Retrieval by Content of 3D Objects

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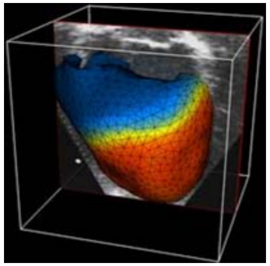
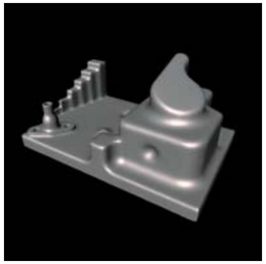
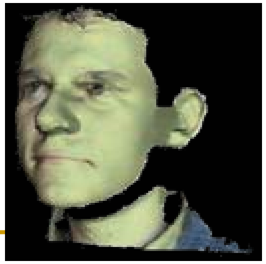
Motivation

- A growing interest is emerging in archives of 3D models:
  - Consolidated technologies for acquisition/creation of 3D models;
  - Increasing use of 3D data in real application contexts.

- Exploitation of 3D model archives relies on solutions enabling retrieval by content of 3D objects:
  - Analysis of clinical materials to support diagnosis.
  - Cataloguing of mechanical components.
  - Reuse of 3D models for multimedia production.
  - Support for new and unconventional ways of experiencing ancient and modern works of art .
  - Improved person identification (3D face models).
  - ....

Description

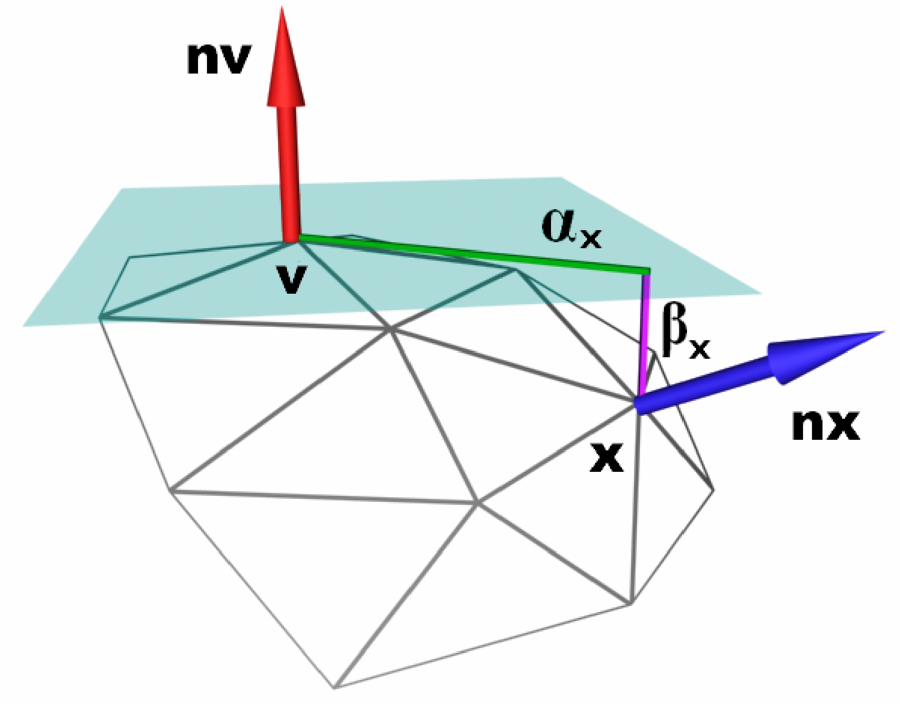
- A model is proposed to support effective description and retrieval by content of 3D objects based on properties of the object surface.

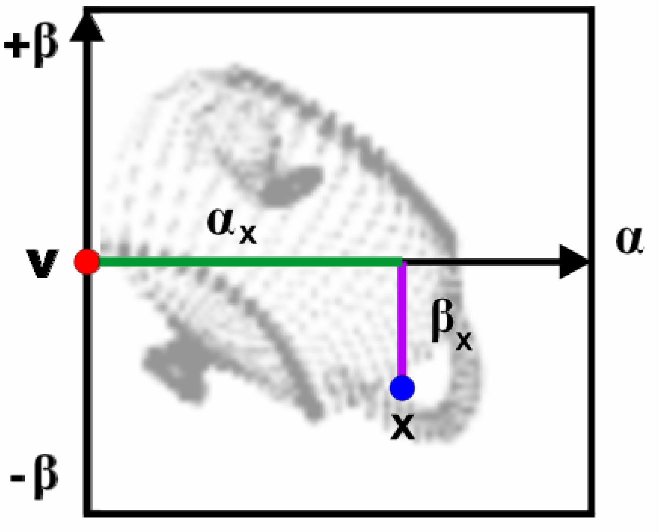
- The proposed solution relies on:

  - Representation of object surface through a polygonal mesh.
  - Preprocessing: Mesh simplification through Taubin filtering and reduction of vertices.
  - Use of Spin Images to extract content descriptors for 3D objects.
  - Definition of a metric to capture the similarity between 3D models.

Representation using Spin Images

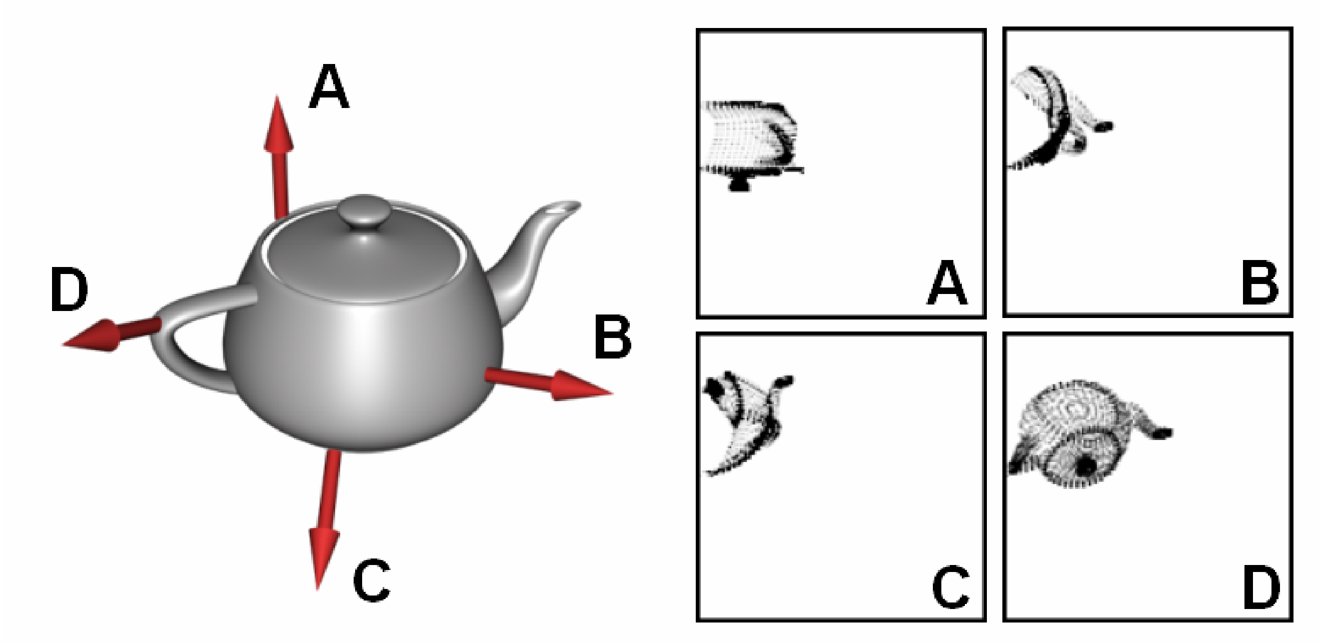
- Given an oriented point <v,n_v> on the object surface, a generic point x is mapped onto point (α_x, β_x) on the spin map:
  - α_x is the radial distance of x with respect to <v,n_v>
  - β_x is the elevation of x with respect to <v,n_v>.





Representation using Spin Images

- Given a reference vertex v, each point (α, β) on the spin map is obtained by counting the number of mesh vertices that map to (α, β).



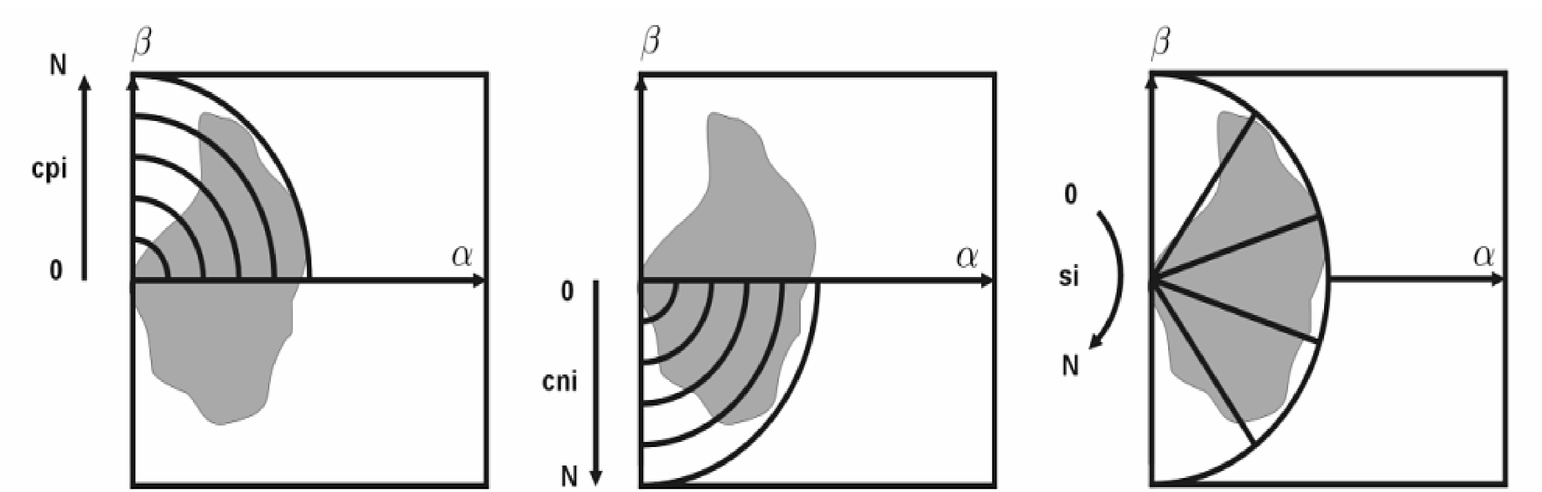
Representation using Spin Images

- One Spin Image is generated for each mesh vertex:
  - Data required to represent even simple objects (1000 vertices) can be unmanageable for the purpose of content based retrieval.

- Data reduction is accomplished through two steps:
  - Compact description of spin image content through *Spin Image Signature;*
  - Clustering of Spin Image Signatures.

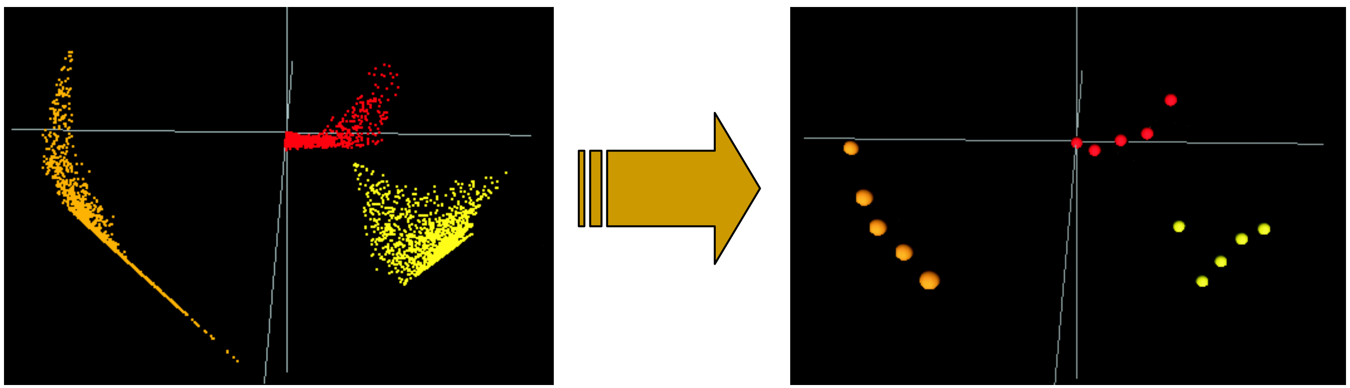
Spin image signatures

- A compact representation of spin image content is captured through shape matrix descriptors.
- We consider 18 different region masks: 6 sectors of positive circular crowns, 6 sectors of negative circular crowns and 6 circular sectors.
- For each region mask, the normalized integral of the spin image on that region is retained.

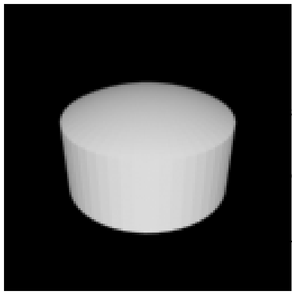


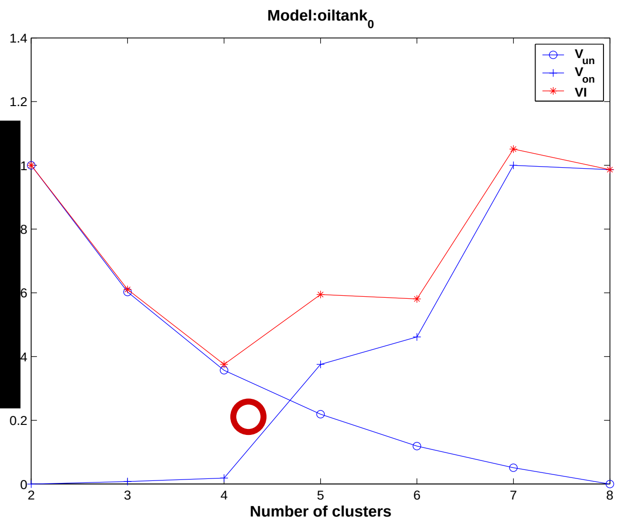
Clustering

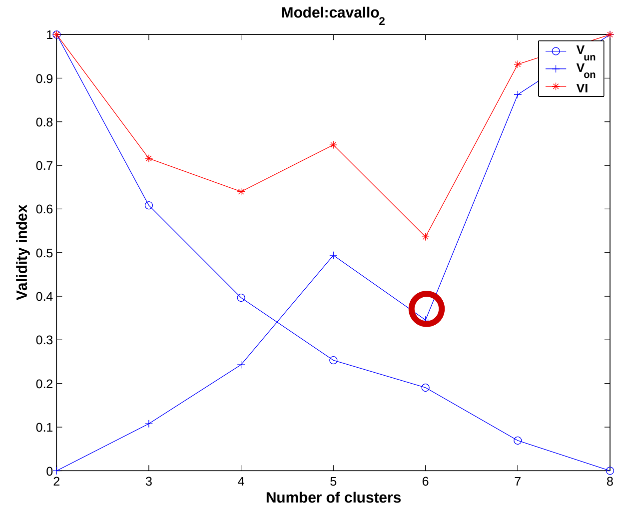
- 18 dimensional spin image signatures are clustered using *Fuzzy c-means*.

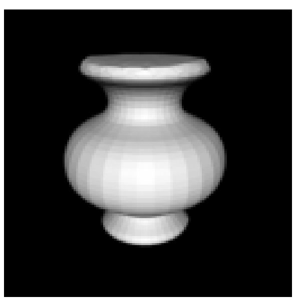


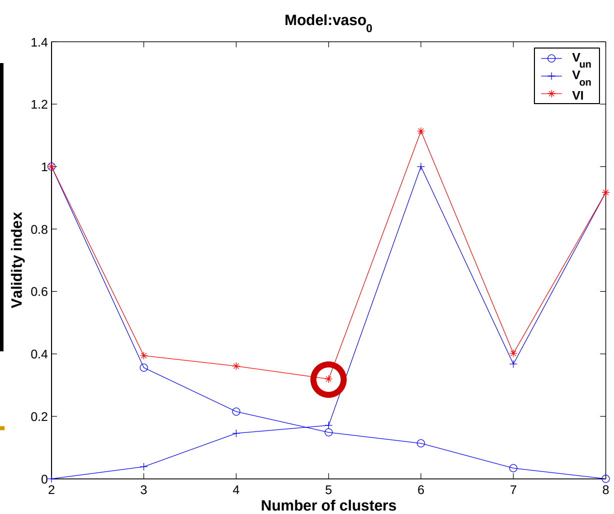
Clustering




Model:oiltank$_0$
V_{un}
V_{on}
VI
Number of clusters


Model:cavallo$_2$
V_{un}
V_{on}
VI
Validity index
Number of clusters




Model:vaso$_0$
V_{un}
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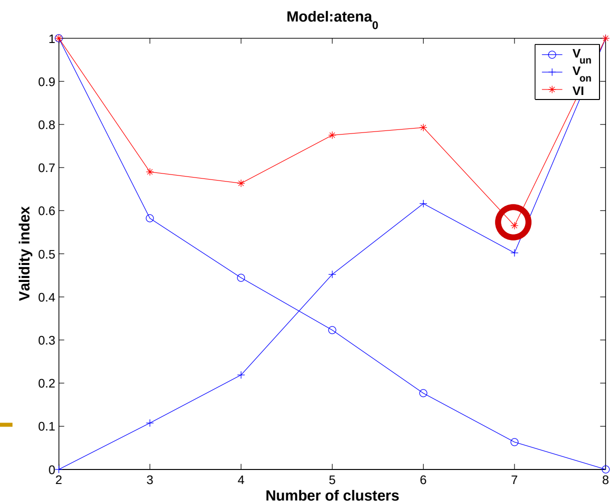
Validity index
Number of clusters


Model:atena$_0$
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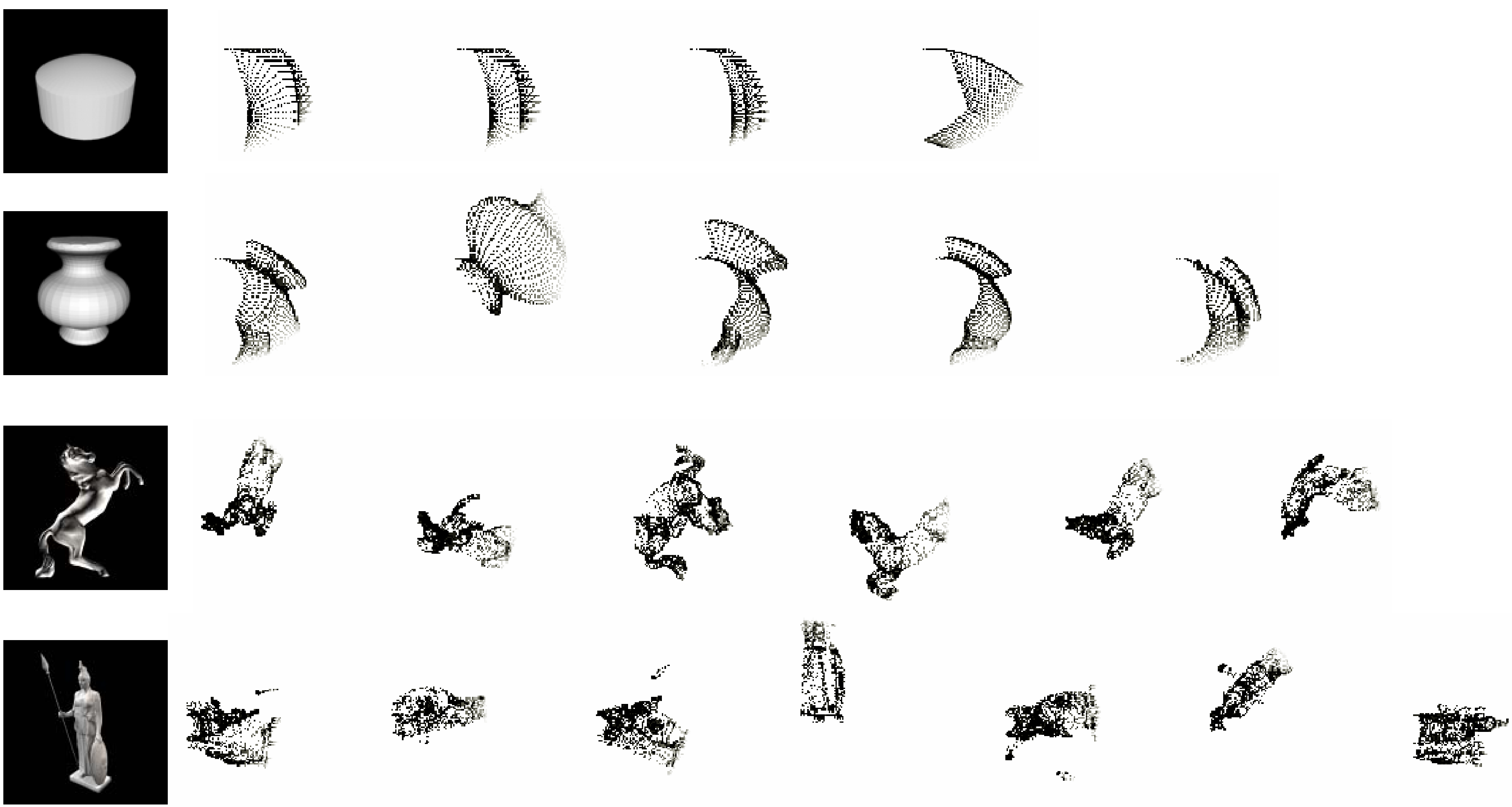
VI
Validity index
Number of clusters

Clustering

- Sample cluster centers:

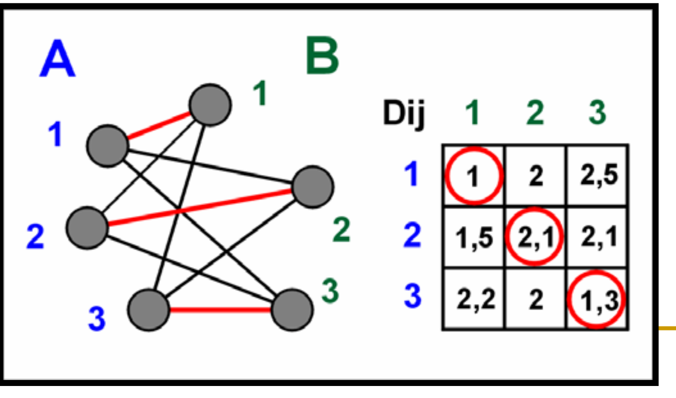


Similarity metric

- To compute the similarity between two 3D objects, the distance between their descriptor sets $D_1 = \{(v_i^{(1)}, p_i^{(1)})\}_{i=1}^{N}$ and $D_2 = \{(v_j^{(2)}, p_j^{(2)})\}_{j=1}^{M}$ is considered.

- This is defined as the permutation $\pi:\{1, . . . , N\} \rightarrow \{1, . . . , M\}$ that minimizes the sum of distances between elements of the two description sets, that is:

$$\Delta(D_1, D_2) = \min_{\pi} \left\{ \sum_{i=1}^{N} \delta\left[\left(v_i^{(1)}, p_i^{(1)}\right), \left(v_{\pi(i)}^{(2)}, p_{\pi(i)}^{(2)}\right)\right] \right\}$$



Experimental results

Comparison in terms of Precision/Recall of:

- Light Field
- Curvature histograms
- Shape functions
- Geometric moments
- Spin Images