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Shape Matching Part 4: 3D Shape

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Slides of the SMI04 paper A Survey of Content Based 3D Shape Retrieval Methods

Overview

- Introduction
- Feature based methods
- Graph based methods
- Other methods
- Summary
- Further research

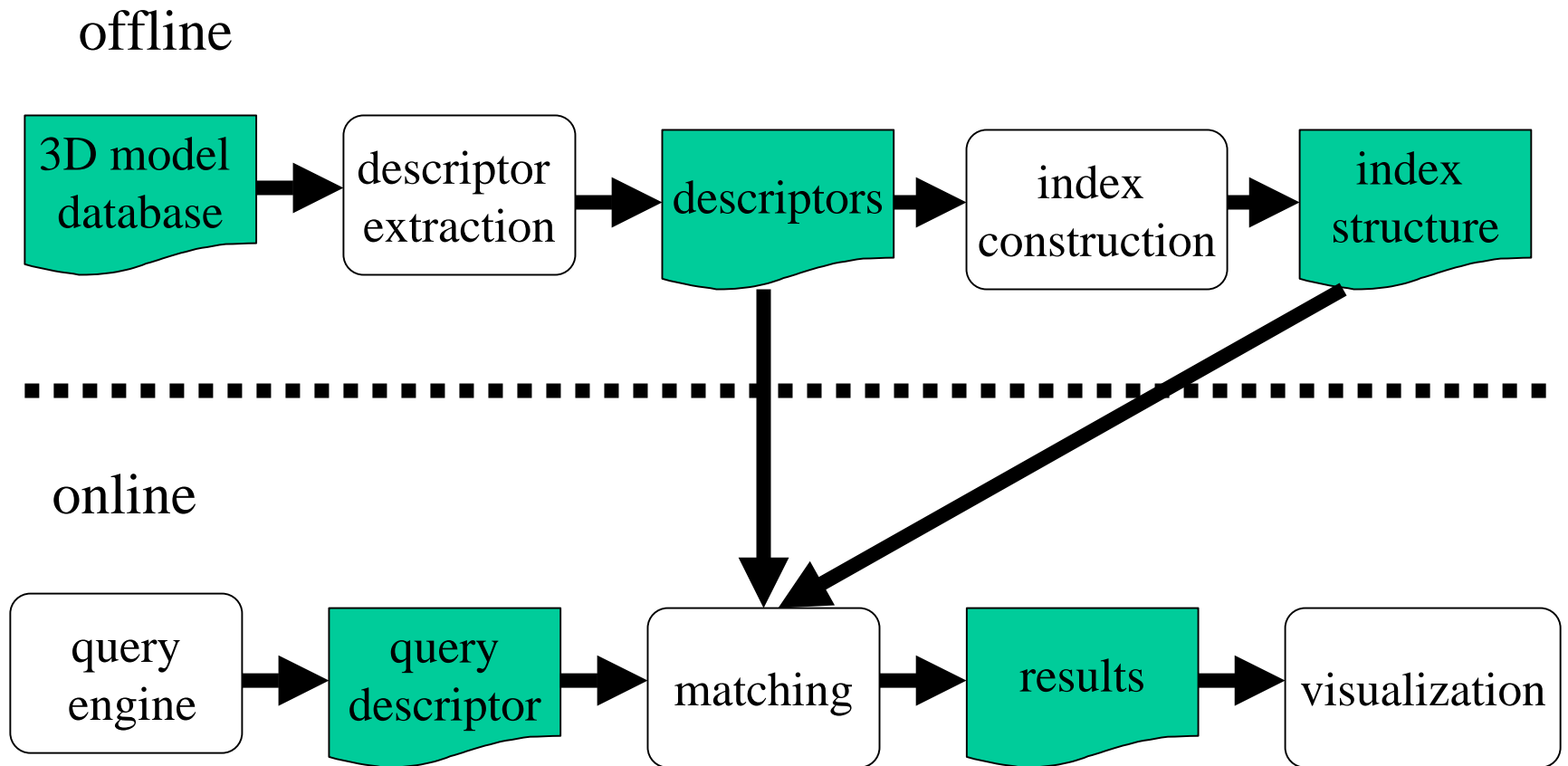
Why Content Based 3D Shape Retrieval ?

- Huge amount of 3D shape models available on the internet and domain-specific databases
- Creating a model from scratch takes much time
- Text-based searching does not work in many cases

Terminology

- Matching: given two 3D shapes A and B determine their similarity
⇒ dissimilarity measures
- Retrieval: given a query object and a database of models find the most similar ones
⇒ indexing, build a data structure to speed up the search

Conceptual framework for shape retrieval



Normalization

- Normalize for size by scaling.
- Normalize for translation by moving the center of mass of a model to the origin. (or use a translation-invariant descriptor)
- Normalize for rotation by aligning the principal axes of a model to the x -, y - and z -axes. (or use a rotation-invariant descriptor)

3D shape retrieval aspects

- Efficiency
- Discriminative power
- Partial matching
- Robustness

A taxonomy of shape matching methods

Methods based on feature descriptors	Global features	Global feature distribution
	Spatial map	
	Local features	
Methods based on graph descriptors	Model graph	
	Skeleton	
	Reeb graph	
Methods based on other descriptors	View based	
	Volumetric error	
	Weighted point set	
	Deformation	

Methods based on feature descriptors

Methods based on feature descriptors	Global features	Global feature distribution
	Spatial map	
	Local features	


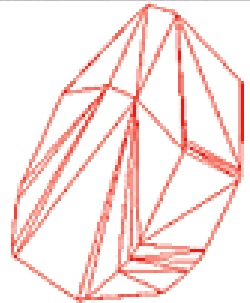
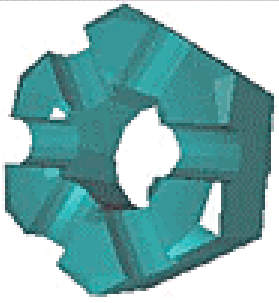
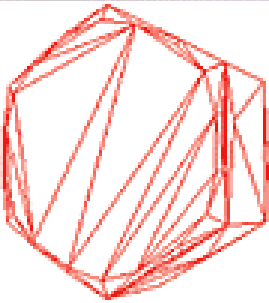
Global feature based methods

- Volume, area, Fourier coefficients
[Zhang and Chen, 2001] [Paquet et al., 2000]
- Hull based [Corney et al., 2002]
- Reflective symmetry [Kazhdan et al., 2004]



Global feature based methods

Example: Hull based descriptor [Convey et al.]

	Model 1	Model 1's Convex Hull	Model 2	Model 2's Convex Hull
Bounding-box aspect ratio				
Hull crumpliness	1.8840		2.3096	
Hull packing	0.8754		0.8803	
Hull compactness	0.2531		0.3297	
	194.6		205.59	

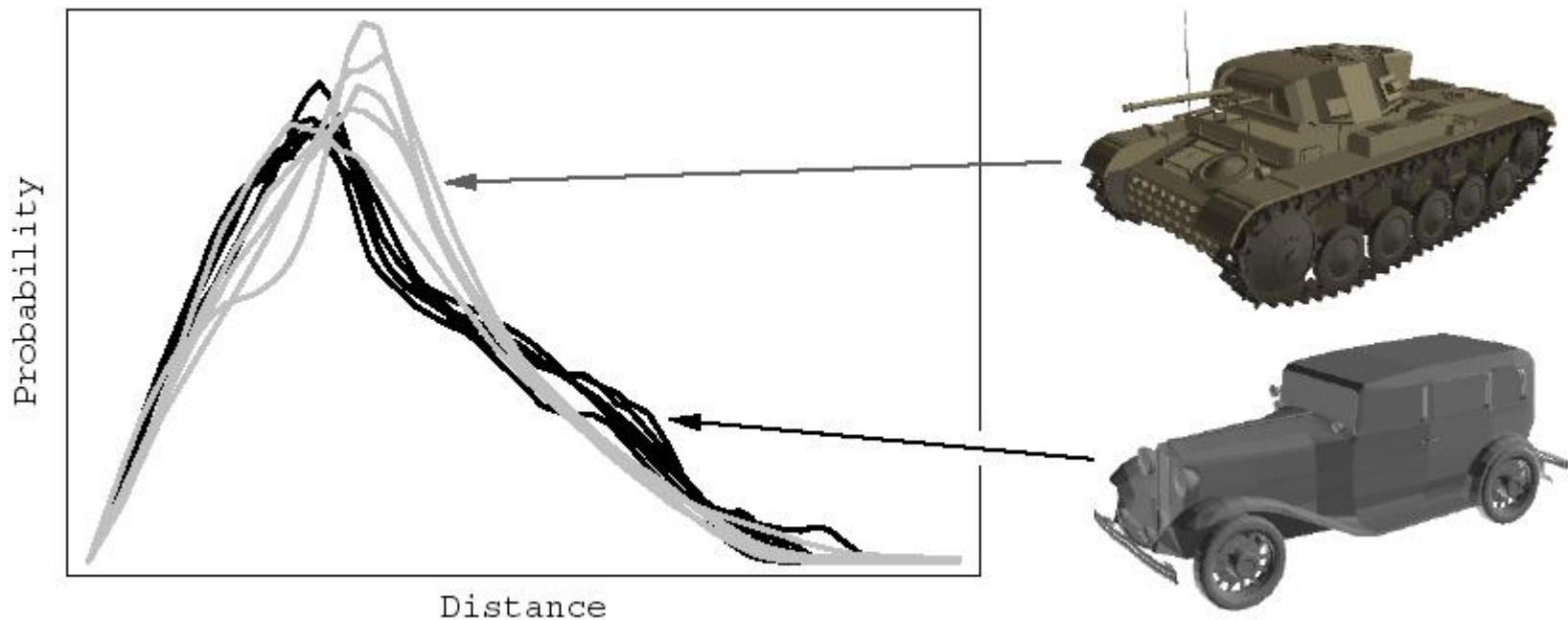
effective coarse filter

Global feature distribution based methods

- [Osada et al., 2002]
- Parameterization along principal axes [Ohbuchi et al., 2002]
- Volume models [Ip et al., 2002]
- Absolute angle-angle distance histogram [Ohbuchi et al., 2002]
- Alpha-shape [Ohbuchi et al., 2003]

Global feature distribution based methods

Example: Probability distribution of random surface points [Osada et al.]



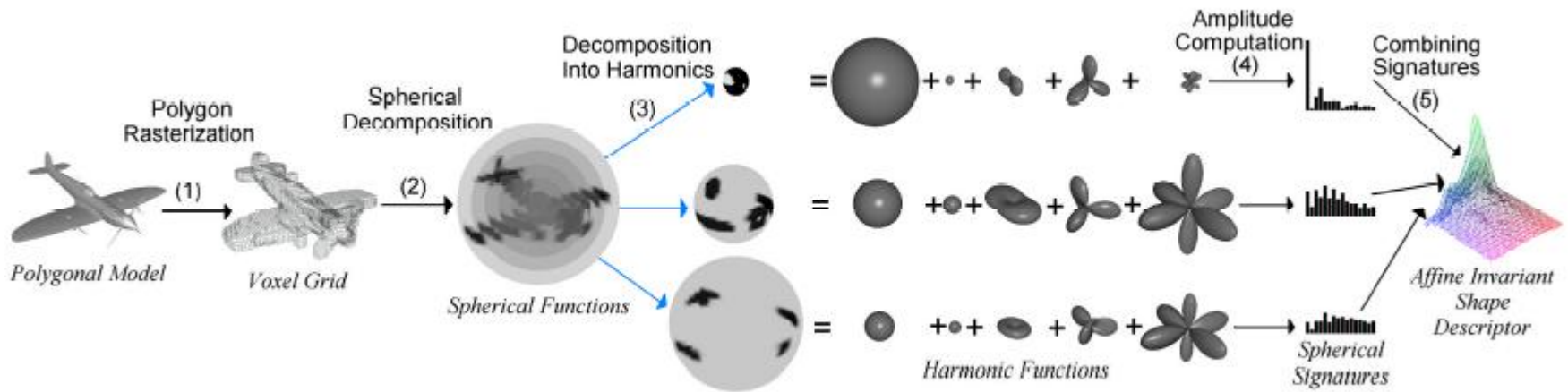
robust, easy to compute, less sensitive to details

Spatial map based methods

- Occupancy of grid cells [Ankerst et al., 1999]
- Spherical harmonics of extent function [Vranic et al., 2001]
- Spherical harmonics [Kazhdan et al., 2003]
- 3D Zernike descriptors [Novotni and Klein, 2003]
- Voxel based properties [Kriegel et al., 2003]

Spatial map based methods

Example: spherical harmonics [Kazhdan et al.]



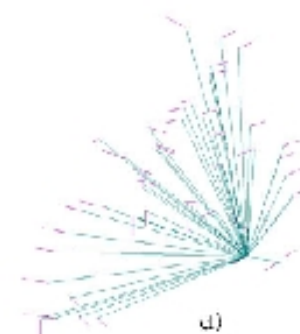
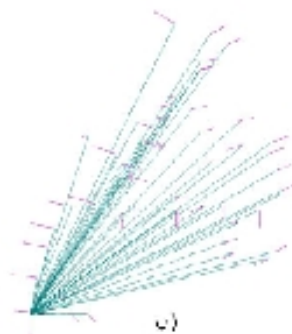
high discriminative power [Kazhdan et al., Vranic, Novotni and Klein]

Local feature based methods

- Surface curvature [Shum et al., 1996]
- Shape index [Zaharia and Preteux, 2001]
- Point signatures [Chua and Jarvis, 1997]
- Spin images [Johnson and Hebert, 1999]
- Shape contexts [Kriegel et al., 2003]

Local feature based methods

Example: shape contexts [Kriegel et al.]

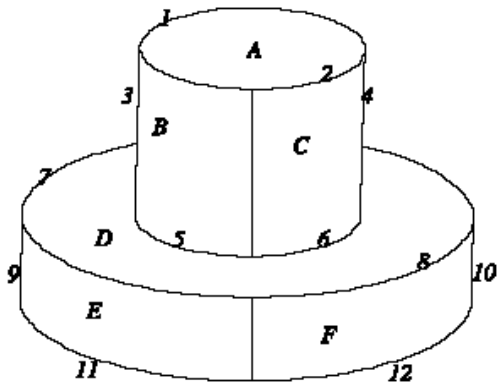


Less efficient, but more suitable for partial matching

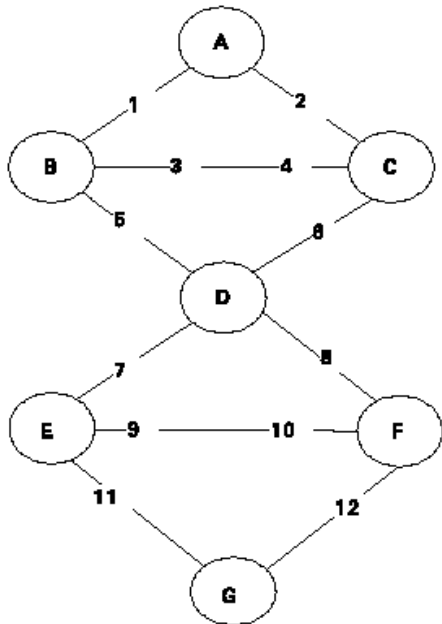
Methods based on graph descriptors

Methods based on graph descriptors	Model graph
	Skeleton
	Reeb graph

Model graph based methods

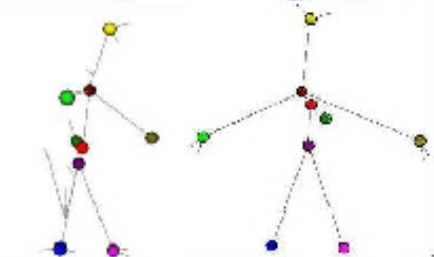
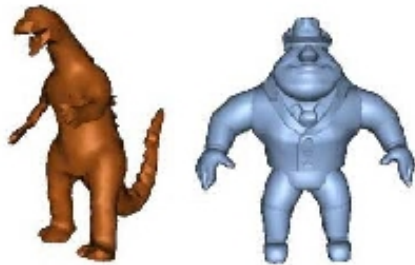
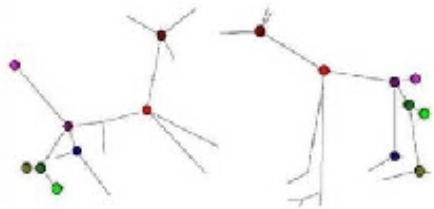


- Machining features [Elinson et al., 1997] [Cicirelli and Regli, 2001]
- Model signature graphs [McWerhter et al., 2001], [El-Mehalawi and Miller, 2003]



Relevant for CAD/CAM

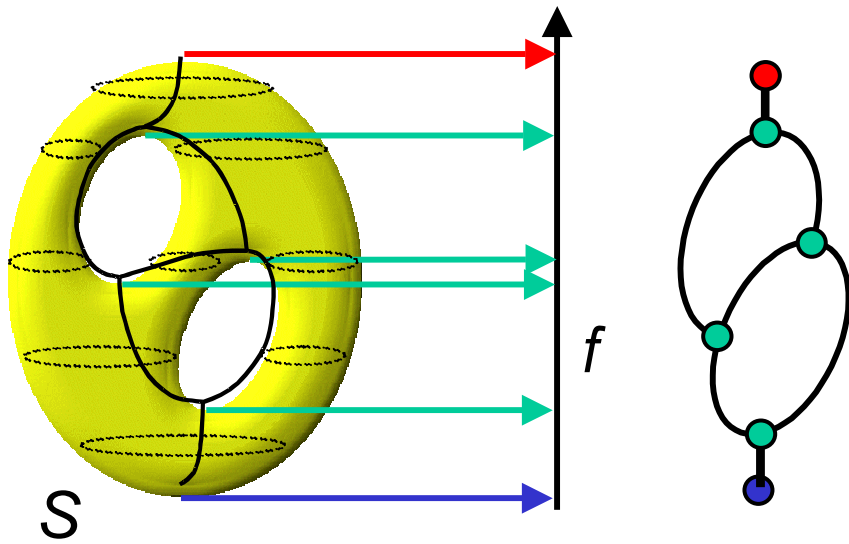
Skeletal graph based methods



- Approximate graph based matching [Sundar et al., 2003]
- Graph matching based on detecting subgraph isomorphism [Iyer et al., 2003]

Suited for articulated and partial matching

Reeb graph based methods



- Articulated models
[Hiliga et al., 2001]
- Solid models
[Bespalov et al., 2003]
- Augmented Reeb graphs
[Tung and Schmitt, 2004]

Suited for articulated
and partial matching

Methods based on other descriptors

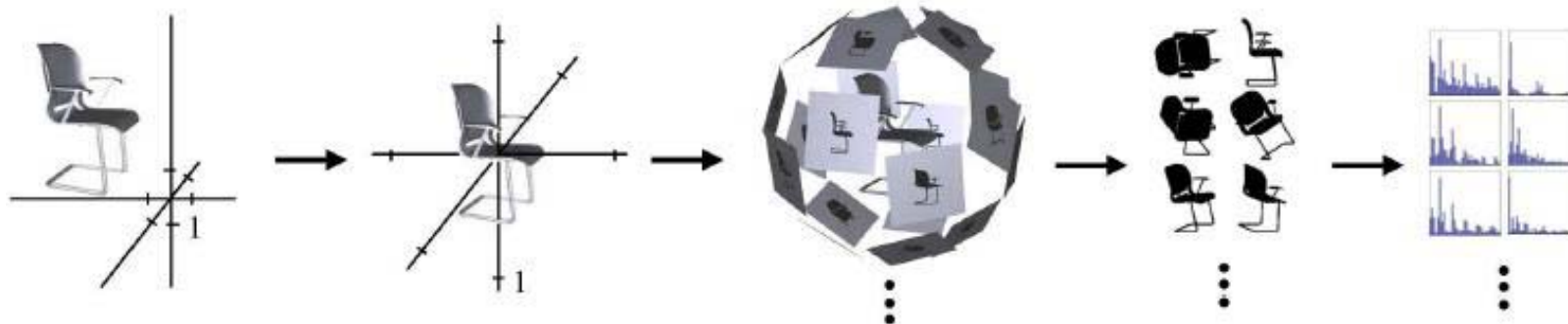
Methods based on other descriptors	View based
	Volumetric error
	Weighted point set
	Deformation

View based methods

- 2D query interface
[Loffler, 2000]
[Funkhouser et al., 2003]
- Shock matching
[Cyr and Kimia, 2001]
[Macrine et al., 2002]
- Lightfield descriptor [Chen et al., 2003]

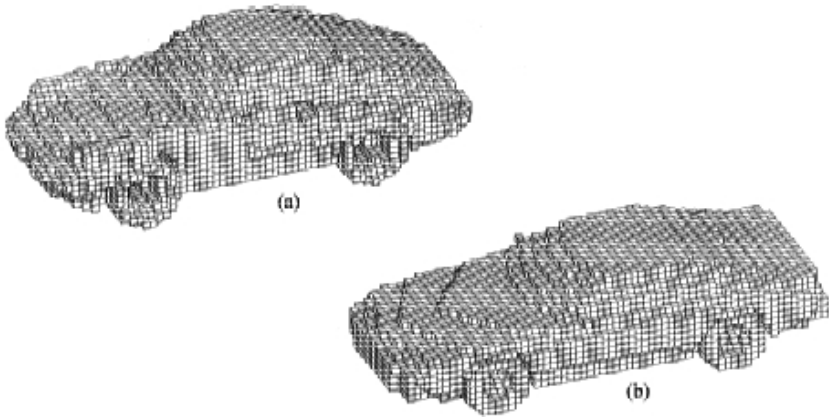
View based methods

Example: Light field descriptor [Chen et al.]



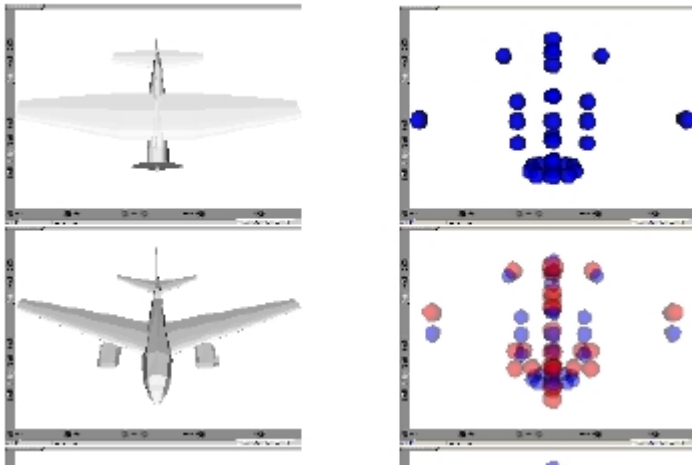
High discriminative power

Volumetric error based methods



- Offset hulls
[Novotni and Klein, 2001]
- Transportation distance
[Sanchez-Cruz and Bribiesca, 2003]

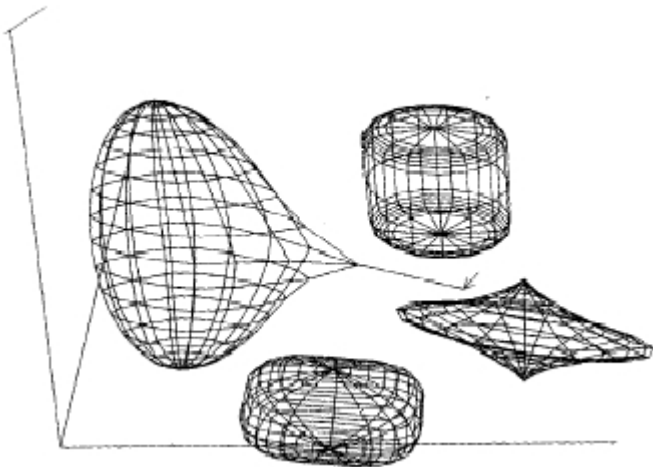
Weighted point set based methods



- Curvature values
[Tangelder and Veltkamp, 2003]
- Volume of components
et al., 2003]

[Dey

Deformation based methods



- Deformable superquadrics
[Terzopolous and Metaxas, 1991]
- Blending
[DeCarlo and Metaxas, 1998]

Summary

	Efficiency	Discriminative power	Partial matching
Global feature	fast	medium	no
Global feature distribution	fast	medium	no
Spatial map	fast	high	no
Local feature	medium	medium	yes
Model graph	medium	medium	yes
Skeleton	medium	medium	yes
Reeb graph	medium	medium	yes
View	medium	high	no
Volumetric error	fast	medium	no
Weighted point set	medium	medium	no
Deformation	medium	medium	no

Future work

- Comparison using benchmarks
- Efficient indexing
- Partial matching
- Combining shape matching methods