

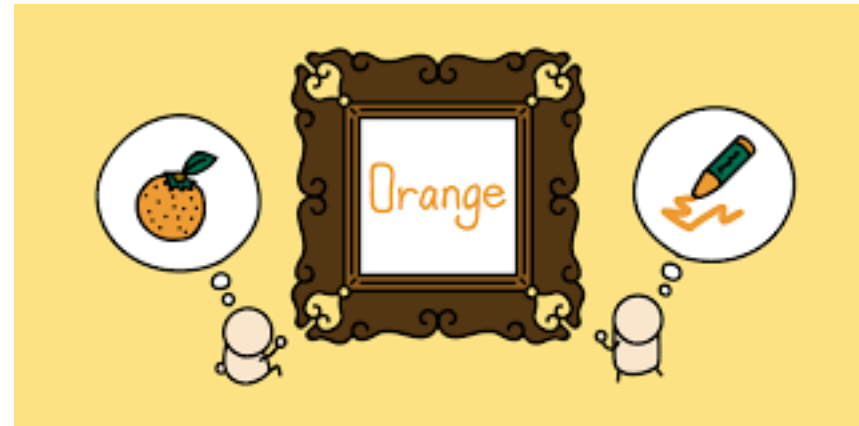
Ontological Engineering

Knowledge Representation

- Knowledge-representation is the field of AI dedicated to representing information about the world in a form that a computer system can utilize to solve complex tasks.
- This topic addresses what *content* to put into knowledge base
- How to represent facts about the world?

Ontological engineering

- Ontology engineering is a set of tasks related to the development of ontologies for a particular domain.
- Google definition: a set of concepts and categories in a subject area or domain that shows their properties and the relations between them.



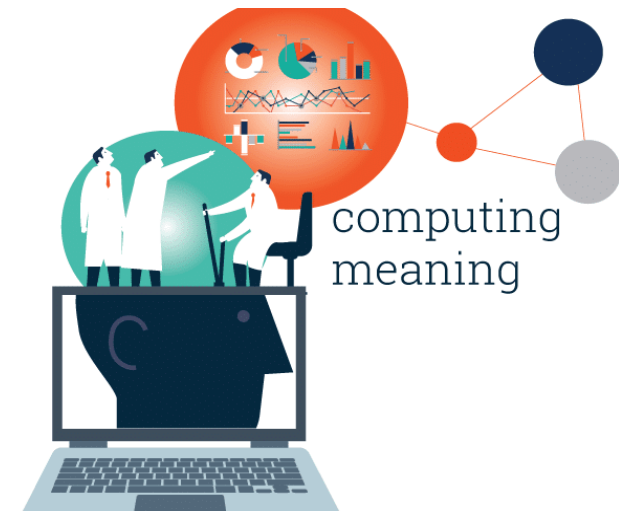
Ontological engineering

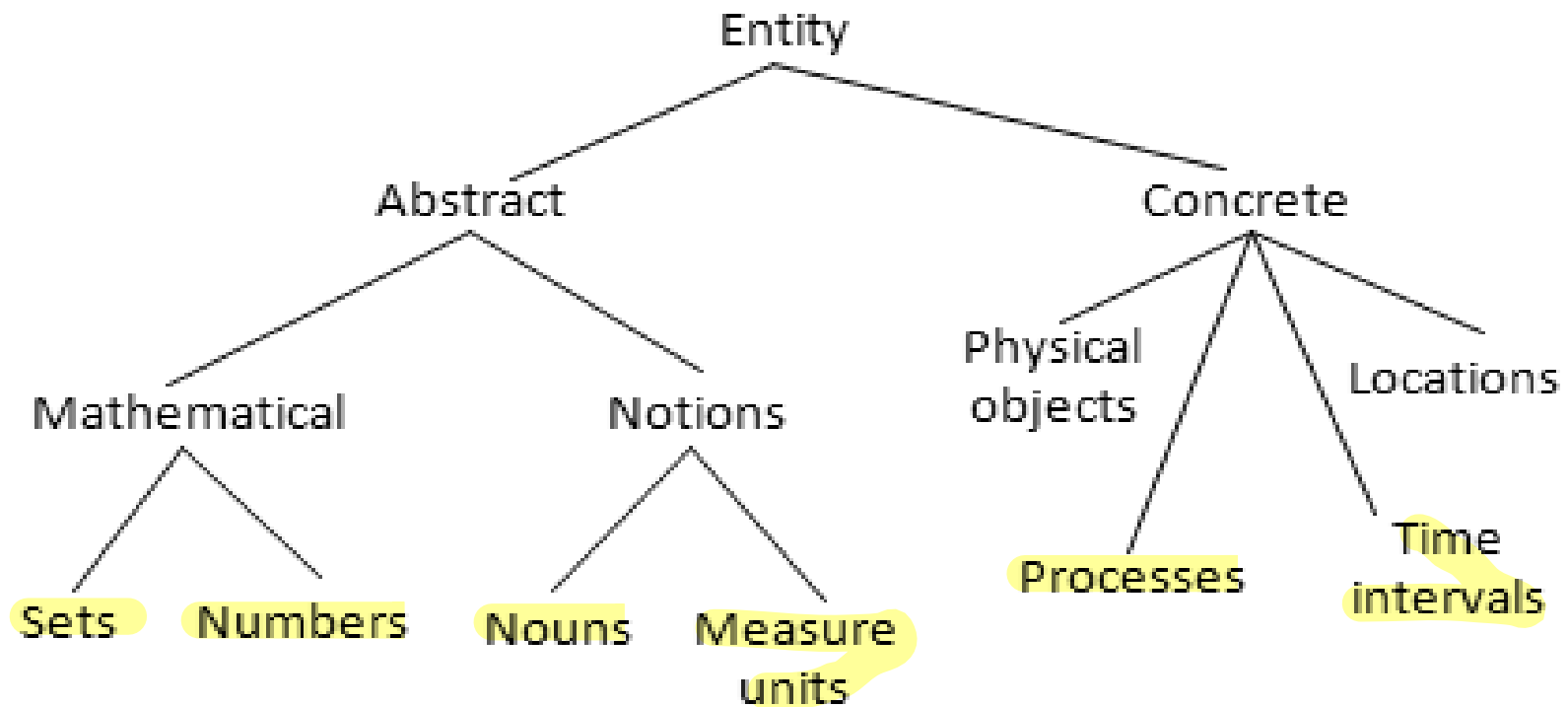
- How to create more general and flexible representations
 - Concepts like actions, time, physical objects and beliefs
 - Operates on a bigger scale than knowledge engineering
- Representing these abstract concepts is sometimes called **ontological engineering**.
- Define general framework of concepts (because representing everything is challenging) called as **upper ontology** with general concepts at the top and more specific concepts below the hierarchy
- Limitations of logic representation
 - Red, green and yellow tomatoes: exceptions and uncertainty

Ontological engineering

- Defining terms in the domain and relations among them
 - Defining concepts in the domain(classes)
 - Arranging the concepts in a hierarchy(subclass-superclass hierarchy)
 - Defining which attributes and properties classes can have and constraints on their values
 - Defining individuals and filling in property values

Today's ontologies conceptualize the world by defining classes and relationships.

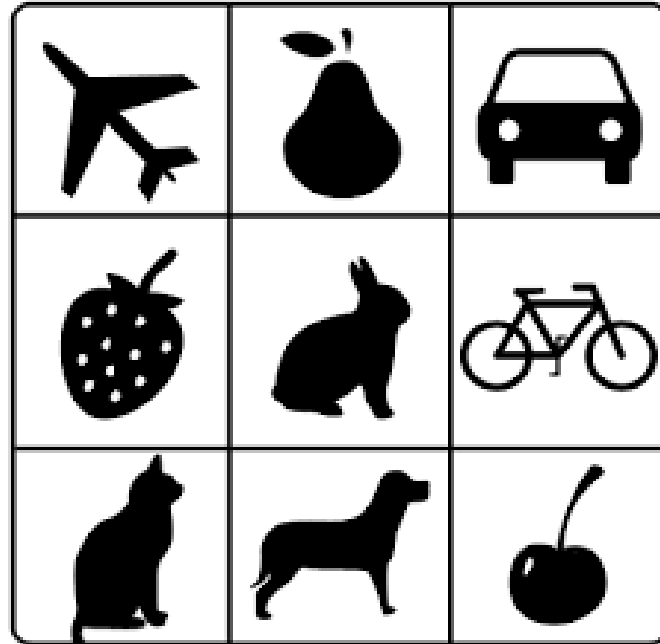




The upper ontology of the world. Each link indicates that the lower concept is a specialization of the upper one.

General-purpose ontology

- A general-purpose ontology should be applicable in more or less any special-purpose domain.
 - Add domain-specific axioms
- In any sufficiently demanding domain, different areas of knowledge need to be unified.
 - Reasoning and problem solving could involve several areas simultaneously
- What do we need to express?
 - Categories, Measures, Composite objects, Time, Space, Change, Events, Processes, Physical Objects, Substances, Mental Objects, Beliefs



Categories and objects

Categories and objects

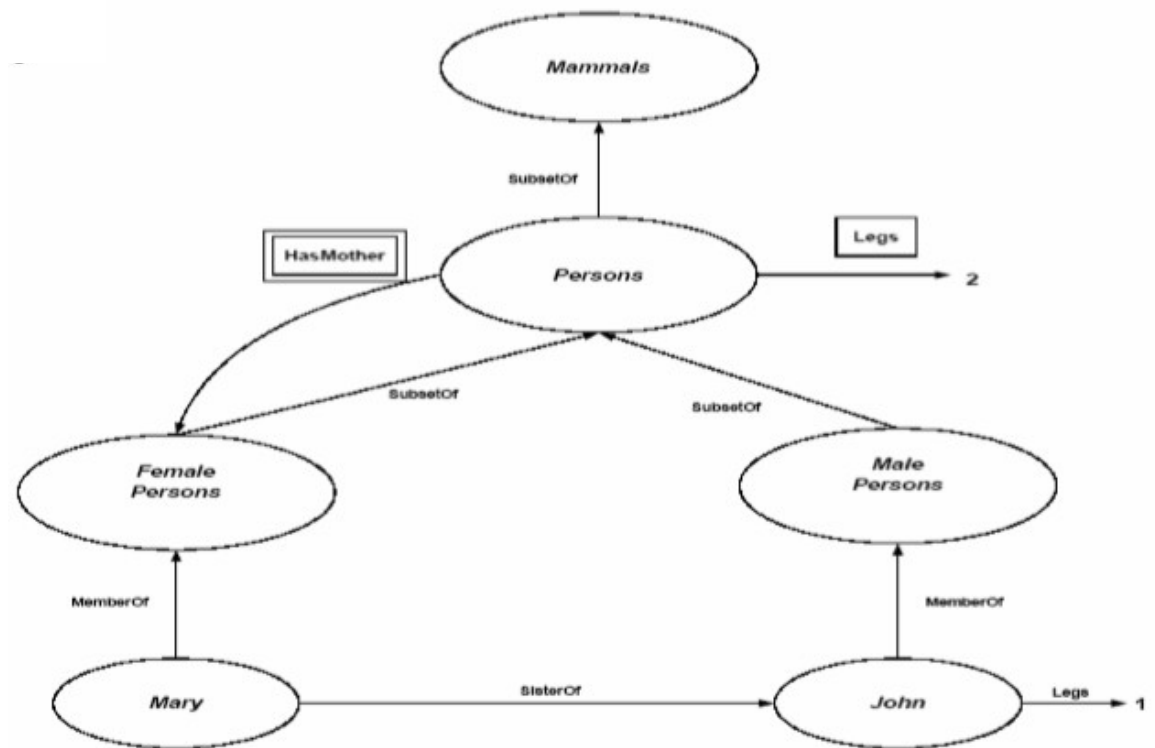
- KR requires the organization of objects into categories. Although
 - Interaction at the level of the object
 - Reasoning at the level of categories
- Categories play a role in predictions about objects
 - Based on perceived properties
- Categories can be represented in two ways by FOL
 1. **Predicates: *apple(x)***
 2. Reification of categories into **objects: *apples***
- Category = set of its members
 - Example: $\text{Member}(x, \text{apples}), x \in \text{apples}$,
 - $\text{Subset}(\text{apples}, \text{fruits}), \text{apples} \subset \text{fruits}$

Reify: make (something abstract) more concrete or real.

Category Organization

- Categories serve to organize and simplify the knowledge base through inheritance.
- Relation = inheritance:
 - All instance of food are edible, fruit is a subclass of food and apples is a subclass of fruit then an apple is edible.
 - Individual apples inherit the property of edibility from food

- Defines a taxonomy
 - Subclass relations organize categories



FOL and Categories

- First-order logic makes it easy to state facts about categories, either by relating objects to categories or by quantifying over their members.

Example:

- An object is a member of a category
 - $\text{MemberOf}(\text{BB12}, \text{Basketballs})$
- A category is a subclass of another category
 - $\text{SubsetOf}(\text{Basketballs}, \text{Balls})$
- All members of a category have some properties
 - $\forall x (\text{MemberOf}(x, \text{Basketballs}) \Rightarrow \text{Round}(x))$
- All members of a category can be recognized by some properties
 - $\forall x (\text{Orange}(x) \wedge \text{Round}(x) \wedge \text{Diameter}(x)=9.5\text{in} \wedge \text{MemberOf}(x, \text{Balls}) \Rightarrow \text{MemberOf}(x, \text{Basketballs}))$
- A category as a whole has some properties
 - $\text{MemberOf}(\text{Dogs}, \text{DomesticatedSpecies})$

Relations between Categories

- Two or more categories are **disjoint** if they are mutually exclusive
 - Disjoint({Animals, Vegetables})
- A decomposition of a class into categories is called **exhaustive** if each object of the class must belong to at least one category
 - living = {animal, vegetable, fungi, bacteria}
- A **partition** is an exhaustive decomposition of a class into disjoint subsets.
 - student = {undergraduate, graduate}

Natural kinds

- Many categories have no clear-cut definitions (e.g., chair, bush, book).
- Tomatoes: sometimes green, orange, red, yellow. Mostly spherical, smaller, larger etc
- One solution: Separate what is true of all instances of a category from what is true only of typical instances.
- subclass using category **Typical(Tomatoes)**
 - **Typical(c) \subseteq c**
- **$\forall x, x \in \text{Typical(Tomatoes)} \Rightarrow \text{Red}(x) \wedge \text{Spherical}(x)$**
- This helps us to write down useful facts about categories without providing exact definitions.

Physical composition

- One object may be part of another:
 - **PartOf(Bucharest,Romania)**
 - **PartOf(Romania,EasternEurope)**
 - **PartOf(EasternEurope,Europe)**
- The PartOf predicate is **transitive (and reflexive)**, so we can infer that **PartOf(Bucharest,Europe)**
- More generally:
 - $\forall x \text{ PartOf}(x,x)$
 - $\forall x,y,z \text{ PartOf}(x,y) \wedge \text{PartOf}(y,z) \Rightarrow \text{PartOf}(x,z)$

Logical Minimization: Defining an object as the smallest one satisfying certain conditions.

Measurements

- Objects have height, mass, cost,....
 - Values that we assign to these properties are called measures
- Combine Unit functions with a number to measure line segment object L1
 - $\text{Length}(L1) = \text{Inches}(1.5) = \text{Centimeters}(3.81)$.
- Conversion between units:
 - $\forall i \text{ Centimeters}(2.54 \times i) = \text{Inches}(i)$.
- Some measures have no scale:
 - Beauty, Difficulty, etc.
 - Most important aspect of measures is not numerical values, but measures can be orderable.
 - An apple can have deliciousness .9 or .1

Objects: Things and stuff

- Stuff: Defy any obvious **individuation** after division into distinct objects (mass nouns)
- Things: Individuation(count nouns)
- Example: Butter(stuff) and Cow(things)

$$***b \in Butter \wedge PartOf(p, b) \Rightarrow p \in Butter***$$