3D Shape Analysis

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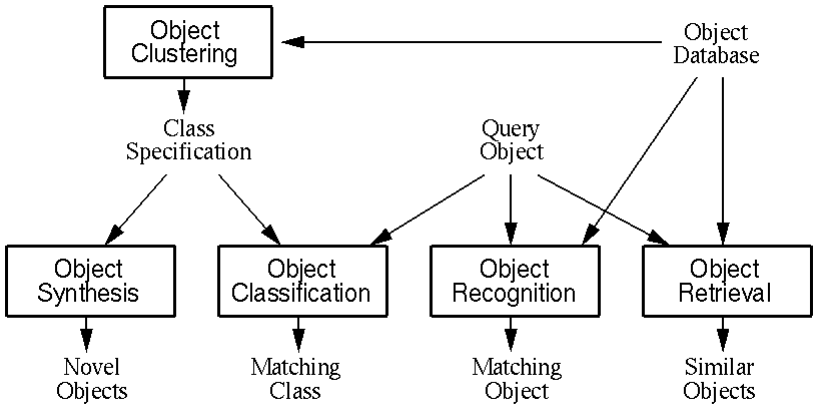
C0S 598B, Spring 2000

Goals

- Develop algorithms for analysis of 3D models
  - Reconstruction
  - Segmentation
  - Feature detection
  - Labeling
  - Matching
  - Classification
  - Retrieval
  - Recognition
  - Clustering

Blanz et al.

Analysis Applications



Key Ideas

- Similarity
  - What makes two objects nearly the same?
    - » Want quantitative metrics that tell us how similar two objects are
- Indexing
  - How can we preprocess database to make searches more efficient?
    - » Want concise, easily searchable representation for 3D objects
- Classes
  - What defines a group of objects?
    - » Want high-level representation for classes of objects

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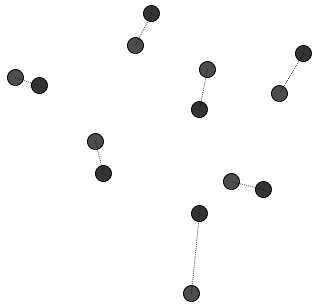
Similarity

- Intuitively, similarity function should:
  - Match our intuitive notion of shape resemblance
  - Be invariant under translation, rotation, and scale
  - Be easy to compute
- Ideally, it should be a metric:
  - Non-negative: $d(A,B) \geq 0$ for all A and B
  - Identity: $d(A,B) = 0$ if and only if A=B
  - Symmetry: $d(A,B) = d(B,A)$ for all A and B
  - Triangle inequality: $d(A,B) + d(B,C) \geq d(A,C)$

Example Similarity Metrics

- L_p norm:

$$d(A,B) = \left(\sum \|a_i - b_i\|^p\right)^{1/p}$$



- Hausdorff distance:

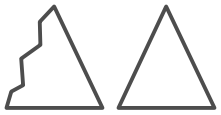
$$\tilde{d}(A,B) = \max_{a \in A} \min_{b \in B} \|a_i - b_i\|$$

$$d(A,B) = \max\left(\tilde{d}(A,B), \tilde{d}(B,A)\right)$$

- Others (Fréchet, etc.)

Similarity Metric Issues

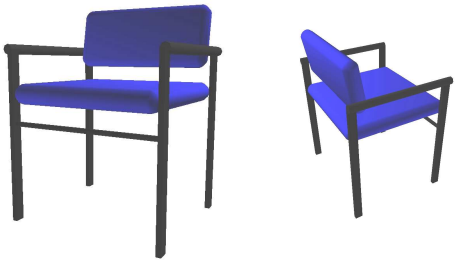
- Data representation
  - Point set, polygon, mesh, etc.?
- Independent of transformations
  - Translation, rotation, scale, affine, projective?
- Automatic feature correspondences
  - Match whole object or part of object?
- Intuitive distance measure
  - Exact match?
  - Sensitive to noise?



What are good similarity metrics for 3D models?

Using a Similarity Metric

- Good for pairwise comparisons
  - Check if two objects are the same
  - Find most similar object among a small set



Are these the same chair?

Using a Similarity Metric

- Bad for many comparisons
  - Search for object in large database = O(n)
  - Clustering objects into similarity classes = $O(n^2)$

Is this blue chair
in the database?

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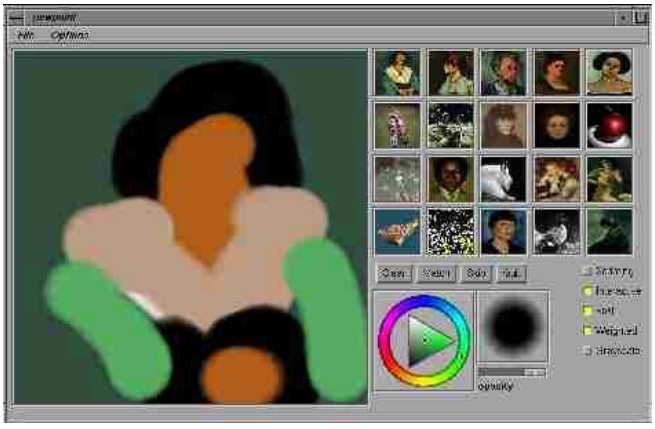
Signatures

- Concise, easily searchable representation for complex data

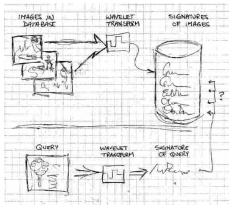


Jacobs, Finkelstein, & Salesin '95

Signatures

- Example: wavelet coefficients for images

16,000 coefficients | 400 coefficients | 100 coefficients | 20 coefficients

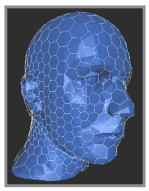


Signature

Jacobs, Finkelstein, & Salesin ‘95

Properties of “Good” Signatures?

- Canonical
- Specified concisely
- Computed efficiently
- Group similar objects and separate others
- Invariant under similarity transformations
- Insensitive to sampling or topology

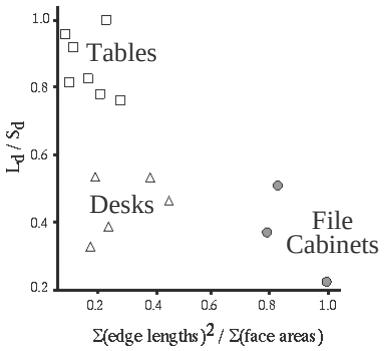


Kalnins ‘00

What are good signatures for 3D models?

Feature Vectors

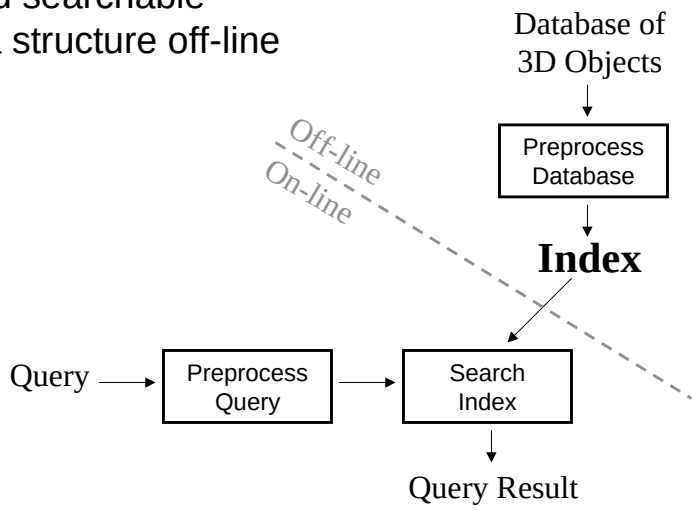
- Compute “features” of 3D model
- Map features into multi-dimensional space
- Similarity measure is distance in feature space



What are good features of 3D models?

Indexing

- Build searchable data structure off-line



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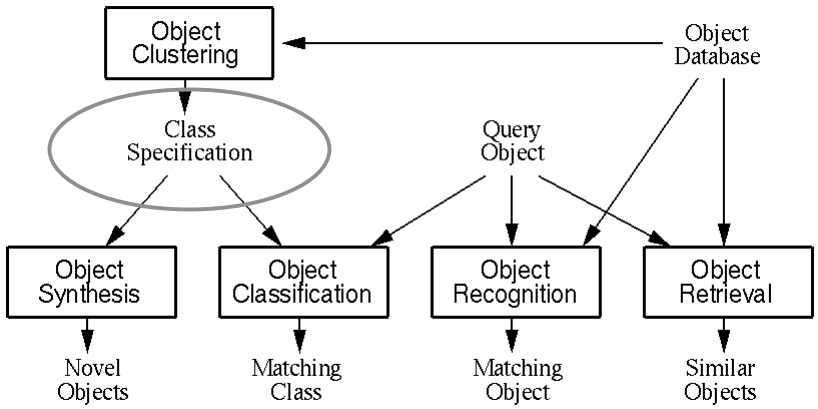
Class Specification



Class Specification

- Model-based?
  - Fit parameterized model to data
  - Quality of fit indicates likelihood of classification

Blanz et al.

Conclusion

- A lot of previous work
  - Computer vision
  - Computational geometry
  - Mechanical engineering
- Look at basics
  - 2D polygons
  - 3D meshes
  - 3D voxels
- Investigate higher-level analysis
  - Course projects