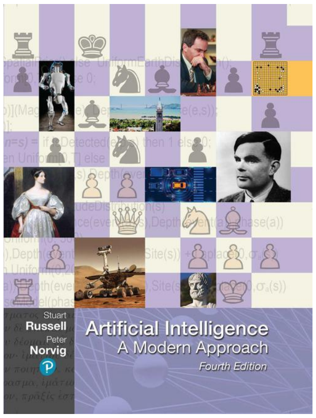
Artificial Intelligence: A Modern Approach

Fourth Edition



Chapter 10

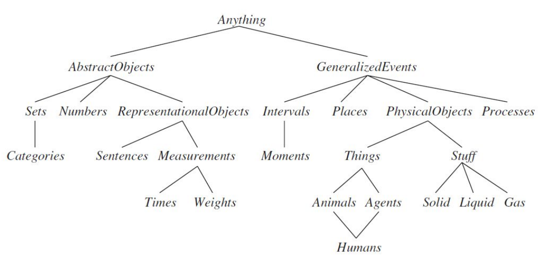
Knowledge Representation

Outline

- Ontological Engineering
- Categories and Objects
- Events
- Mental Objects and Modal Logic
- Reasoning Systems for Categories
- Reasoning with Default Information

Ontological Engineering

- **Ontological Engineering:** General and flexible representations for complex domains.
- **Upper ontology**: The general framework of concepts
- Example of ontology of the world:



Categories and Objects

- The organization of objects into categories is a vital part of knowledge representation
- Categories for FOL can be represented by predicates and objects.
- **Physical composition**: one object can be part of another is a familiar one
  - Eg: Romania is part of Bucharest. *PartOf*(*Bucharest*, *Romania*)
- **Measurements**: values that we assign for properties of objects
  - Eg: $Length(L_1)=Inches(1.5)=Centimeters(3.81)$

Categories and Objects

- **Stuff**: a significant portion of reality that seems to defy any obvious individuation—division into distinct objects
- **Intrinsic**: they belong to the very substance of the object, rather than to the object as a whole.
- **Extrinsic**: weight, length, shape
- **Substance**: a category of objects that includes in its definition only intrinsic properties (mass noun).
- **Count noun**: class that includes any extrinsic properties

Events

- **Event calculus**: events, fluents, and time points
  - Fluents (eg): *At*(*Shankar*, *Berkeley*)
  - Events (eg): Event E_1 of Shankar flying from San Francisco to DC
  - $E_1 \in Flyings \wedge Flyer(E_1, Shankar) \wedge Origin(E_1, SF) \wedge Destination(E_1, DC)$
  - *Flyings* is the category of all flying events.
- Categories for FOL can be represented by predicates and objects.
- **Physical composition**: one object can be part of another is a familiar one
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- **Measurements**: values that we assign for properties of objects
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Mental Objects and Modal Logic

Mental objects are knowledge in someone's head (or KB)

Propositional attitudes that an agent can have toward mental objects
- Eg*: Believes*, *Knows*, *Wants*, and *Informs*

Lois knows that Superman can fly:
Knows(*Lois*, *CanFly*(*Superman*))

Sentences can sometimes be verbose and clumsy. Regular logic is concerned with a single modality, the modality of truth.

Modal logic addresses this, with special modal operators that take sentences (rather than terms) as arguments

"A knows P" is represented with the notation $\mathbf{K}_A P$, where **K** is the modal operator
for knowledge. It takes two arguments, an agent (written as the subscript) and a sentence.

The syntax of modal logic is the same as first-order logic, except that sentences can also be formed with modal operators

Mental Objects and Modal Logic

Agents are able to draw conclusions. If an agent knows *P* and knows that *P* implies *Q*, then the agent knows *Q:*

$$(\boldsymbol{K}_a P \wedge \boldsymbol{K}_a(P \Rightarrow Q)) \Rightarrow K_a Q$$

Logical agents (but not all people) are able to introspect on their own knowledge.
If they know something, then they know that they know it:

$$\boldsymbol{K}_a P \Rightarrow \boldsymbol{K}_a\,(\boldsymbol{K}_a P)$$

Reasoning Systems for Categories

Semantic networks
- convenient to perform inheritance reasoning
- Eg: Mary inherits the property of having two legs. Thus, to find out how many legs Mary has, the inheritance algorithm follows the *MemberOf* link from *Mary* to the category she belongs to and then follows *SubsetOf* links up the hierarchy until it finds a category for which there is a *boxed* Legs link

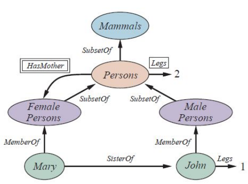

Figure 10.4 A semantic network with four objects (John, Mary, 1, and 2) and four categories. Relations are denoted by labeled links.

Reasoning Systems for Categories

Description logics
- notations that are designed to make it easier to describe definitions and properties of categories
- evolved from semantic networks in response to pressure to formalize what the networks mean while retaining the emphasis on taxonomic structure as an organizing principle
- Principal inference tasks:
  - **Subsumption**: checking if one category is a subset of another by comparing their definitions
  - **Classification**: checking whether an object belongs to a category

- The CLASSIC language (Borgida et al., 1989) is a typical description logic
  - Eg: bachelors are unmarried adult males
  - *Bachelor* = *And*(*Unmarried*, *Adult*, *Male*)

Reasoning with Default Information

Circumscription and default logic

- **Circumscription** can be seen as a more powerful and precise version of the closed-world assumption.
  - Specify particular predicates that are assumed to be "as false as possible"
  - It is an example of a model preference logic

- **Default logic** is a formalism in which default rules can be written to generate contingent nonmonotonic conclusions
  - Eg: *Bird*(*x*) : *Flies*(*x*)/*Flies*(*x*)
  - This rule means that if *Bird*(*x*) is true, and if *Flies*(*x*) is consistent with the knowledge base, then *Flies*(*x*) may be concluded by default.

Reasoning with Default Information

Truth maintenance systems

- **Belief revision**: inferred facts will turn out to be wrong and will have to be retracted in

- **Truth maintenance systems**, or TMSs, are designed to handle complications of any additional sentences that inferred from a wrong sentence.

- **Justification-based truth maintenance system (JTMS)**
  - Each sentence in the knowledge base is annotated with a justification consisting of the set of sentences from which it was inferred
  - Justifications make retraction efficient
  - Assumes that sentences that are considered once will probably be considered again

Summary

- **Upper ontology** based on categories and the event calculus
- Special-purpose representation systems, such as **semantic networks** and **description logics**, have been devised to help in organizing a hierarchy of categories
- Nonmonotonic logics, such as **circumscription** and **default logic**, are intended to capture default reasoning in general.
- **Truth maintenance systems** handle knowledge updates and revisions efficiently