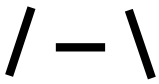
Relational Models

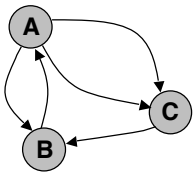
Relational models describe objects (object classes) based on parts (components) and relations between the parts

Relational model can be represented as structure with nodes and edges:

nodes: parts with properties

e.g.





edges: relations between parts

e.g.

- obtuse-angle
- 2cm-distance
- touches
- surrounds
- left-of
- after

1

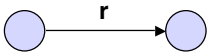
Relations between Components

unary relation: property

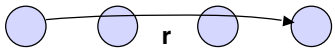
n-ary relation: relation, constraint

Graphical representation

binary relation:



n-ary relation:



"hypergraph"

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Relational Models for High-level Vision

Relational models describe objects (object classes) based on parts (components) and relations between the parts

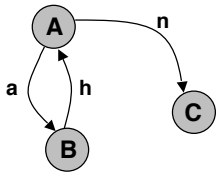
A relational model can be represented as a structure with nodes and edges:

Nodes: parts with properties

A	B	C
is-a person state running	is-a person state jumping	is-a ball colour black

Edges: relations between parts

- approaches A B
- nearby B A
- holds B C



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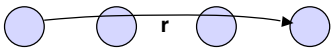
Representing N-ary Relations

Awkward graphical representation:

"hypergraph"



Reification:

(BETWEEN A B C) ⇒
(INSTANCE BETW1 BETWEEN)
(BETWEEN-ARG1 BETW1 A)
(BETWEEN-ARG2 BETW1 B)
(BETWEEN-ARG3 BETW1 C)

(OVERTAKE VEH1 VEH2 23 46) ⇒
(INSTANCE OT1 OVERTAKE)
(OVERTAKER OT1 VEH1)
(OVERTAKEE OT1 VEH2)
(TBEG OT1 23)
(TEND OT1 42)

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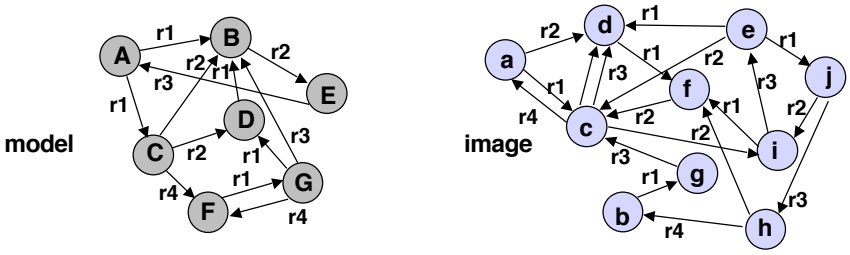
Recognition by Relational Matching

Principle:

- **construct relational model(s) for object class(es)**
- **construct relational image description**
- **compute morphism (best partial match) between image and model(s)**



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Compatibility of Relational Structures

Different from graphs, nodes and edges of relational structures may represent entities with rich distinctive descriptions.

Example: **nodes = image regions with diverse properties**
edges = spatial relations

1. Compatibility of nodes

An image node is compatible with a model node, if the properties of the nodes match.

2. Compatibility of edges

An image edge is compatible with a model edge, if the edge types match.

3. Compatibility of structures

A relational image description B is compatible with a relational model M, if there exists a bijective mapping of nodes of a partial structure B´of B onto nodes of a partial structure M´of M such that

- corresponding nodes and edges are compatible
- M is described by M´ with sufficient completeness

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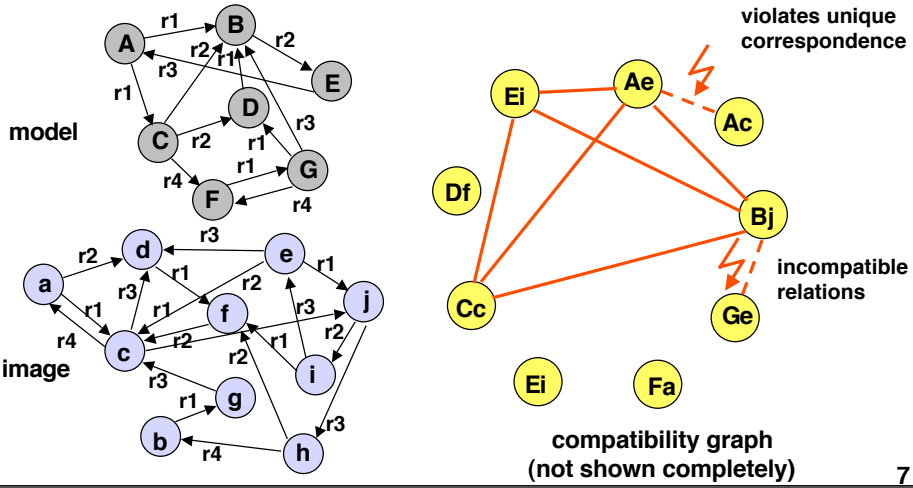
Relational Matching Using a Compatibility Graph

nodes of compatibility graph = pairs with compatible properties
edges of compatibility graph = compatible pairs
cliques in compatibility graph = compatible partial structures



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Finding Maximal Cliques

Algorithms are available in the literature, e.g.

Bron & Kerbusch, Finding all Cliques of an Undirected Graph, Communications of the ACM, Vol. 16, Nr. 9, S. 575 - 577, 1973.

- Complexity is exponential relative to number of nodes of compatibility graph
- Efficient (suboptimal) solutions based on heuristic search

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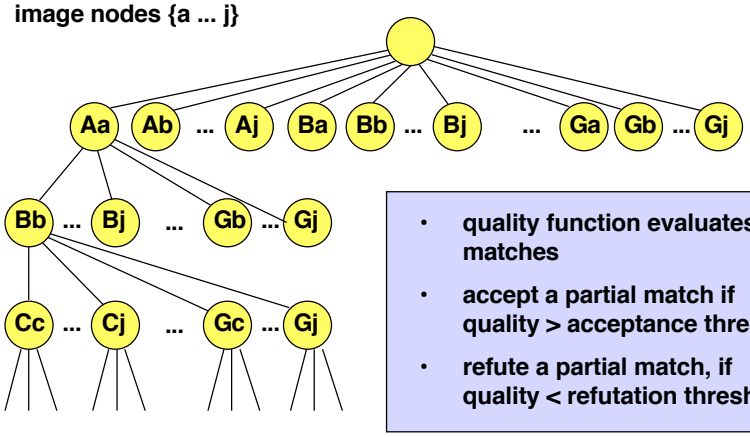
Relational Matching with Heuristic Search

Stepwise correspondence search between model nodes {A ... G} and image nodes {a ... j}



- quality function evaluates partial matches
- accept a partial match if quality > acceptance threshold
- refute a partial match, if quality < refutation threshold

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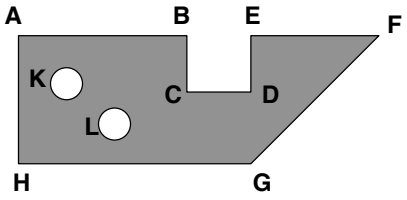
Example of a Relational Model for Object Recognition (1)

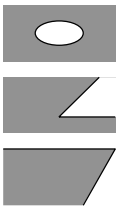
(Bolles & Cain 83)

shape to be recognized:



primitive descriptive elements (nodes)

properties



hole	t	type T1
	f	area
	a	axes relation
interior corner	t	type T2
	w	angle
exterior corner	t	type T3
	w	angle

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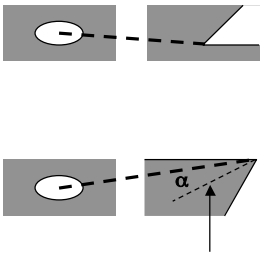
Example of a Relational Model for Object Recognition (2)

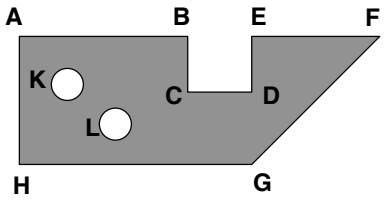
relations between primitive descriptive elements (edges)



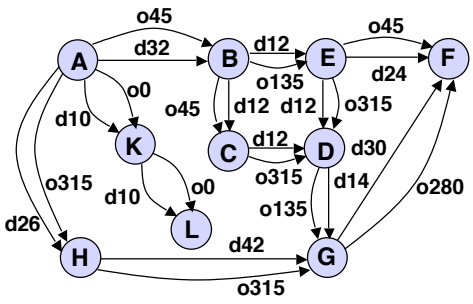
...
d10 distance 10 ± 1
d12 distance 12 ± 1
d14 distance 14 ± 1
...

...
o10 orientation 10 ± 5
o20 orientation 20 ± 5
o30 orientation 30 ± 5
...

Example of a Relational Model for Object Recognition (3)



A t T3 w 90	E t T3 w 90	K t T1 f 48 a 1
B t T3 w 90	F t T3 w 45	K t T1 f 48 a 1
C t T2 w 90	G t T3 w 135	
D t T2 w 90	H t T3 w 90	

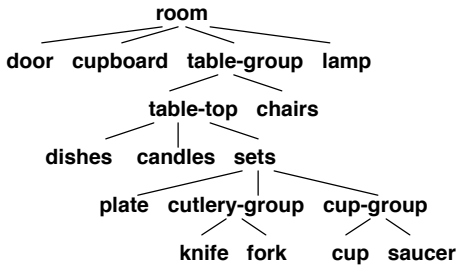


(not all edges are shown)

Shortcomings of Relational Matching for High-level Scene Interpretation (1)

Natural hierarchical structures and groupings are not well represented by flat relational structures

Example: Modelling dining room views



In a model, repeated identical structures should only be represented once

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Shortcomings of Relational Matching for High-level Scene Interpretation (2)

Node compatibility is not clearly defined

Edge compatibility is not clearly defined

Logical relations between different node descriptions and different edge labels must be clarified

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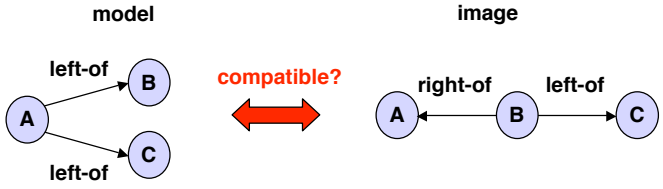
Shortcomings of Relational Matching for High-level Scene Interpretation (3)

Implicit information is not considered



Reasoning may be required to determine compatibility

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How Useful is Relational Matching?

- **relational structure captures basic high-level notions**
- **graceful degradation w.r.t. completeness and degree of match**
- **well-understood computional procedures**
  - finding maximal cliques in compatibility graphs
  - heuristic search
  - constraint satisfaction
  - neural network implementations
- **improvement by hierarchical matching**

- **multi-level aggregate structure required**
- **differentiated compatibility measure required**
  - fuzziness
  - compatibilty vs. consistency
  - probabilities
- **reasoning about temporal, spatial, physical relations**
- **uncertainty management required**

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