Biological Vision and Applications
Module 07-01: Knowledge Representation

Hiranmay Ghosh

Knowledge required for visual interpretation

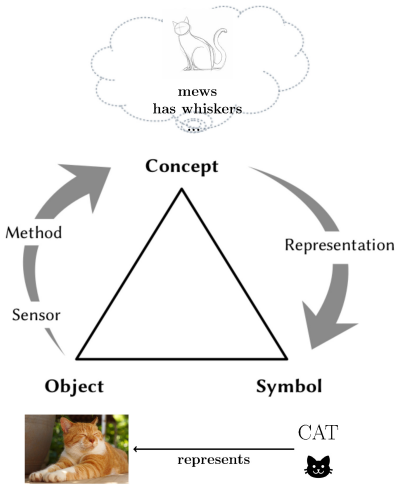
- Types of knowledge required
  - Domain Knowledge (about anatomy / astronomy)
    - also called ontology
  - Knowledge about image formation / processing
    - Mapping of real objects to images ... and vice-versa
    - How to interpret an image
  - The relation between the two

Characterizing knowledge

- Domain knowledge:
  - Declarative: explicit and symbolic representation
  - exists independent of processing structure
  - can be shared
- Knowledge about image formation / processing:
  - Procedural: implicit
  - Encoded as algorithms, neural networks or classifiers
  - Strictly private to the processing scheme
- We shall focus on declarative knowledge in this module

Symbolic representation

The semiotic triangle



- Objects (things): That exist
- Concepts: Mental representations (models)
- Representation: Symbol to represent a concept (text, icon, audio)

Representational Theory of Mind (RTM)

- A concept is a mental model of "something" that exists (with attributes)
- Something can be
  - A real-world thing
  - An internal mental state of the agent
- A name is associated with a concept
  - For reference during manipulation (reasoning)
- Knowledge is
  - A collection of named concepts
  - A set of sentences (propositions) that relate the concepts
    - Named concepts: cat, tail, has
    - Proposition: A cat has a tail

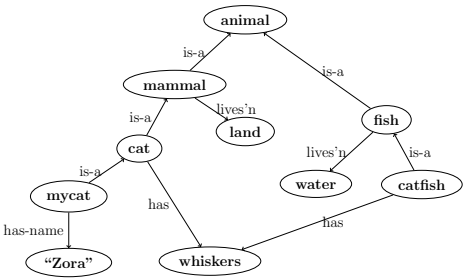
Language of Thought Hypothesis (LoTH)

- Thoughts are mental processes
  - Leads to mental models
  - Result of manipulation of the knowledge
    - That brown cat has a tail
    - If I had wings!
- Represented in a language that is akin to symbolic logic
- Inferences can be drawn from knowledge through the process of thought (reasoning)

Semantic Network

- Knowledge is a set of statements
  - A mammal is an animal
  - A cat is a mammal
  - A cat has whiskers
  - A mammal lives on land
  - A fish is an animal
  - A catfish is a fish
  - A catfish has whiskers
  - A fish lives in water
  - Mycat is a cat
  - Mycat has a name “Zora”

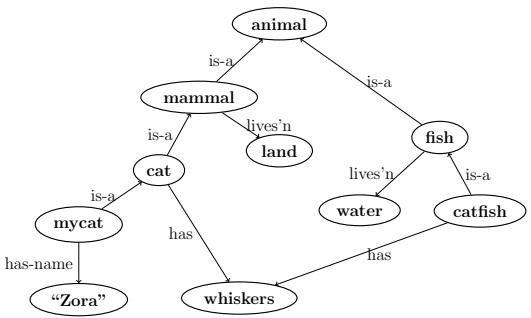
- Equivalently, knowledge is a graph (semantic network)



Semantics of "Semantic Network"

- Each edge of a semantic network represents a proposition (statement)
- Each proposition describes a property of a concept
- For example: cat has whiskers
  - Subject (Concept being described): Cat
  - Predicate (Property): Has
  - Object (Value): Whiskers
- A concept can be a class, or an instance
- A value can be a concept, or a literal
- The network of concepts represent knowledge about a domain

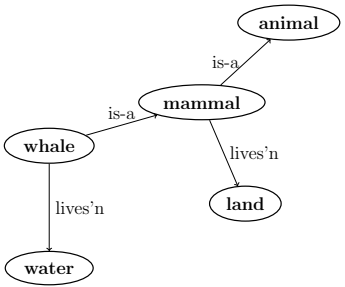
Reasoning with Semantic Network



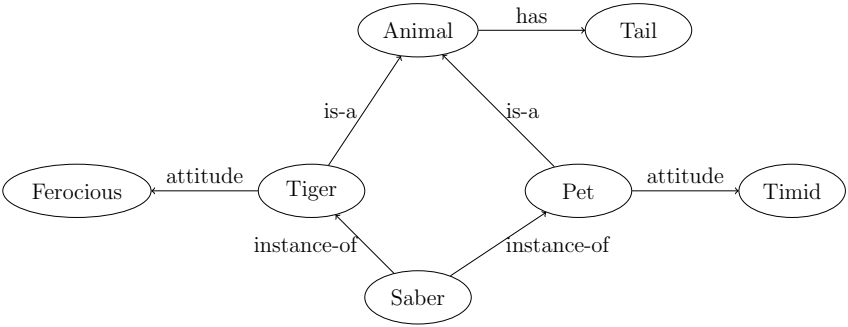
- Requires underlying axioms, e.g.
  - Properety inheritance
    - If *a* "is-a" *b*, then *a* inherits properties of *b*
  - "is-a" is transitive
    - If *a* is-a *b*, and *b* is-a *c*, then *a* is a *c* too
  - These axioms make a semantic network efficient (compact)

Flexibility with "Semantic Network"

- No restrictions on properties / values to be associated to a concept
- There can be exceptions. e.g.
  - Whale is a mammal, but lives in water
- Axioms need to be redefined
  - If *a* "is-a" *b*, then
    - *a* inherits properties of *b*
    - ... unless overruled



Multiple inheritance



Saber has a tail

What's about Saber's attitude ?

Properties of Semantic Network

- A semantic network is extremely flexible
  - At the cost of formalism
  - An informal description of a domain (in it's basic form)
- Semantics is imposed with axioms / constraints
- Many variants have been proposed
  - Definitional network
    - Expresses class-subclass relations
    - ... and properties that distinguish sibling subclasses
    - Cat *is-a* mammal; cat *has* whiskers
  - Implication Network
    - Expresses causal relations
    - Banana *causes* yellow color
  - Hybrid networks combine more than one of paradigms

Sowa. Semantic Networks

Resource Description Framework (RDF)

- A knowledge representation framework based on semantic network
- All entities are treated as "resources"
  - Each resource is identified with a IRI
  - Enables distributed knowledge description
- An RDF sentence is a triplet $\langle subject, predicate, object \rangle$
- A predicate in one sentence can be a subject or an object in another
  - ⟨ hasWeightInKg, is-a, healthParameter ⟩. ⟨ Ramu, hasWeightInKg, 80 ⟩
- Reification: A statement is also a resource (and identified by an IRI)
  - I said that cat is an animal
  - S1: ⟨ cat, is-a, animal ⟩. S2: ⟨ I, said, S1 ⟩
- Constraints and semantics defined with RDF and RDF Schema
- Notations: XML, N3, Turtle

SPARQL Query Language

- To make query on RDF Graphs
- Syntactically similar to SQL
- Implemented with “triple-store” databases
  - Apache Jena / TDB
  - Optimized for storing triplets
- Query on distributed knowledge
  - Distributed knowledge centrally indexed
  - Distributed query processing (distributed index)
- Resources:
  - W3School tutorials
  - W3C Documents

Quiz

No quiz for module 07-01

End of Module 07-01