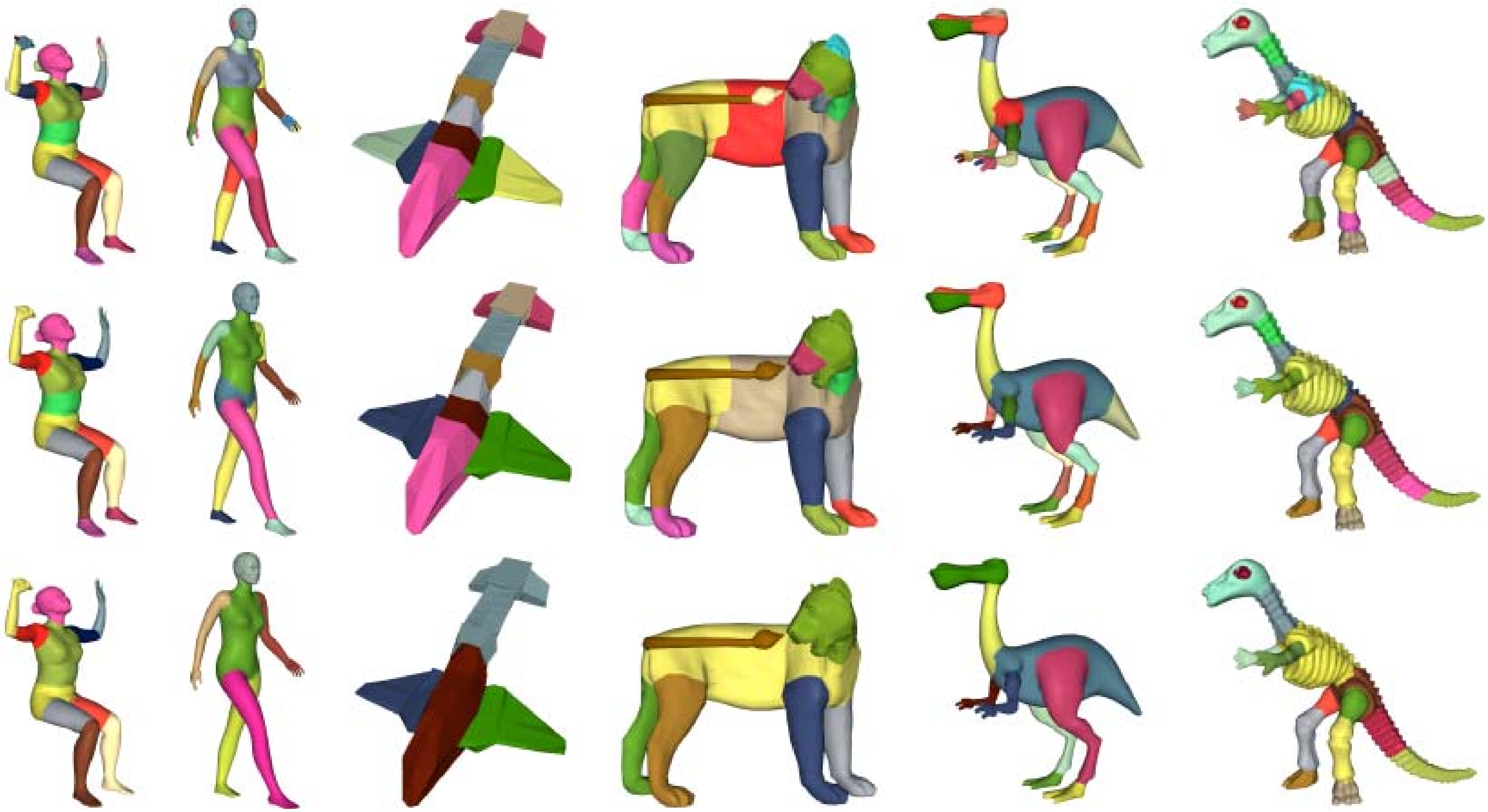
Hierarchical segmentation

- Bottom up
  - Merge patches as long as combined patch satisfies a coarse threshold



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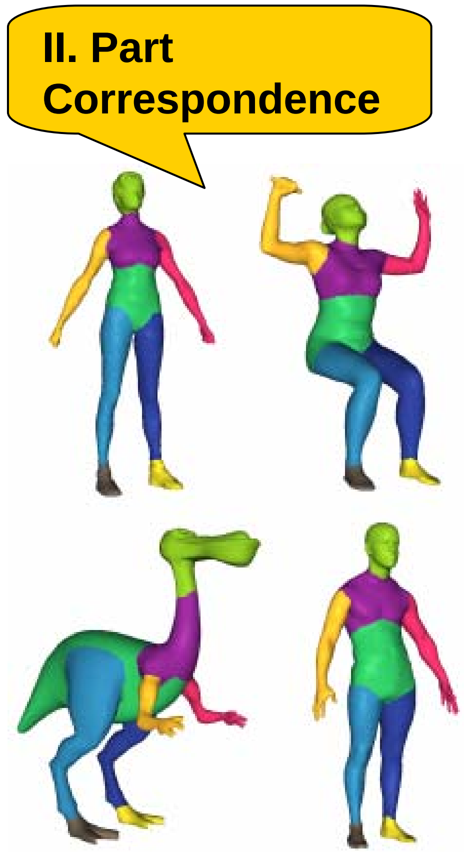
Segmentation



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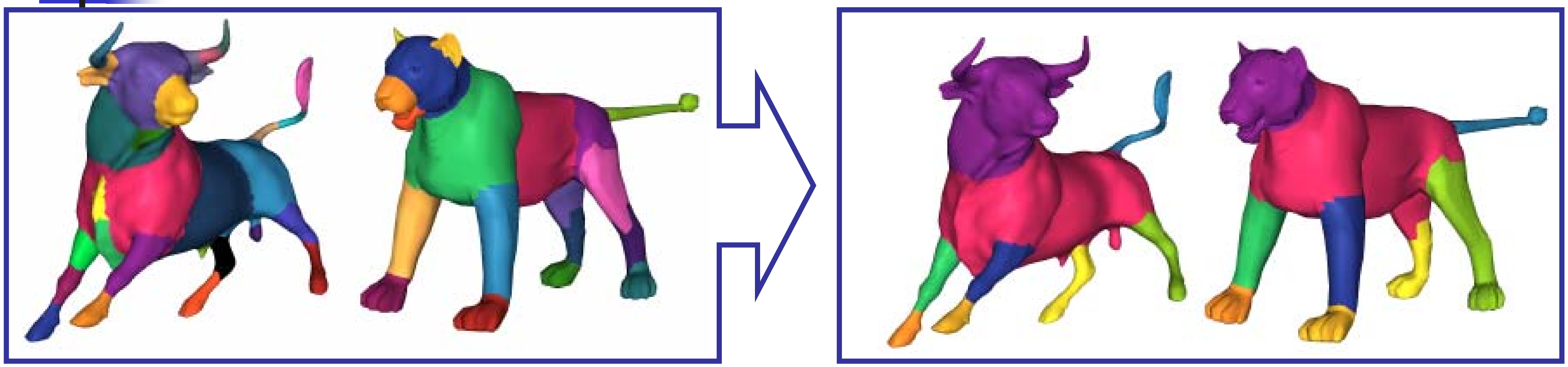
Correspondence



- Many-to-Many
  - Number of groups unknown a priori
  - Groups represent meaningful components
  - Cost function
    - Compare match quality across different groupings & different number of groups

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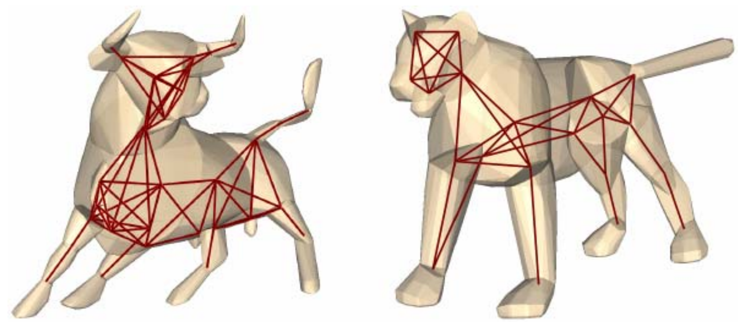
Cost Function

- Group convexity measures grouping quality

$$c_{cost} = \sum_{j=1}^{k} volume(C(g_{1j})) + \sum_{j=1}^{k} volume(C(g_{2j}))$$

- Measure similarity in terms of *mid-point graph* distances
  - supports pose variation



$$g_{cost} = \sum_{a=1}^{k}\sum_{b=1}^{k}\left(d(g_{1a},g_{1b})/s_1 - d(g_{2a},g_{2b})/s_2\right)^2, s_i = \sum_{a=1}^{k}\sum_{b=1}^{k} d(g_{ia},g_{ib})$$

Mid-point graphs

- To resolve symmetries use
  - Euclidean distances & volume

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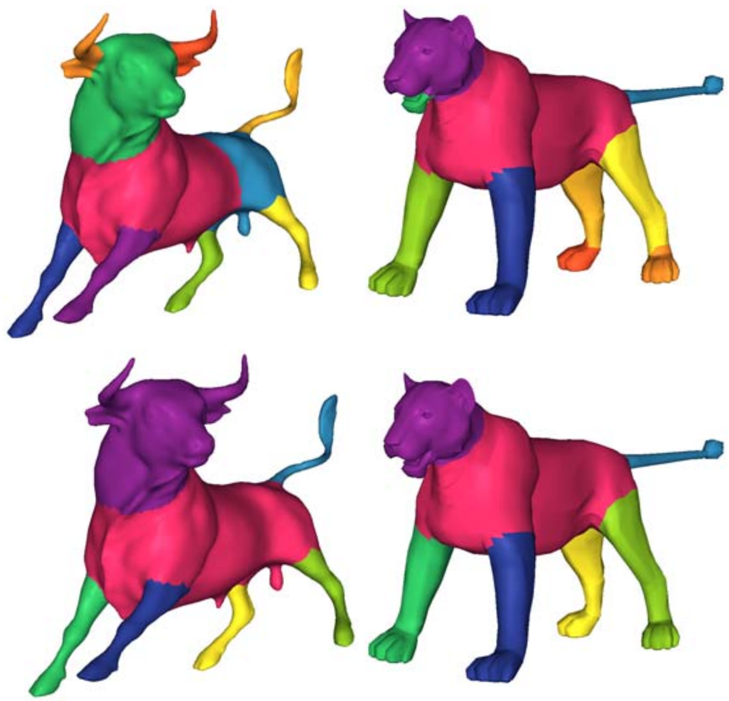
Part Matching - Search

- Use hierarchical segmentation
- Establish correspondences on coarse level
  - Use stochastic local search
    - iterate
      - random initial guess selection
      - local search



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Part Matching - Search

- Do registration based on results
  - Resolves global symmetries
  - Needed for shuffling
- Refine correspondences using fine segmentation level
  - Use group splits

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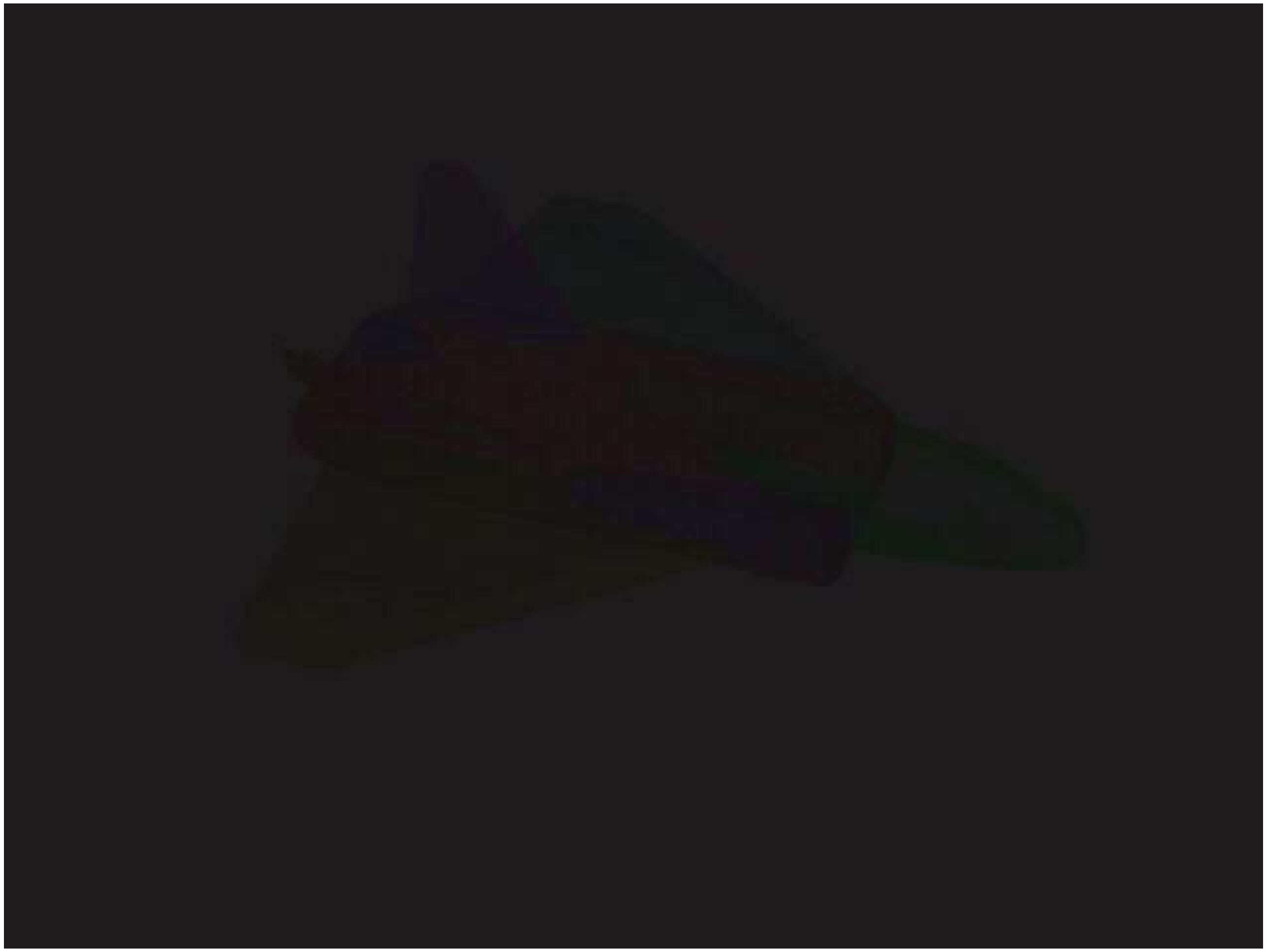
Part Correspondence



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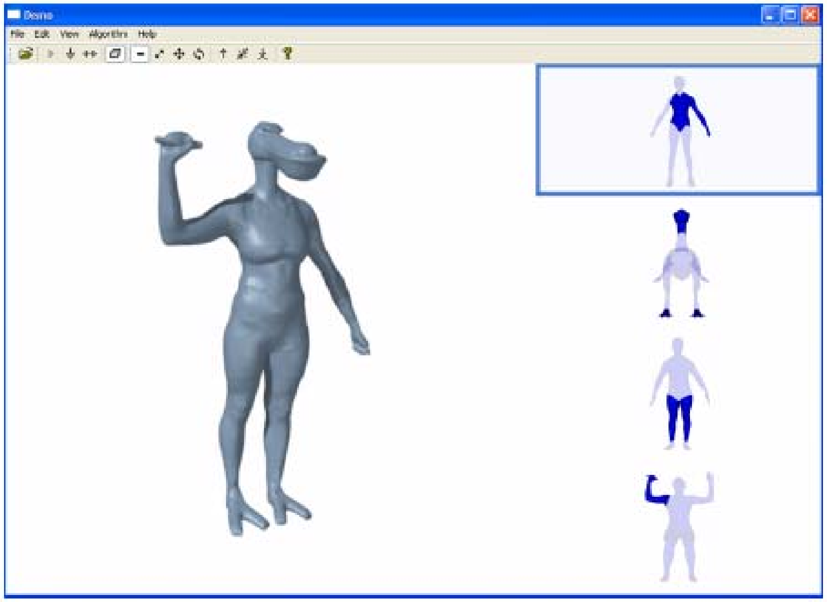
Segmentation

III. Shuffling: alignment & blending



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Shuffling

- Positioning
  - global rotation & scale
    - closest point alignment of matching group centers
  - Position individual parts – use common group graph

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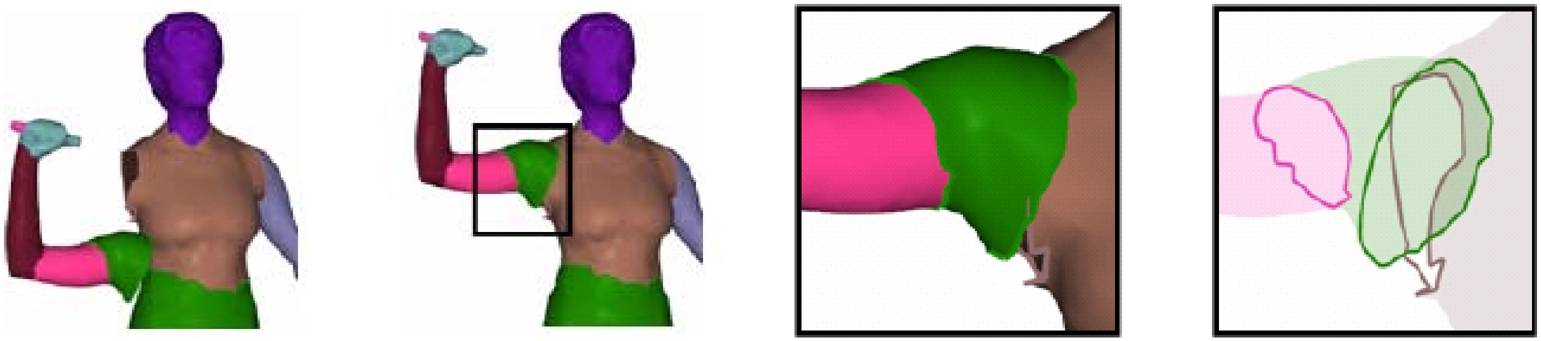
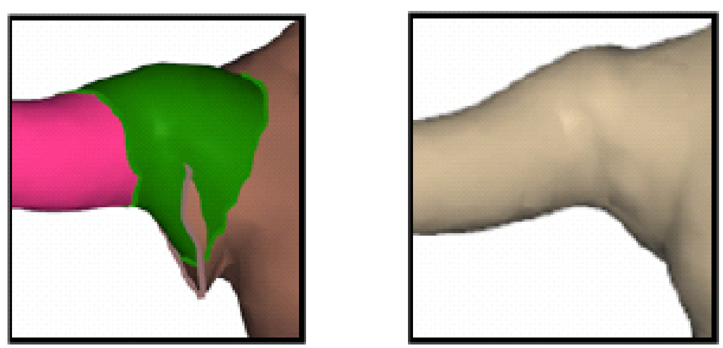
Shuffling



- Blending & Merging
  - Extend meshes to form overlap region
  - Perform zippering [Turk'94] & geometry blending



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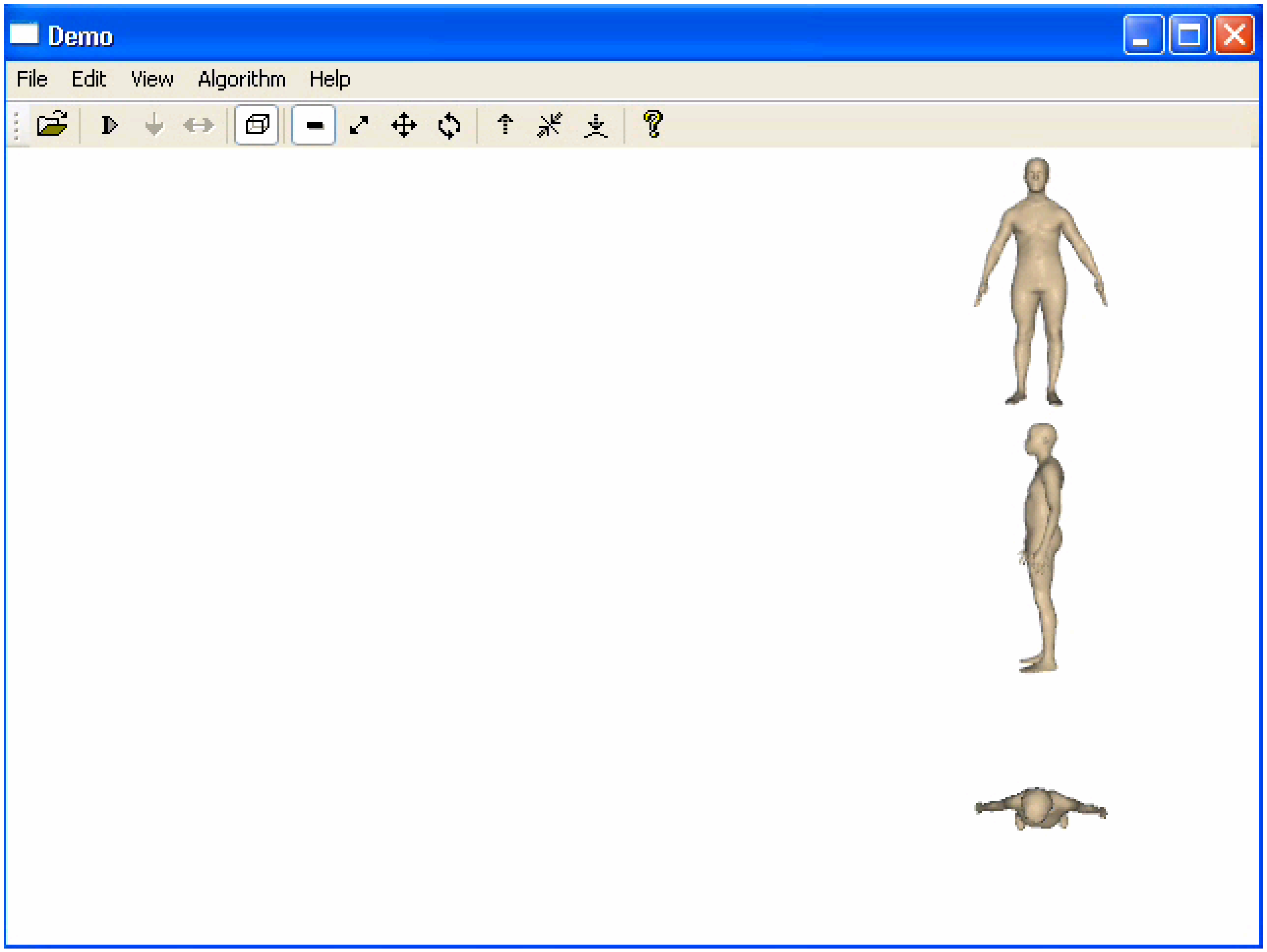
Shuffling - Results



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Results - Example

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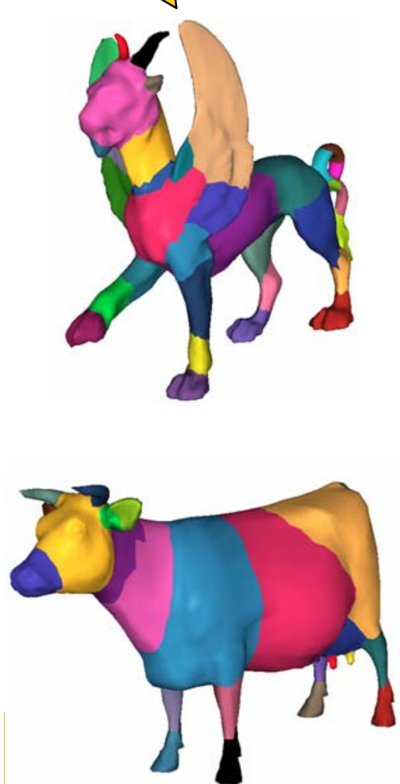

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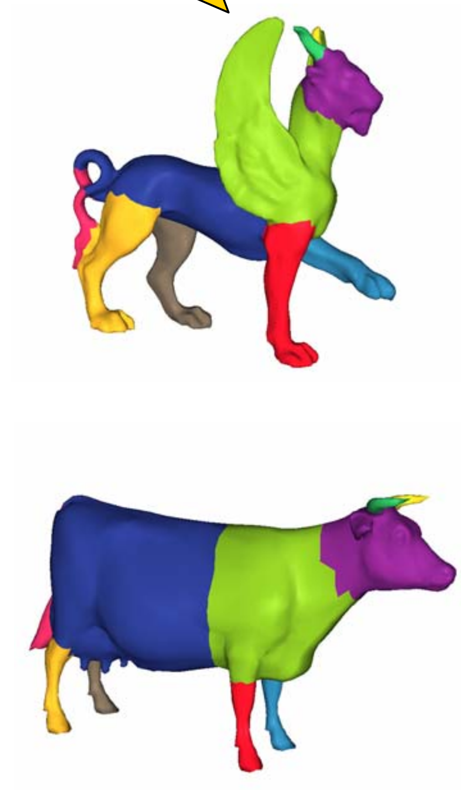

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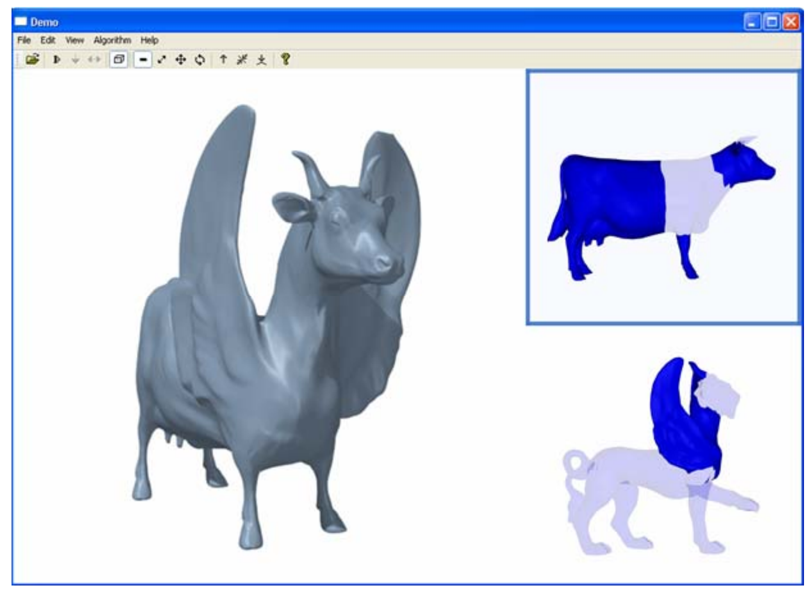

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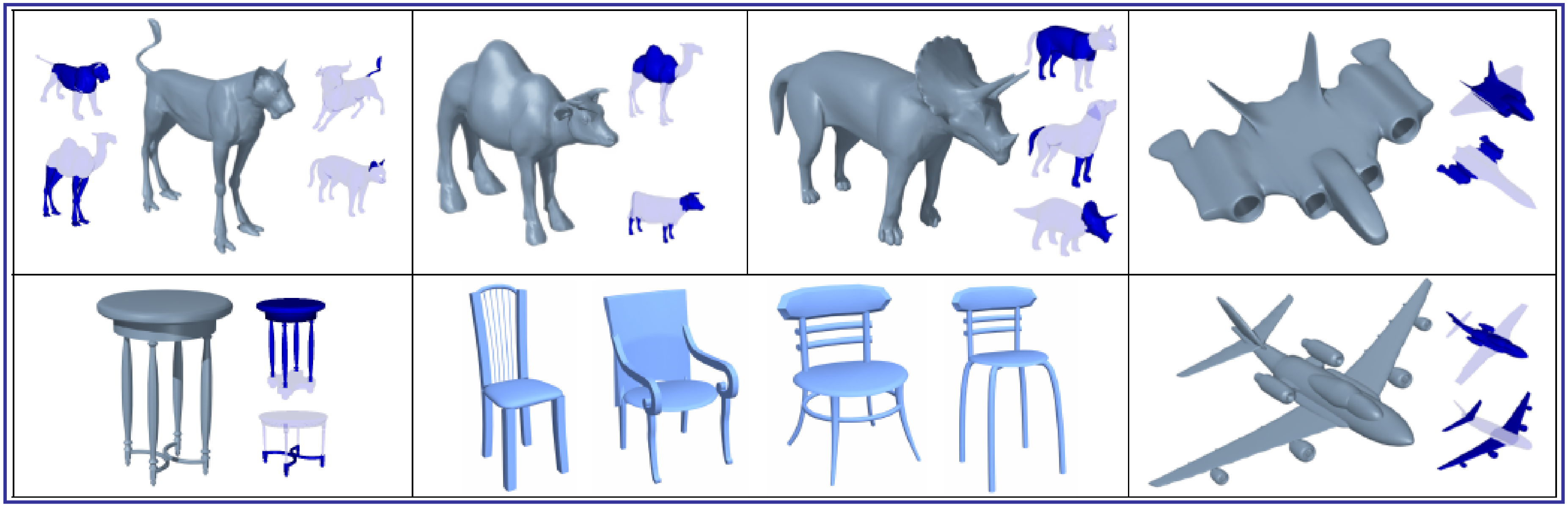
Shuffling - Results



All the models created in less than a minute

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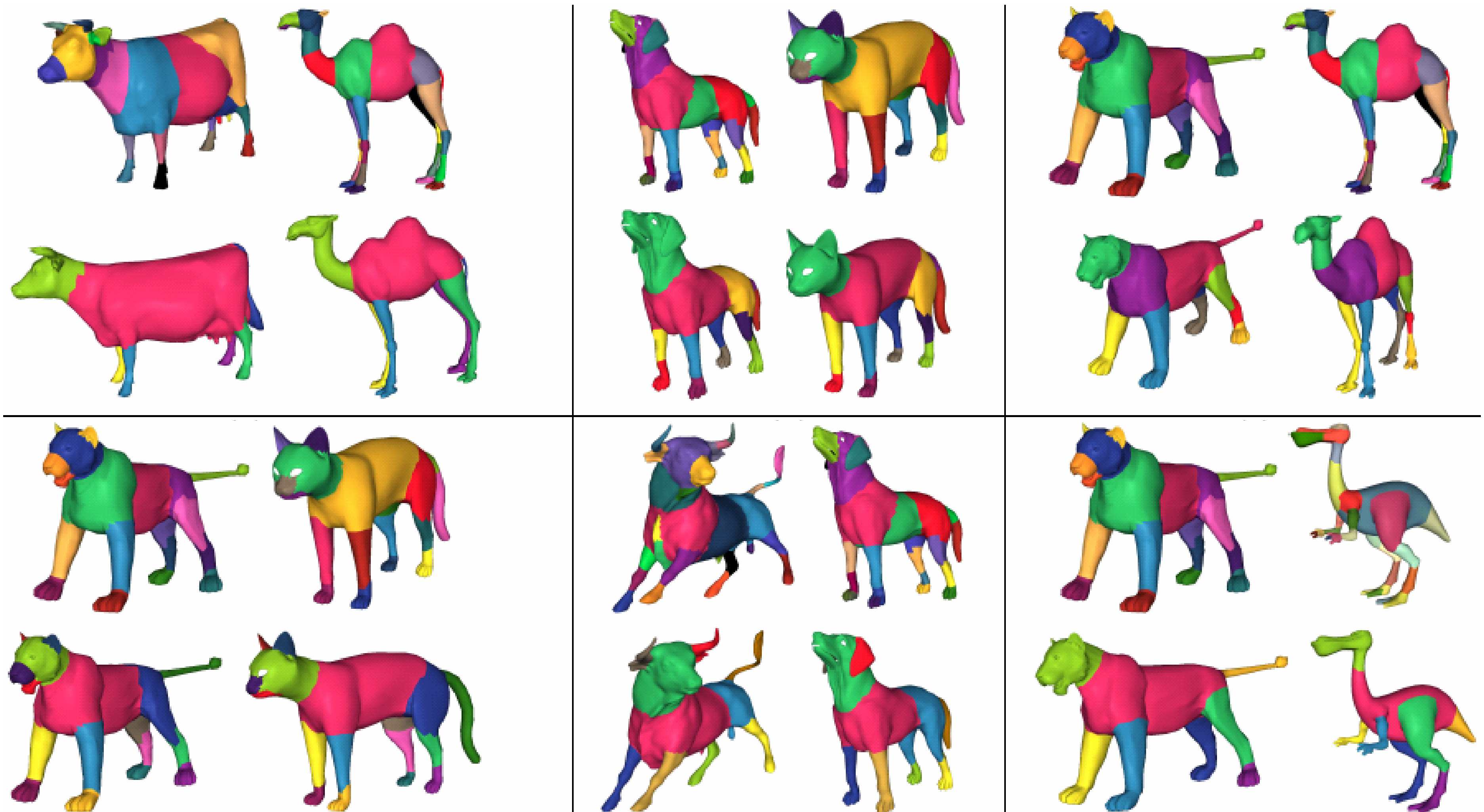
Results – Segmentation & Matching



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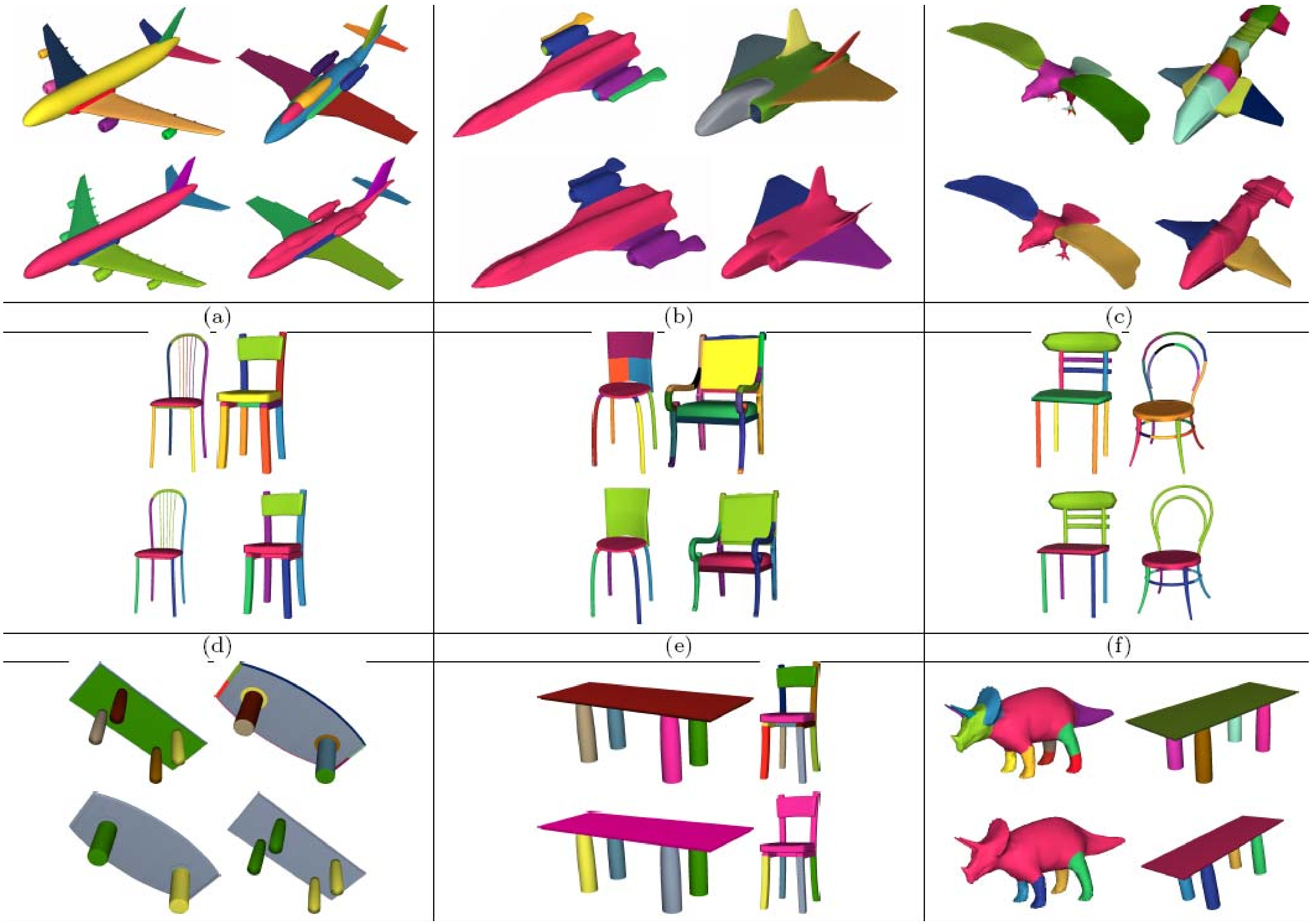
Results – Segmentation & Matching



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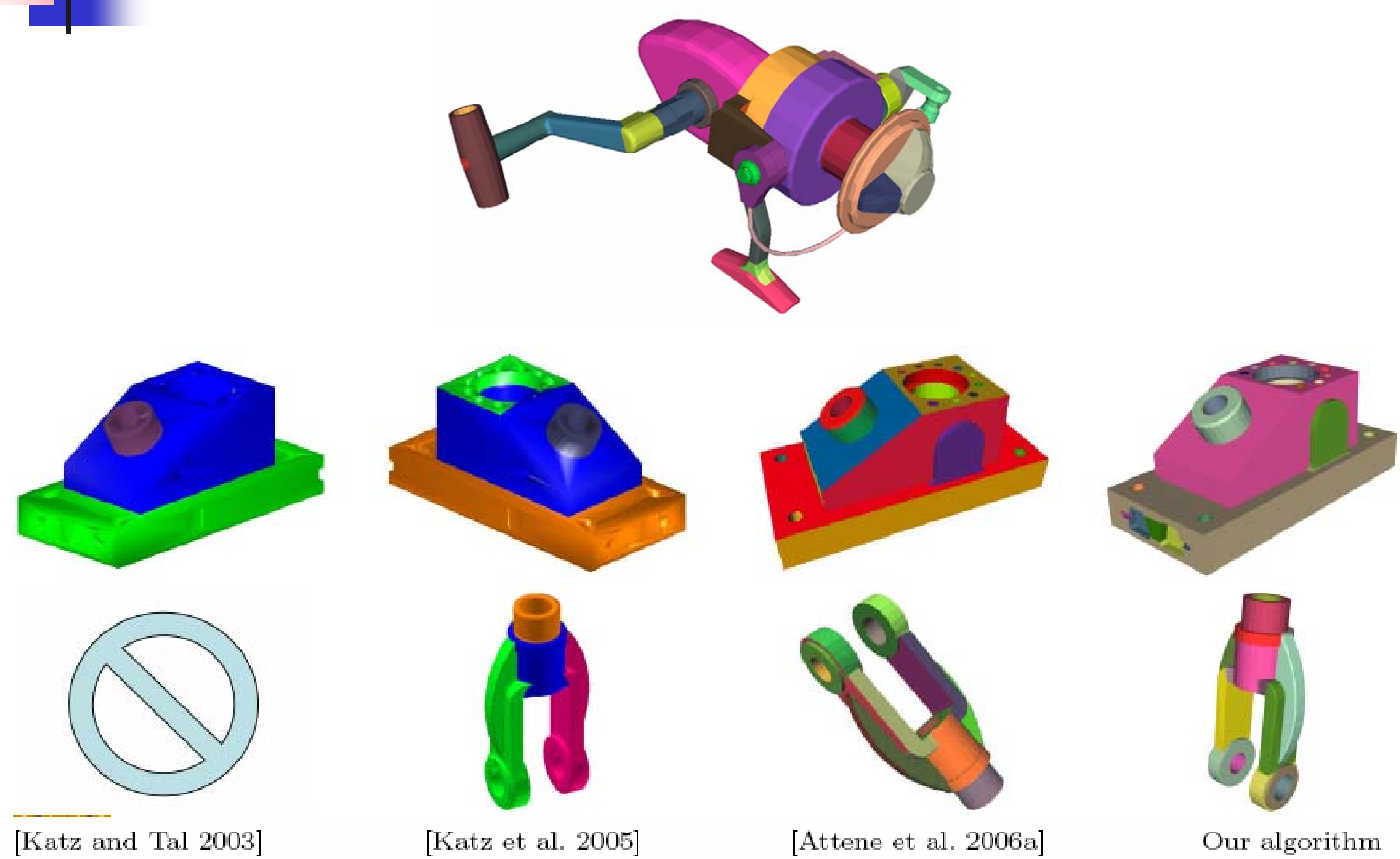
Segmentation (CAD) - Comparison



Comparison (natural models)

[Katz and Tal 2003] | [Katz et al. 2005] | [Attene et al. 2006a] | Our algorithm

Segmentation – Comparison

Comparison with [Lien'06]

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Summary

- New modeling system “for dummies”
  - Button click interface
- Robust segmentation algorithm
  - Outperforms existing methods
- Method for matching interchangeable parts
  - Computes complete correspondences
    - use grouping
  - Disambiguates symmetric parts
- No per-model parameters
- No topology restrictions

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Future/Issues

- Segmentation
  - Symmetry
  - Straighter boundaries
- Matching
  - Better understanding of correlation between human perception and geometric measures

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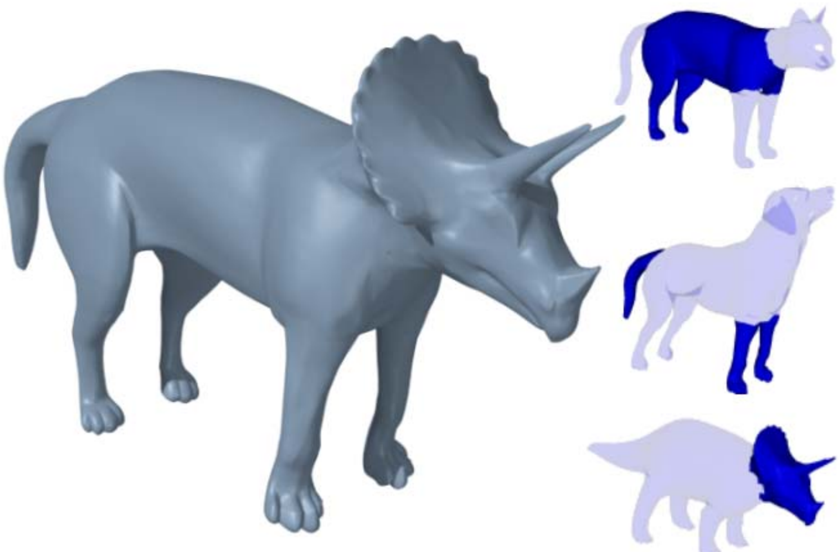
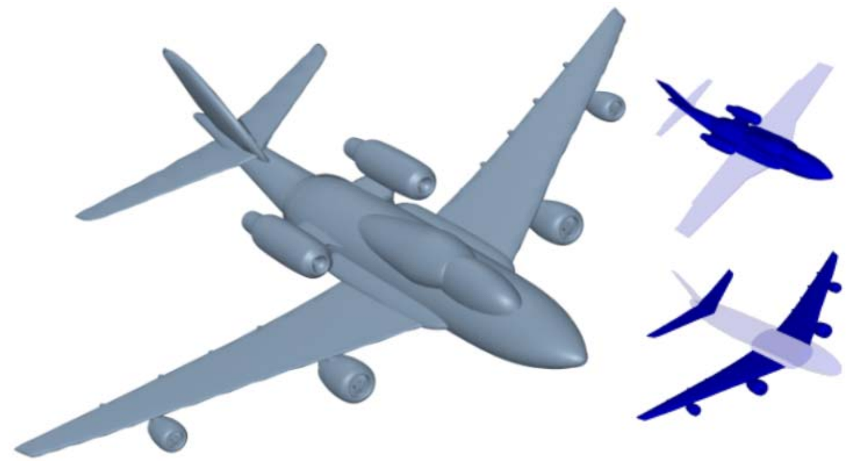
Thank You !!!



Questions?



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