Matching Geometric Models via Alignment

Alignment is the most common paradigm for matching 3D models to either 2D or 3D data. The steps are:

1. **hypothesize a correspondence** between a set of model points and a set of data points

2. From the correspondence **compute a transformation** from model to data

3. **Apply the transformation** to the model features to produce transformed features

4. **Compare** the transformed model features to the image features to verify or disprove the hypothesis

2D-3D Alignment

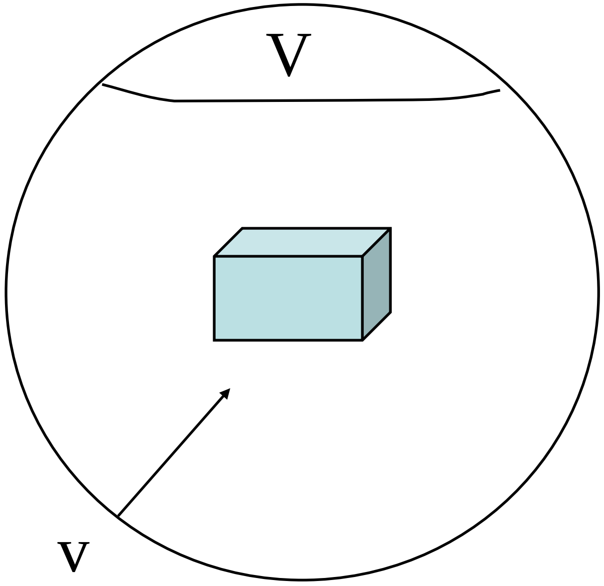
- single 2D images of the objects
- 3D object models
  - full 3D models, such as GC or SEV
  - view class models representing characteristic views of the objects

View Classes and Viewing Sphere

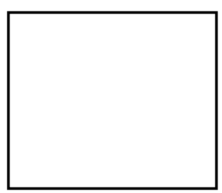
- The space of view points can be partitioned into a finite set of characteristic views.

- Each view class represents a set of view points that have something in common, such as:

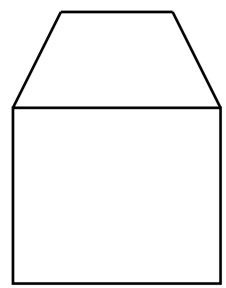
  1. same surfaces are visible
  2. same line segments are visible
  3. relational distance between pairs of them is small



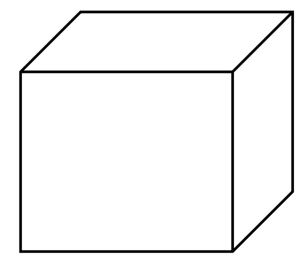
3 View Classes of a Cube



1 surface



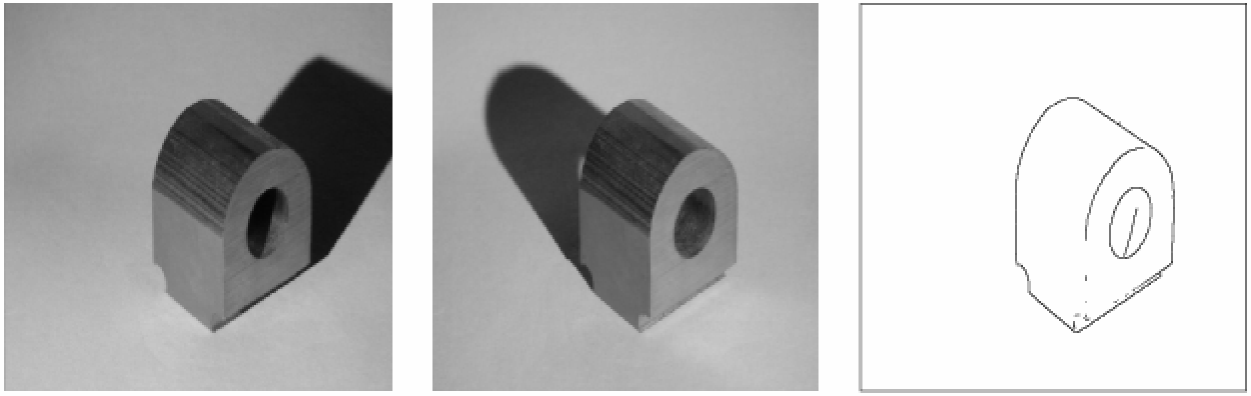
2 surfaces



3 surfaces

RIO: Relational Indexing for Object Recognition

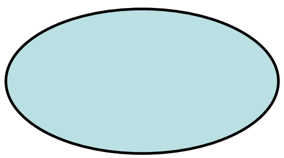
- RIO worked with industrial parts that could have
  - planar surfaces
  - cylindrical surfaces
  - threads



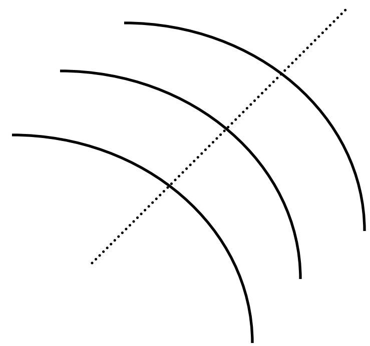
Object Representation in RIO

- 3D objects are represented by a 3D mesh and set of 2D view classes.
- Each view class is represented by an attributed graph whose nodes are features and whose attributed edges are relationships.
- For purposes of indexing, attributed graphs are stored as sets of 2-graphs, graphs with 2 nodes and 2 relationships.

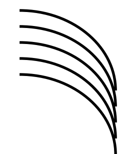
RIO Features



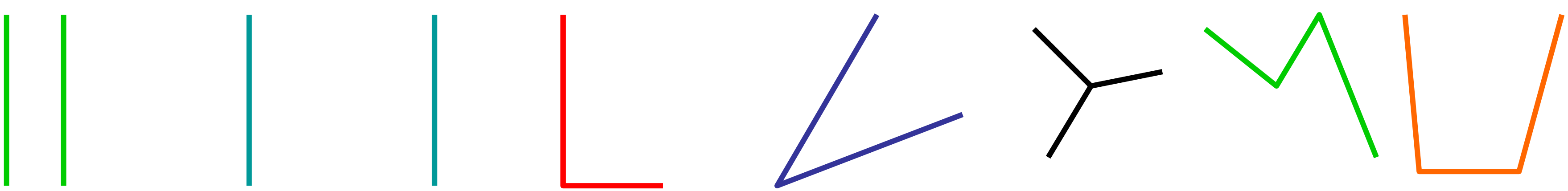
ellipses



coaxials



coaxials-multi

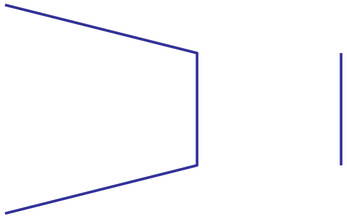


parallel lines
close and far

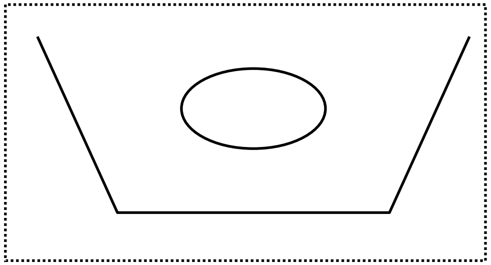
junctions
L V

triples
Y Z U

RIO Relationships

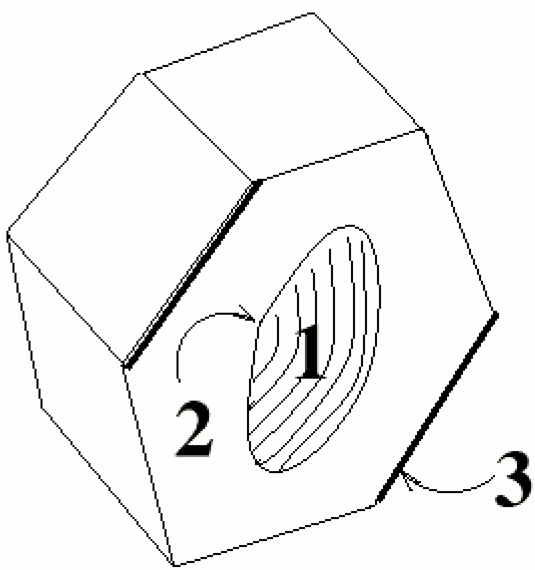


- share one arc
- share one line
- share two lines
- coaxial
- close at extremal points
- bounding box encloses / enclosed by



Hexnut Object

MODEL-VIEW

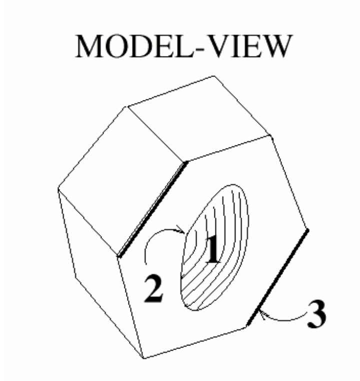


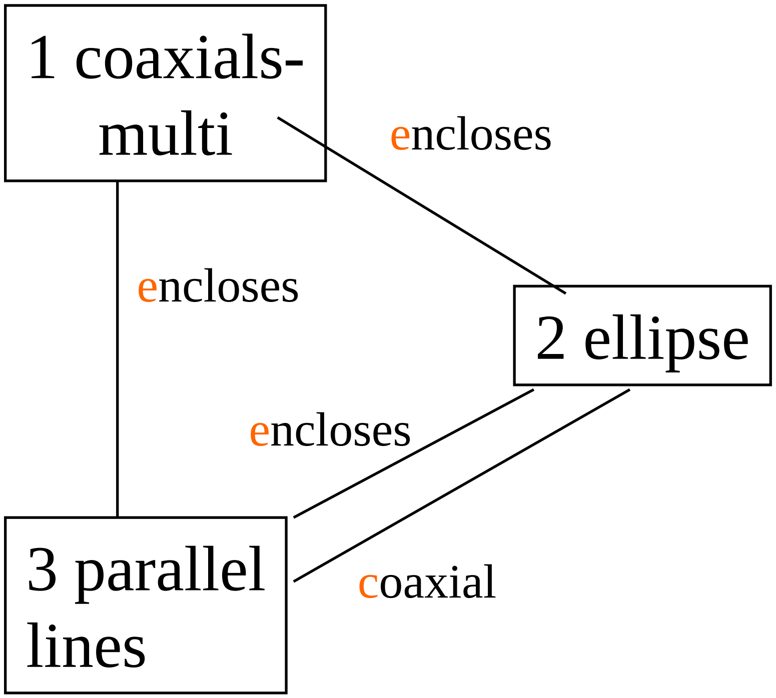
RELATIONS:
a: encloses
b: coaxial

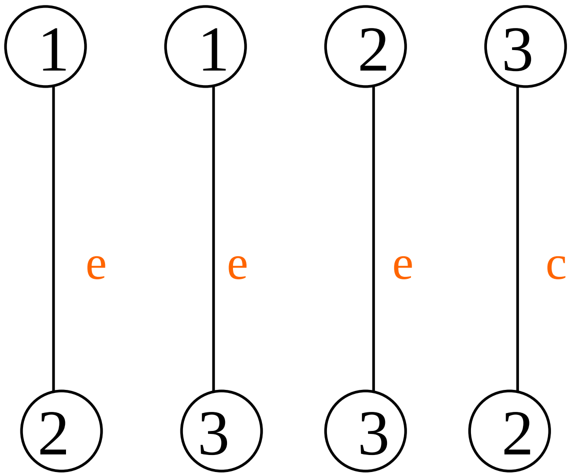
FEATURES:
1: coaxials-multi
2: ellipse
3: parallel lines

What other features and relationships can you find?

Graph and 2-Graph Representations







Relational Indexing for Recognition

Preprocessing (off-line) Phase

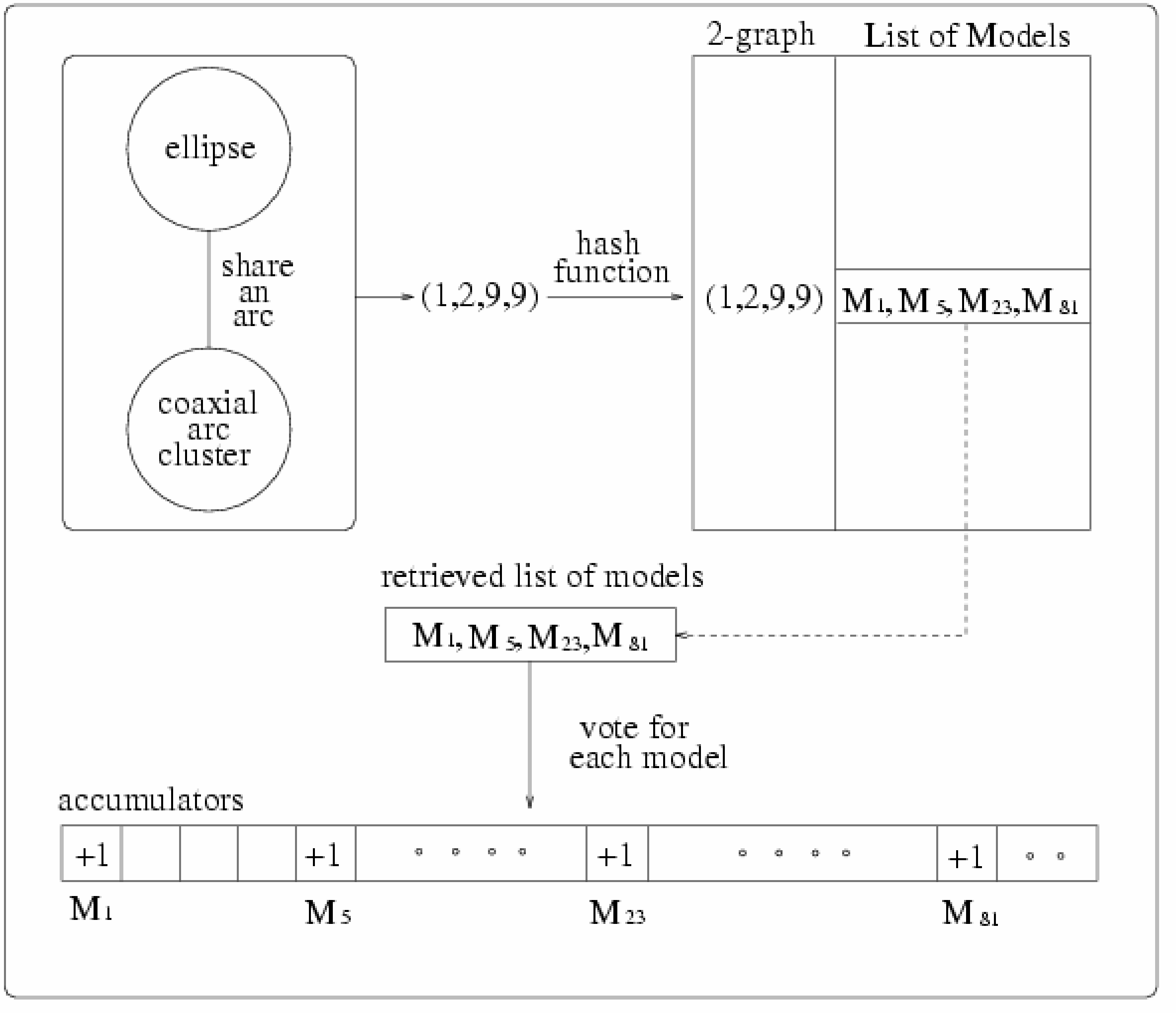
for each model view M_i in the database

- encode each 2-graph of M_i to produce an index
- store M_i and associated information in the indexed bin of a hash table H

Matching (on-line) phase

1. Construct a relational (2-graph) description D for the scene
2. For each 2-graph G of D
    - encode it, producing an index to access the hash table H
    - cast a vote for each M_i in the associated bin
3. Select the M_is with high votes as possible hypotheses
4. Verify or disprove via alignment, using the 3D meshes

The Voting Process



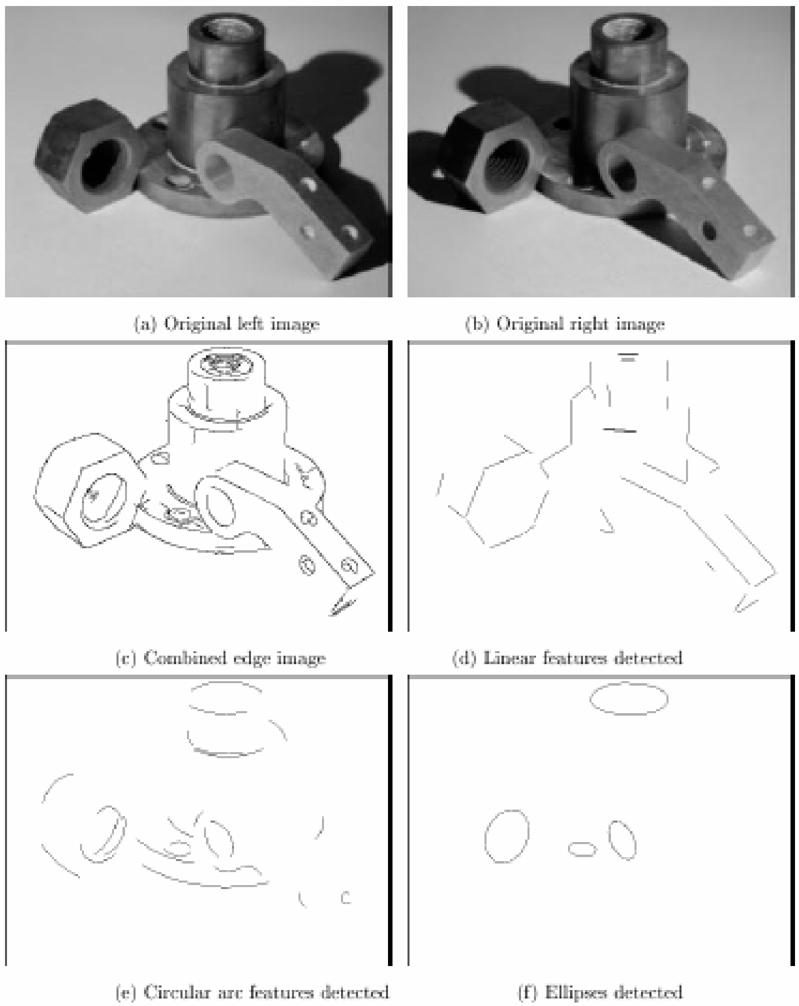
Verification

1. The matched features of the hypothesized object are used to determine its **pose**. Pose is computed from correspondences between 2D and 3D points, lines, and circles.

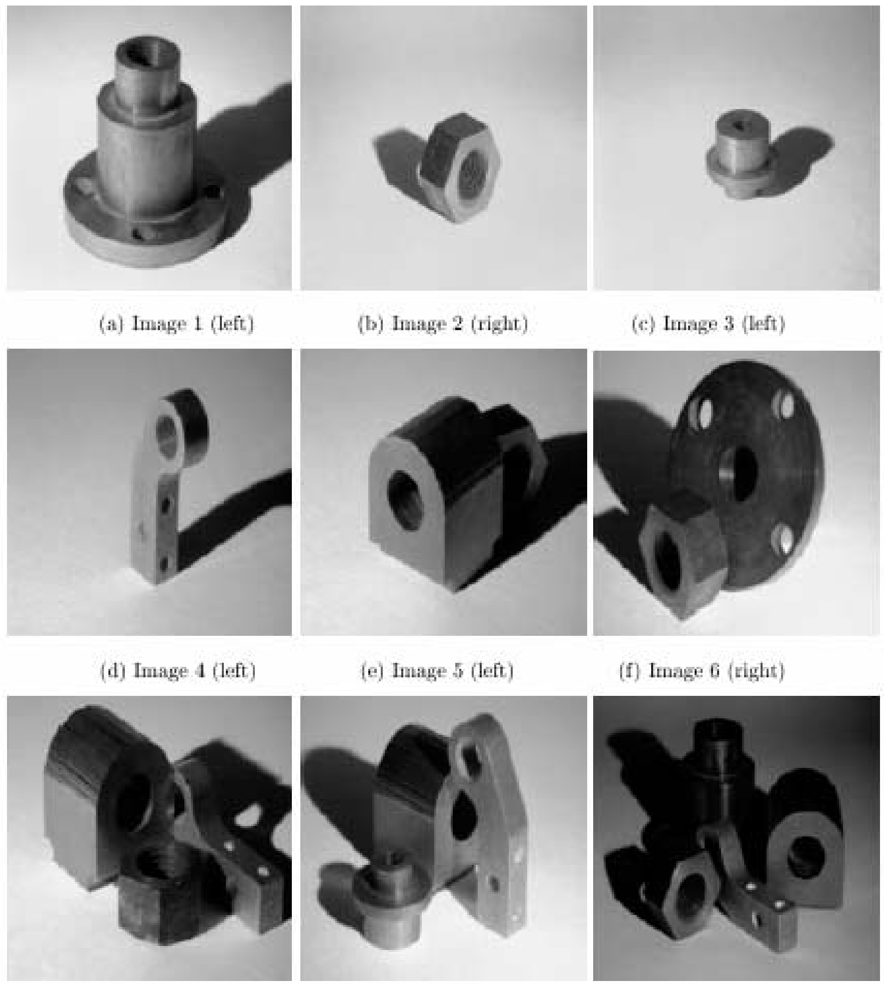
2. The **3D mesh** of the object is used to project all its features onto the image using perspective projection and hidden feature removal.

3. A **verification procedure** checks how well the object features line up with edges on the image, using a Hausdorf distance between expected and existing edges.

Feature Extraction



Some Test Scenes

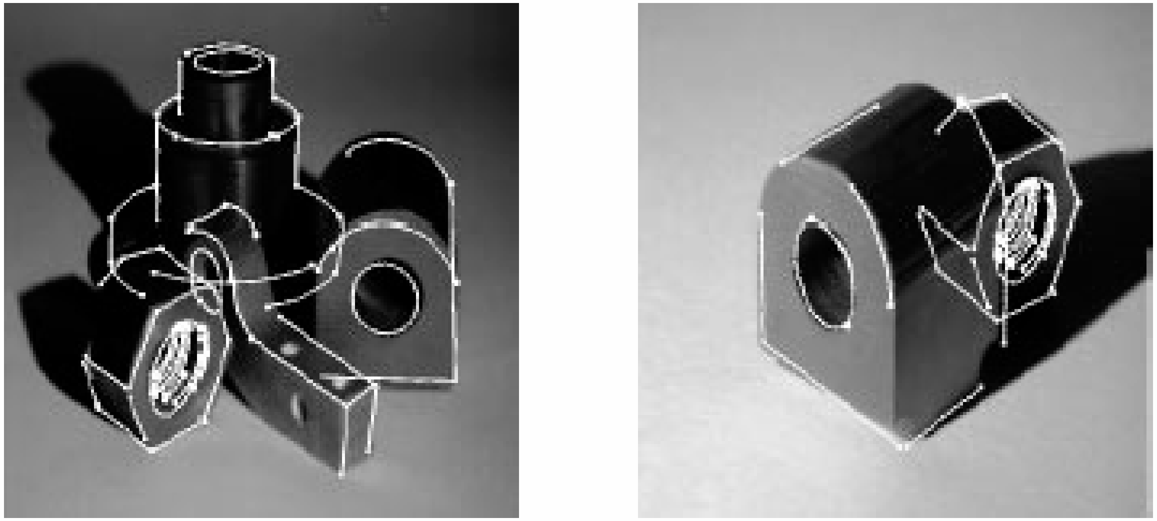


(a) Image 1 (left) (b) Image 2 (right) (c) Image 3 (left)

(d) Image 4 (left) (e) Image 5 (left) (f) Image 6 (right)

(g) Image 7 (left) (h) Image 8 (right) (i) Image 9 (right)

Sample Alignments
3D to 2D Perspective Projection



(a) (b)

RIO Verifications

incorrect hypothesis