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Chapter 10
Knowledge Representation

KR

• Last 3 chapters: syntax, semantics, and proof theory of propositional and first-order logic
• Chapter 10: what content to put into an agent’s KB
• How to represent knowledge of the world
Natural Kinds

- Some categories have strict definitions (triangles, squares, etc)
- Natural kinds don’t
- Define a cup (distinguishing it from bowls, mugs, glasses, etc)
- Bachelor: is the Pope a bachelor?
- But logical treatment can be useful (can extend with typicality, uncertainty, fuzziness)

Upper Ontologies

- An ontology is similar to a dictionary but with greater detail and structure
- Ontology: concepts, relations, axioms that formalize a field of interest
- Upper ontology: only concepts that are meta, generic, abstract; cover a broad range of domain areas
- IEEE Standard Upper Ontology Working Group
- Semantic Web paper, CYC project
Lower concepts are specializations of their parents

**Categories and Objects**

- I want to marry a Swedish woman
  - Category of Swedish woman?
  - A particular woman who is Swedish?
- Choices for representing categories: predicates or reified objects
- basketball(b) vs member(b, basketballs)
- Let's go with the reified version...
Facts about categories and objects in FOL

• An object is a member of a category
• A category is a subclass of another category
• All members of a category have some properties (necessary properties)
• Members of a category can be recognized by some properties (sufficient properties)
• A category as a whole has some properties

Note: idealization of real categories

Other Relationships

• disjoint (no members in common)
• exhaustive decomposition of a category (all members are in at least one of the sets)
• Partition: disjoint, exhaustive decomposition
• Examples in lecture
Composite Objects

- partof(england, europe)
- All X,Y,Z ((partof(X,Y) ^ partof(Y,Z)) → partof(X,Z))
- Heavy(bunchOf({apple1, apple2, apple3}))
- Before continuing: inspiration for creative reification!
- From Through the Looking Glass

Measures

- Diameter(basketball12) = inches(9.5)
- All XY ((member(X, dimestore) ^ sells(X,Y)) → cost(Y) = $(1))
- member(db1, dollarbills)
- member(db2, dollarbills)
- denomination(db1) = $(1)
- denomination(db2) = $(1)

There are multiple dollar bills, but a single $(1)
Ordinal Comparisons

- But often scales are not so precisely defined
- Often, ordinal comparisons among members of categories are useful
- `member(p1, poems) ^ member(p2, poems) ^ beauty(p1) < beauty(p2)`
  
  We don't have to say p1 has beauty 54.321

Qualitative physics: reasoning about physical systems without detailed equations and numerical simulations.

Actions, Situations, Events, Time, Situation Calculus

- Next time
Inheritance

- If a property is true of a class, it is true of all subclasses of that class
- If a property is true of a class, it is true of all objects that are members of that class
- (If a property is true of a class, it is true of all objects that are members of subclasses of that class)
- There are exceptions

Semantic Networks

- Example of a special purpose KR
- Graphical aids for visualizing the knowledge base
- Efficient algorithms for inferring properties based on category membership
- Often, correspond to a subset of first-order logic
- Many variants
- All distinguish among individual objects, categories of objects and relations among objects
Example

• See figure 10.9
• Specify what edges and nodes mean
• In Figure 10.9, individuals and categories look the same
•memberOf(indiv,category)
•sisterOf(indiv,indiv)
•subsetOf(category,category)
•hasMother(indiv,indiv)

Semantic Networks

• How about hasMother(persons,femalePersons)?
• Nope: hasMother is a relation between individuals
• cat1- label cat2 means:
• all X X in cat1 → [all Y label(X,Y) → Y in cat2]
  (So, this does not say that each person has a mother)
Semantic Networks

- cat \( \rightarrow \) label \( \rightarrow \) value
- All \( X \) in cat \( \rightarrow \) label(\( X \), value)

Inheritance

- Inheritance is efficient and convenient
- Trace paths from individuals to categories, inheriting properties as you go
- In Figure 10.9, how many legs does John have? Most specific (nearest) information wins
  - Default information
Semantic Networks

• In a semantic network, only binary relations are possible
• A richer representation is possible by reifying propositions and events
• This forces creation of a rich ontology of reified concepts; many current ideas originated in semantic network systems

Description Logics

• Evolved from semantic networks
  - *Old:* emphasis on taxonomic structure
  - *New:* formalization, emphasis on tractability
Mental Events

- Beliefs, Knowledge, Desires, Intentions..
- Useful in NLP, Planning