2.2 Terminologies / Ontologies

A. Motivation

Definition: Terminology
Terminology is a general term for all kinds of controlled vocabularies.

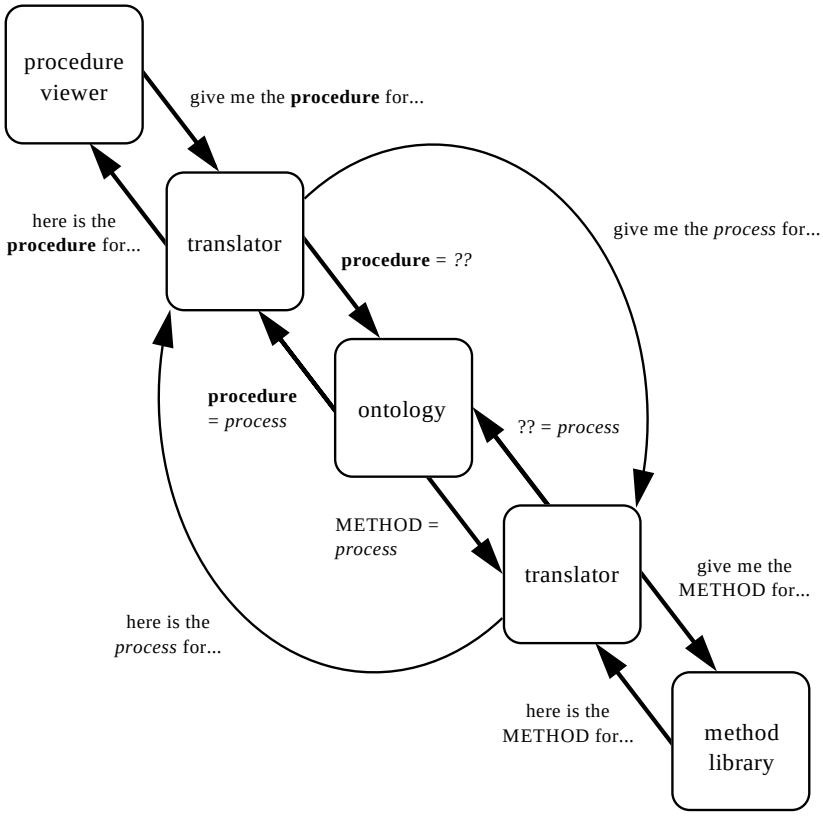
Definition: Taxonomy
A taxonomy is a controlled vocabulary which is arranged in a concept hierarchy (i.e., super-, sub-concepts).

Definition: Thesaurus
A thesaurus is a controlled vocabulary distinguishing super-concepts (BT), sub-concepts (NT), synonyms (USE), related concepts (RT), etc.

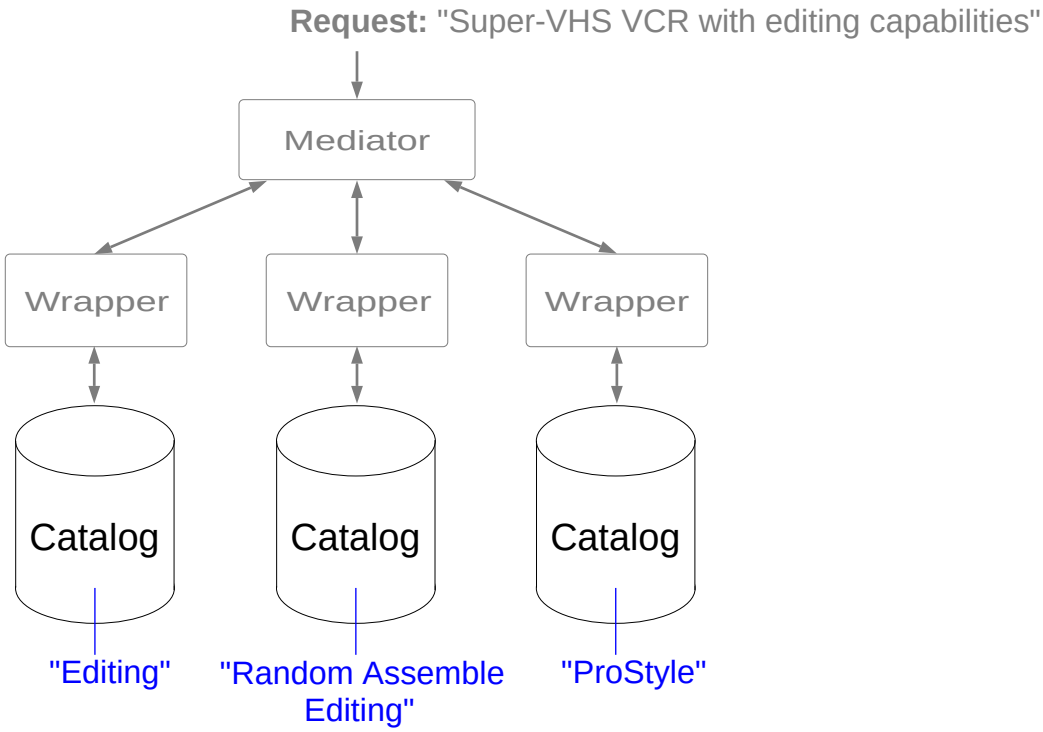
Definition: Ontology
An ontology is a taxonomy where the meaning of each concept is defined by specifying properties, relations to other concepts, and axioms narrowing down the interpretation.

A (controlled) vocabulary provides the representational building blocks.

Agents need to share a vocabulary but not a knowledge base:

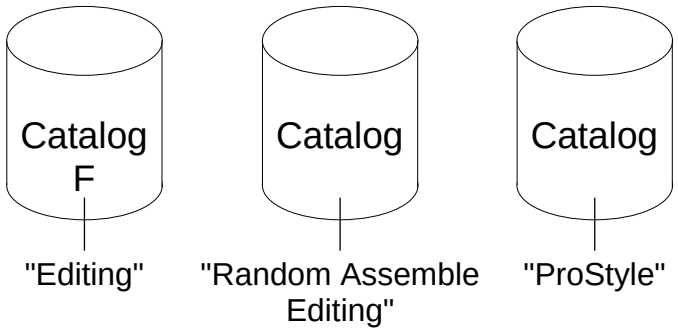


Problem: Different Terminology



Solution:

Request: "Super-VHS VCR with editing capabilities"



Ontology:

Class VCR **with**
  attribute
  features: { Editing,
    Slow-Motion, ... }
  ...
end

Translation Rules:

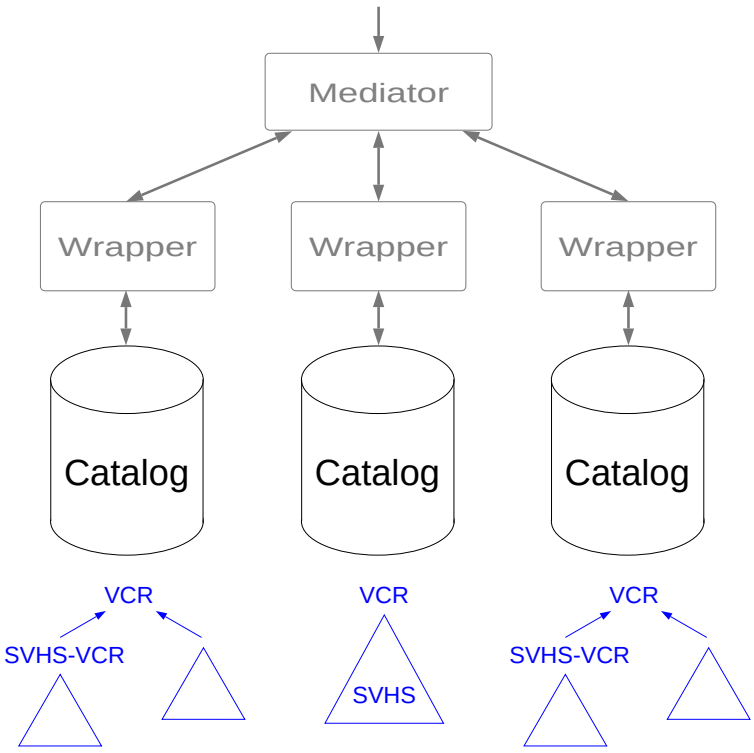
Class F.Editing **isa** Editing

Class RandomAssembleEditing **isa** Editing

Class ProStyle **isa** Editing

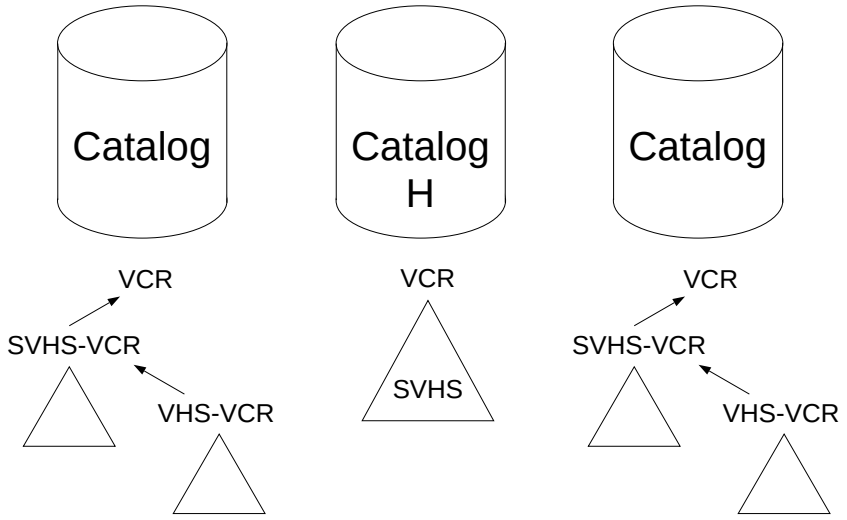
Problem: Implicit Context

Request: "Super-VHS VCR with editing capabilities"



Solution:

Request: "Super-VHS VCR with editing capabilities"



Ontology:

Class VHS-VCR **isa** VCR

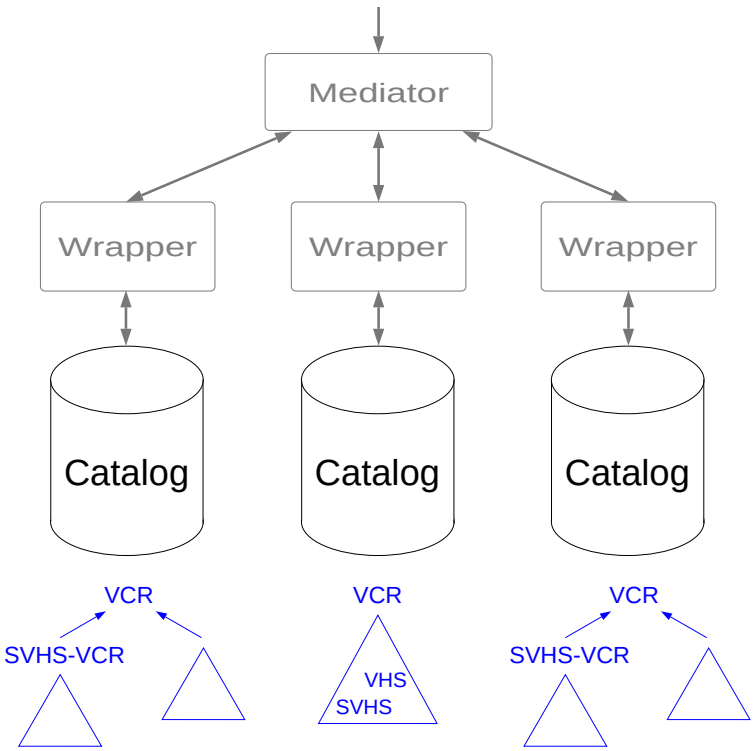
Class SVHS-VCR **isa** VHS-VCR

Translation Rule:

H.VCR = SVHS-VCR

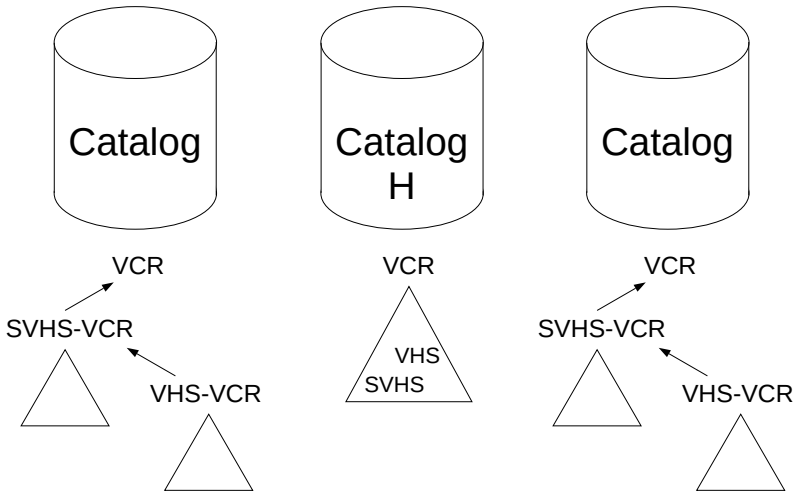
Problem: Missing Concepts

Request: "Super-VHS VCR with editing capabilities"



Solution:

Request: "Super-VHS VCR with editing capabilities"



Ontology:

Class VHS-VCR **isa** VCR

Class SVHS-VCR **isa** VHS-VCR

Axiom:

instance(i, H.VHS-VCR) & (bandwidth(i) > value1
v resolution(i) > value2) => instance(i, SVHS-VCR)

B. Representation formalism: Description logics

Description logics are a unifying formalism for

- semantic networks
- frames
- object-oriented representations
- semantic data models
- type systems
- ...

For example, what does the following representation mean:

$$\textbf{car} \xrightarrow{\textbf{has-part}} \textbf{engine}$$

- every car has an engine
- every car has the same engine
- typically, cars have engines
- there is a car which has an engine

Any (basic) description logic is a subset of first-order logic.

The representation is at the predicate level, i.e. no variables are present in the formalism.

A description logic is divided into two parts:

- definitions of predicates
  (concept definitions – TBox)
- assertions over constants
  (description of individuals – ABox)

The TBox language knows

- concepts, which correspond to unary predicates, e.g.
  $\{x \mid customer(x)\}$, $\{x \mid delivery(x)\}$
- roles, which correspond to binary predicates, e.g.
  $\{\langle x, y\rangle \mid has\text{-}part(x, y))\}$, $\{\langle x, y\rangle \mid sold\text{-}by(x, y)\}$

The TBox language allows to define concepts (maybe roles), referring to already defined concepts (and roles).

Examples of concept expressions

$C^{\mathcal{I}} \subseteq D^{\mathcal{I}}$ if $C \dot{\leq} D$

professor $\dot{\leq}$ (**some** teaches courses)

$C^{\mathcal{I}} = D^{\mathcal{I}}$ iff $C \doteq D$

bachelor $\doteq$ (**and** adult male (**not** (**some** married person)))

(**and** C D)$^{\mathcal{I}} = C^{\mathcal{I}} \cap D^{\mathcal{I}}$

(**all** R C)$^{\mathcal{I}} = \{x \in \Delta \mid \forall y : \langle x, y\rangle \in R^{\mathcal{I}} \Rightarrow y \in C^{\mathcal{I}}\}$

(**all** has-child person) (**all** has-child adult)

(**some** R C)$^{\mathcal{I}} = \{x \in \Delta \mid \exists y : \langle x, y \rangle \in R^{\mathcal{I}} \wedge y \in C^{\mathcal{I}}\}$

parent $\doteq$ (**and** person (**some** has-child person))

(**or** C D)$^{\mathcal{I}} = C^{\mathcal{I}} \cup D^{\mathcal{I}}$

living-thing $\doteq$ (**or** plant animal)

(**not** C)$^{\mathcal{I}} = \Delta^{\mathcal{I}} \setminus C^{\mathcal{I}}$

female $\doteq$ (**not** male)

(**at-least** R n C)$^{\mathcal{I}} = \{x \in \Delta \mid \|\{y \mid \langle x, y \rangle \in R^{\mathcal{I}} \wedge y \in C^{\mathcal{I}}\}\| \geq n\}$

(**at-least** has-child 1 person)

(**at-most** married 1 person)

The ABox language knows individuals and

- their concept memberships, e.g.
  customer(frank), delivery(object-241)
- their relationships to other individuals (roles), e.g.
  sold-by(dvd-97,frank)

The ABox language allows to talk about individuals.

Terminological reasoning services on a knowledge base Σ

- *Concept satisfiability*

  $\Sigma \not\models C \equiv \bot$ (**and** student (**not** person))

  check whether C has a model, i.e., $C^{\mathcal{I}} \neq \emptyset$

- *Subsumption*

  $\Sigma \models C \dot{\leq} D$ student $\dot{\leq}$ person

  check whether $C^{\mathcal{I}} \subseteq D^{\mathcal{I}}$ in every model $\mathcal{I}$ of Σ

- *Instance checking*

  $\Sigma \models C(a)$ student(frank)

  check whether $C(a)$ is satisfied in every model of Σ

- *Retrieval*

  $\{a \mid \Sigma \models C(a)\}$ student $\Rightarrow$ frank

  get all instances belonging to a concept

- *Realization*

  $\{C \mid \Sigma \models C(a)\}$ frank $\Rightarrow$ student

  check to which concepts an individual belongs

- *Classification*

  given a concept C and a TBox (terminology) $\mathcal{T}$,

  determine for all concepts D of $\mathcal{T}$ wether D subsumes C

  or D is subsumed by C

C. Ontologies

Motivation

A representation has a context that corresponds to a certain viewpoint, e.g.:

- a car from the viewpoints of the manufacturer, the car dealers, the garages, the drivers;
- a tax-supported life insurance in different countries;
- a customer in different business units.

A representation of the underlying view is needed to reuse, integrate, compare knowledge from different contexts.

Definition:
An ontology is an explicit conceptualization of a domain of discourse, and thus provides a shared and common understanding of the domain.

Ontology:	**Terminology:**
a) concerns more than one domain of discourse	specific to a domain of discourse
b) vocabulary is cognitively adequate	vocabulary is given by the things in the domain
c) underlying viewpoints are made explicit	underlying viewpoints are not necessarily made explicit
Examples:	*Examples:*
hypothesis animate inanimate state process	crankshaft clutch investment fund pension

Terminology:

$\forall x : customer(x) \Rightarrow person(x)$

Specification of the underlying ontological commitments:

$\Box(\forall x : customer(x) \Rightarrow person(x))$

$\Box(\forall x : person(x) \Rightarrow \Box person(x))$

In a meta language:

$customer \leq person$

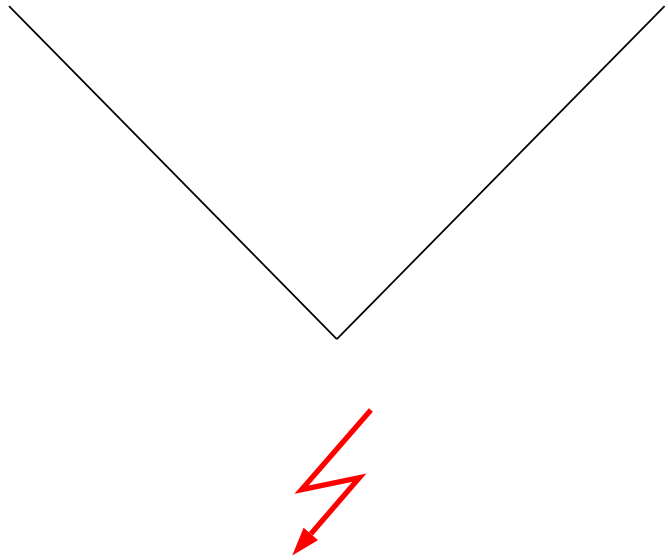
$rigid(person) \qquad \neg rigid(customer)$

Terminology 1:

$\forall x : customer(x) \Rightarrow person(x)$

Terminology 2:

$\forall x : customer(x) \Rightarrow company(x)$



Resolution:

$\forall x : customer(x) \Rightarrow person(x) \vee company(x)$

Hierarchies of ontologies

Base Ontologies:

- define common terms
  like business terminology ("customer", "sale", "business process", "organisational unit", ...)
- are used by all knowledge sources in an OM
- provided by standardization committees, research institutes,

Corporate Ontologies:

- define terms for all organizational units
  like "premium", "annuity insurance", "pension"
- refers to base ontologies
- provided on a corporate level

Domain Ontologies:

- define terminology specific to a (sub-)domain,
  like "tariff", "customer"
- refers to corporate ontologies
- provided by organizational units

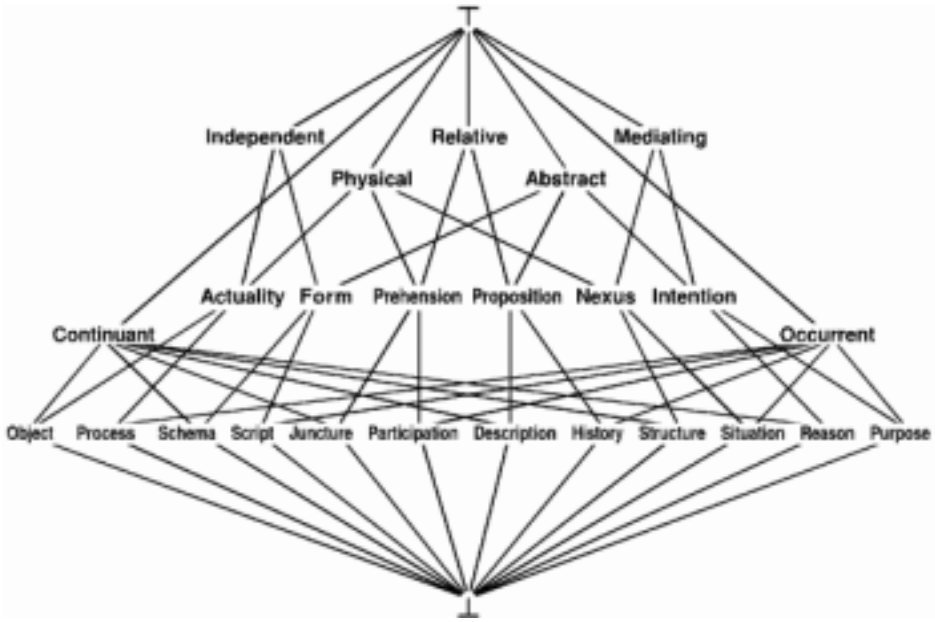
Translation Ontologies:

- make use of base and domain ontologies
- provide translation rules between ontologies

Examples of ontologies:

John Sowa's Top-level Ontology:

(http://www.bestweb.net/~sowa/ontology/toplevel.htm)



Abstract:

Pure information as distinguished from any particular encoding. No abstract has a location in space or occurs at a point in time:

$\neg\exists x : abstract(x) \Rightarrow \exists y : (place(y) \Rightarrow loc(x, y))$

$\neg\exists x : abstract(x) \Rightarrow \exists t : (time(t) \Rightarrow tim(x, t))$

Continuant:

An entity whose identity continues to be recognizable over some extended time interval.

Independent:

An entity characterized by some inherent Firstness,

independent of any relationships it may have to other entities.

$\forall x : independent(x) \Rightarrow \neg\Box\exists y : (has(x,y) \vee has(y,x))$

Physical:

An entity that has a location in space-time.

$\forall x : physical(x) \Rightarrow \exists y : (place(y) \Rightarrow loc(x,y))$

$\forall x : physical(x) \Rightarrow \exists t : (time(t) \Rightarrow tim(x,t))$

Relative:

An entity in a relationship to some other entity.

$\forall x : relative(x) \Rightarrow \Box\exists y : (has(x,y) \vee has(y,x))$

Enterprise Ontology:

(University of Edinburgh: http://www.aiai.ed.ac.uk/~entprise/enterprise/ontology.html)

time, events, activity, capability, purpose, customer,

legal entity, market, sales, sales offer, etc.

uses semantic relationships and axioms

The TOVE Enterprise Ontology:

(University of Toronto: http://www.eil.utoronto.ca/tove/ontoTOC.html)

time, resources, groups, individuals, communication links,

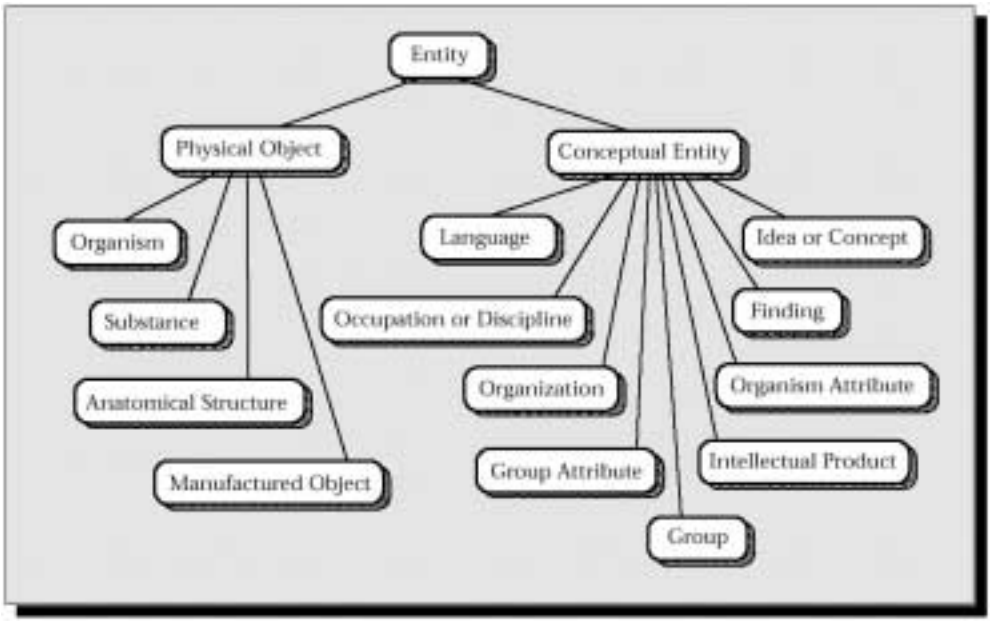
empowerment, authority, etc.

uses semantic relationships and axioms

Unified Medical Language System Top-level Ontology:

(http://www.nlm.nih.gov/research/umls/umlsmain.html)

many semantic relationships (part-of, time and space)



WordNet:

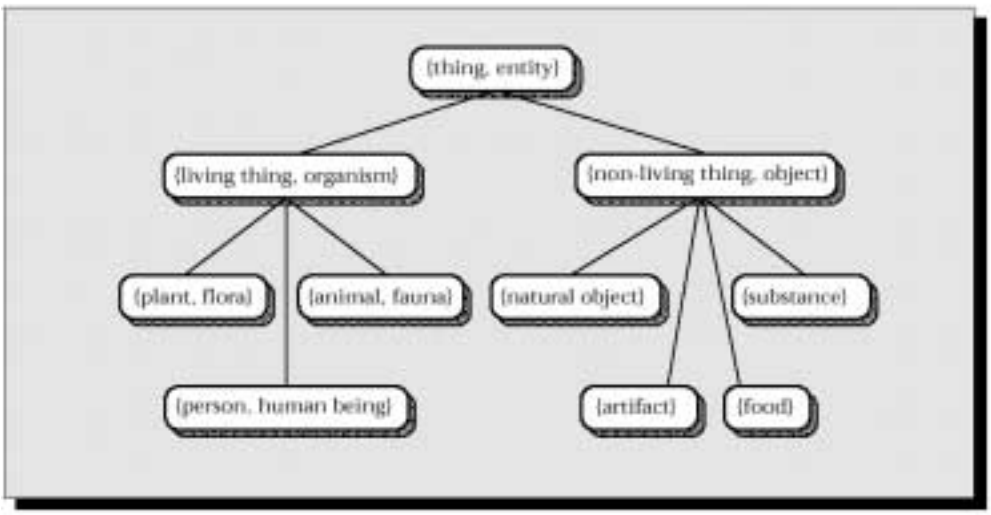
(http://www.cogsci.princeton.edu/~wn/)

lexical objects (nouns, verbs, adjectives, adverbs)

synset – a set of synonyms (i.e., a concept)

part-of relationships

no structured concepts or axioms



Ontologies – Research issues

- Methodology for developing ontologies
- Support the collaborative development process
- Integration and reuse of ontologies
- Combine definitions from different ontologies
- Content-rich representation languages