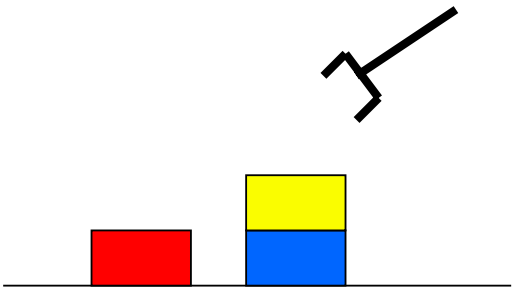
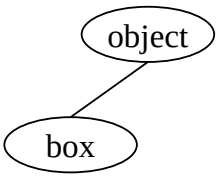
Ontologies

Hideaki Takeda

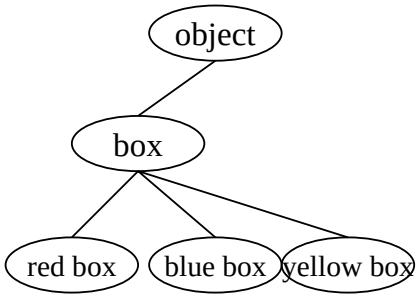
Conceptualization



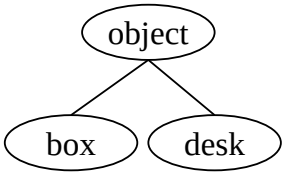


on_desk(A)
on(A, B)
put(A,B)

box
color:{red, blue, yellow}



on_desk(A)
on(A, B)
put(A,B)



on(A/box, B/object)
put(A/box,B/object)

box
color:{red, blue, yellow}

There are many possible ways to conceptualize the target world

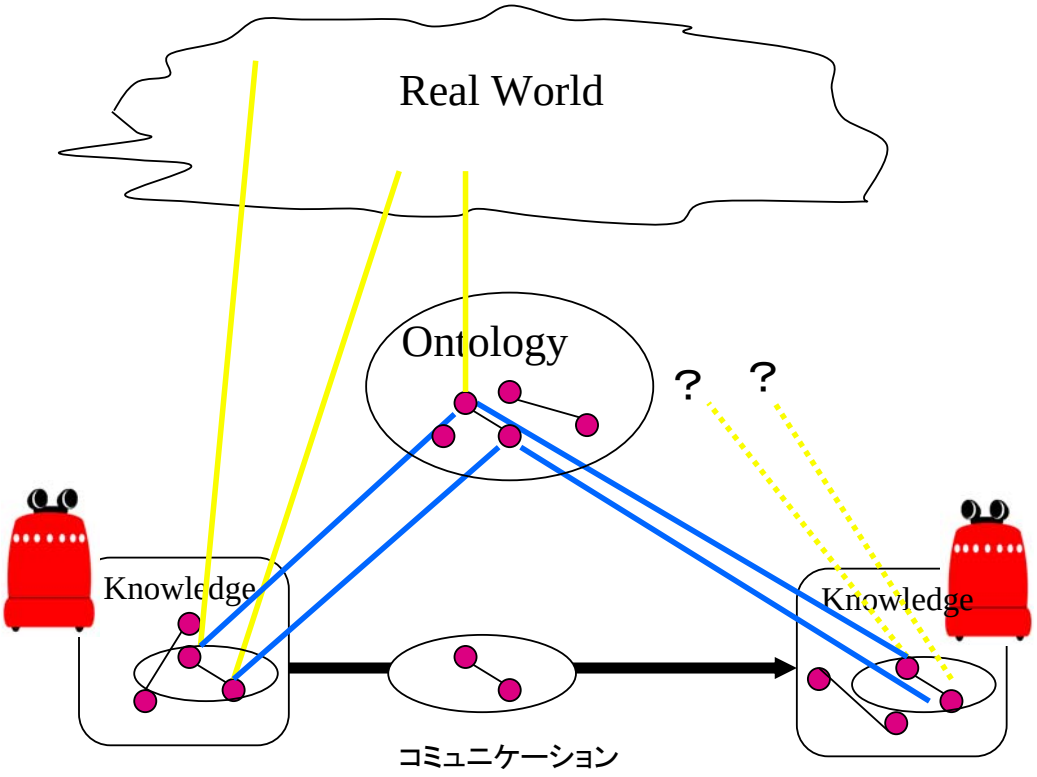
Trade off between generality and efficiency

Ontology

An ontology is an explicit specification of a conceptualization [Gruber]

- An **ontology** is an explicit specification of a conceptualization. The term is borrowed from philosophy, where an Ontology is a systematic account of Existence. For AI systems, what "exists" is that which can be represented. When the knowledge of a domain is represented in a declarative formalism, the set of objects that can be represented is called the universe of discourse. This set of objects, and the describable relationships among them, are reflected in the representational vocabulary with which a knowledge-based program represents knowledge. Thus, in the context of AI, we can describe the ontology of a program by defining a set of representational terms. In such an ontology, definitions associate the names of entities in the universe of discourse (e.g., classes, relations, functions, or other objects) with human-readable text describing what the names mean, and formal axioms that constrain the interpretation and well-formed use of these terms. Formally, an ontology is the statement of a logical theory.

Ontology and Agent Communication



Types of Ontologies

- Upper (top-level) ontology vs. Domain ontology
  - Upper Ontology: A common ontology throughout all domains
  - Domain Ontology: An ontology which is meaningful in a specific domain
- Object ontology vs. Task ontology
  - Object Ontology: An ontology on “things” and “events”
  - Task Ontology: An ontology on “doing”

Types of Ontologies

- Heavy-weight ontology vs. light-weight ontology
  - Heavy-weight ontology: fully described ontology including concept definitions and relations, in particular in a logical way
    - Definition of concepts with axioms
  - Light-weight ontology: partially described ontology including typically only is-a relations
    - Taxonomy
    - Thesaurus

Domain ontologies

- Ontologies for individual domains
  - UMLS (Unified Medical Language System):
  - Open Biomedical Ontologies (OBO)
  - Gene Ontology: for genomics
  - Plant Ontology: for plant structures and growth/development stages, etc
  - CIDOC CRM (Conceptual Reference Model) - an ontology for "cultural heritage information".
  - …

Top-level ontology

- Ontology which covers all of the world!
- Very…. Difficult
  - e.g., how does a thing exist?
    - A thing is four dimensional existence?
    - A thing exists three-dimensionally over time?
- Common requirements
  - A small number of concepts can cover the world
  - Concepts can be used in lower ontologies

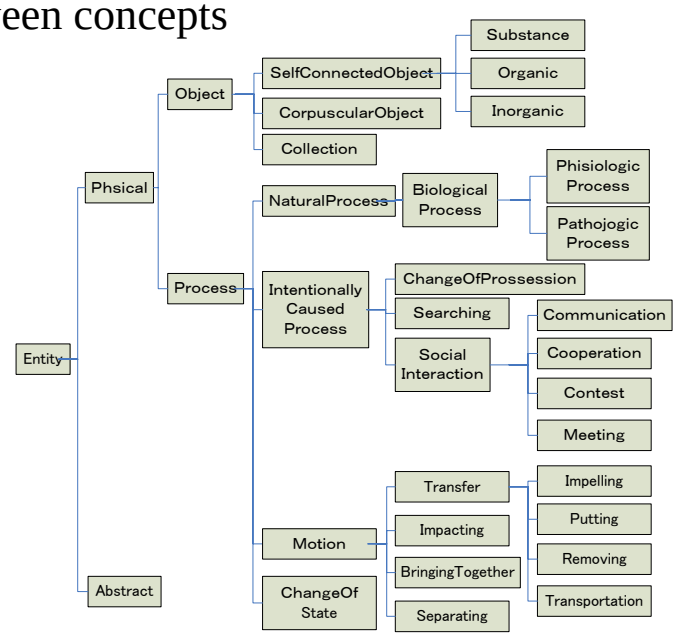
  - Concept should be general and abstract

Top-level ontology

- Three approaches
  - Formal approach
    - Logical formalization
    - Fully Abstract
    - Pros: clean
    - Cons: hardly understandable
    - e.g., Sowa's top-level ontology, DOLCE
  - Linguistic approach
    - Use and extension of linguistic concepts
    - Partially abstract and partially general
    - Pros: understandable
    - Cons: limitation to the linguistic world
    - e.g., Penman Upper Model, WordNet
  - Pragmatic Approach
    - Use and extension of everyday concepts
    - Mostly general
    - Pros: understandable and applicable to all the world
    - Cons: lack of solid foundation
    - e.g. SUMO, OpenCyc, EDR

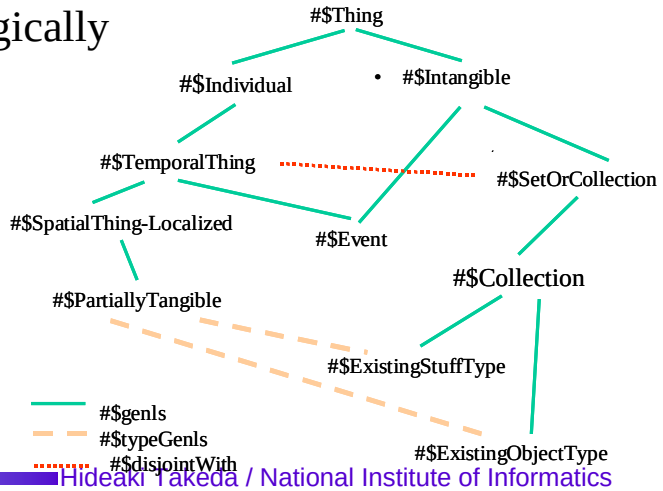
Pragmatic top-level ontology

- SUMO(Suggested Upper Merged Ontology)
  - Collection and organization of concepts used frequently
  - Simple relationship between concepts



Pragmatic top-level ontology

- OpenCyc
  - Cyc: A project to construct very-large common knowledge base
  - OpenCyc: top-level concepts in Cyc knowledge base
    - Cyc: 120, 000 concepts and their relations
    - OpenCyc: 6,000 concepts and their relations
  - Concepts are defined logically



Empirical top-level ontology

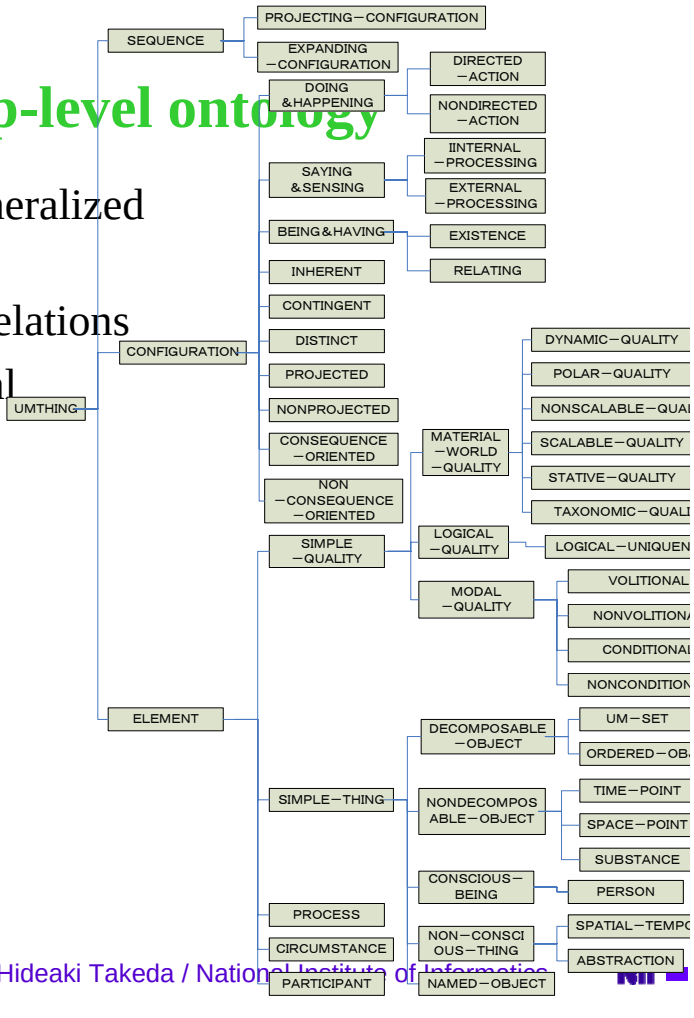
- OpenCyc
  - Basic relations
    - #$genls: set inclusion
      - Hierarchy of categories is set inclusion
    - #$isa: relationship between a class and its instance
      - E.g,
        - (#$isa #$Dog #$BiologicalSpecies)
        - (#$genls #$Dog #$Carnivore)
        - An instance of #$Dog is also an instance of #$Carnivore but not an instance of #$BiologicalSpeicies
    - Logical operators like #$and and #$disjointWith
    - Specific operators like #$biologicalRelatives

Linguistic top-level ontology

- Lexicon, thesaurus and dictionaries are close to ontology
  - Plenty of concepts and their relations
  - Lack of formal system
- Difference between linguistic knowledge and object knolwedge
  - Linguistic knowledge: grammar, categories …
  - Object knowledge: knowledge about target (ontology)
  - Two knowledge are dependent to each other

Linguistic top-level ontology

- Penman Upper Model/The Generalized Upper Model
  - ca. 250 concepts and their relations
  - Initially as a part of a natural language generation system
  - Things and processes



Linguistic top-level ontology

- WordNet
  - A lexical reference system
    - “Link-based electronic dictionary”

http://www.cogsci.princeton.edu/cgi-bin/webwn

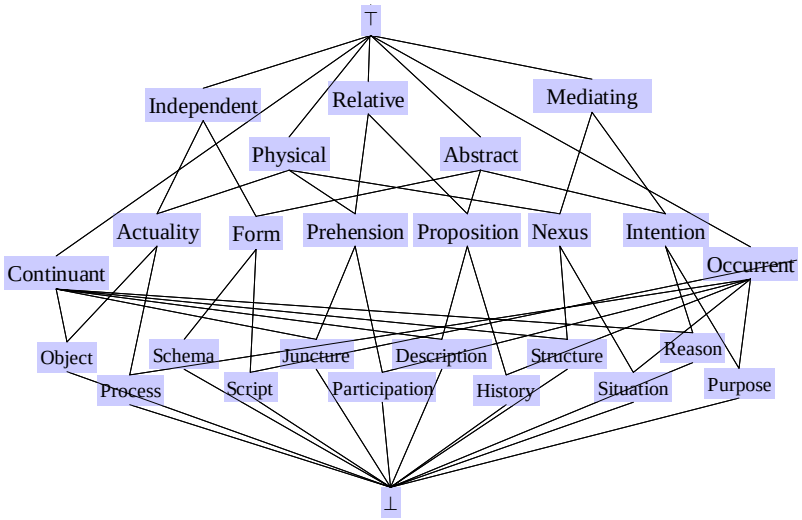
  - Concepts
    - synset
      - Noun 79,689
      - Verb 13,508
  - Relations
    - synonym
    - hypernym/hyponym (is-a)
    - holonym/meronym (a-part-of)

Linguistic top-level ontology

- WordNet
  - Top-level
    - { **entity, physical thing** (that which is perceived or known or inferred to have its own physical existence (living or nonliving)) }
    - { **psychological_feature**, (a feature of the mental life of a living organism) }
    - { **abstraction**, (a general concept formed by extracting common features from specific examples) }
    - { **state**, (the way something is with respect to its main attributes; "the current state of knowledge"; "his state of health"; "in a weak financial state") }
    - { **event**, (something that happens at a given place and time) }
    - { **act, human_action, human_activity**, (something that people do or cause to happen) }
    - { **group, grouping**, (any number of entities (members) considered as a unit) }
    - { **possession**, (anything owned or possessed) }
    - { **phenomenon**, (any state or process known through the senses rather than by intuition or reasoning) }

Formal Ontology

- Sowa's top-level ontology
  - Physical / Abstract
  - Independent / Relative / Mediating
  - Continuant ／ Occurrent

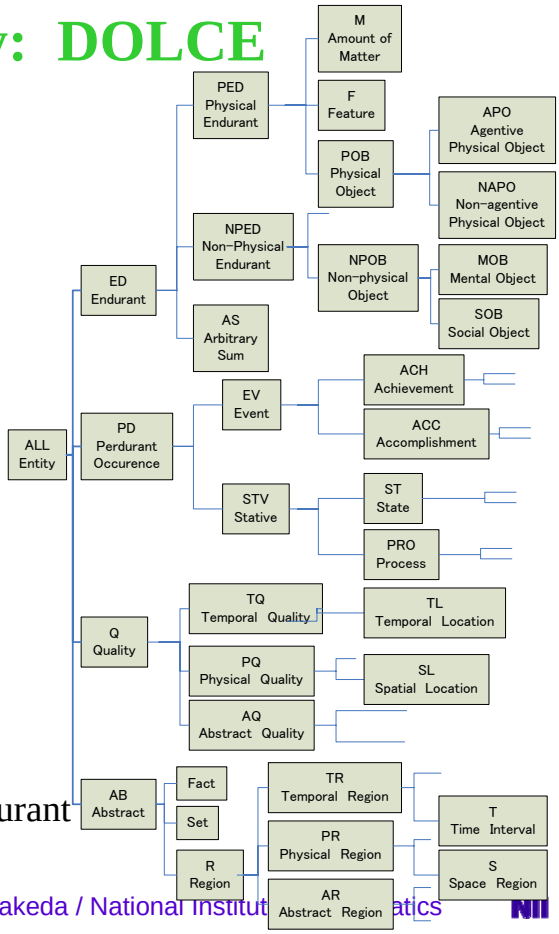


Formal Ontology: DOLCE

- DOLCE(a Descriptive Ontology for Linguistic and Cognitive Engineering)
  - Intended to a reference system for top-level ontology
  - Logical definition
  - Particular (DOLCE) vs. Universal
    - Particular: ontology about things, phenomena, quality…
    - Universal: ontology for describing particular like categories and attributes

Formal Ontology: DOLCE

- Concepts
  - Endurant / Perdurant / Quality / Abstract
    - Endurant:
      - “Things”
      - An existence over time
      - May change its attribute
    - Perdurant
      - “process”
      - No change over time
      - May switch a part to the other
- Relations
  - Parthood (abstract or perdurant)
  - Temporally Parthood (endurant)
  - Constitution (endurant or perdurant)
  - Participation between perdurant and endurant

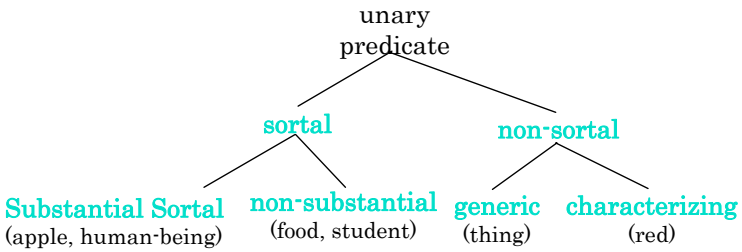


Meta ontology

- Ontology for ontology
  - Only abstract aspect
    - Ontology for Universals
      - Attribute of attribute

Ontology for Universals

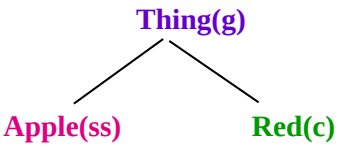
- natural:
  - $C \models \exists x \Diamond Px$
- rigid
  - $C \models \forall x(Px \supset \Box Px)$
- divisive
  - $C \models \exists x \Diamond(Px \wedge \exists y.y<x) \wedge \forall x \Box(Px \supset (\exists y.(y<x \supset Py)))$



- generic predicate : rigid and divisive
- substantial sortal: rigid and non-divisive
- non-substantial sortal: non-rigid natural and subsumed by some substantial sortal
  - $C \models \forall x \Box(Px \supset Sx)$
- characterizing predicate : non-rigid natural and not subsumed by some substantial sortal

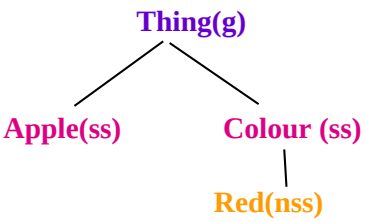
Ontology for Universals

(1)



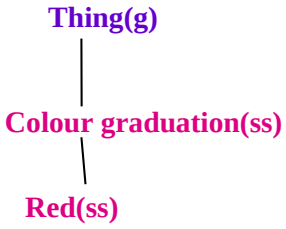
This apple is red.

(2)



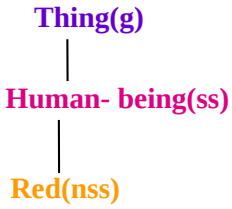
The colour of this apple is red.

(3)

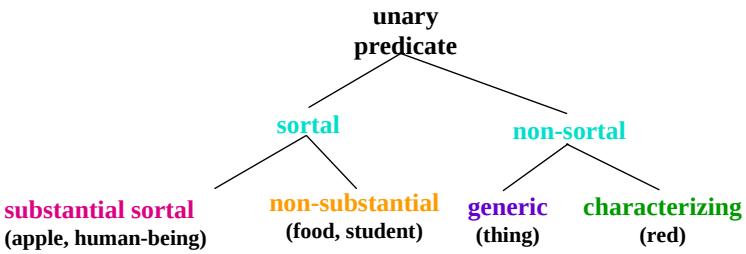


Crimson is a red

(4)

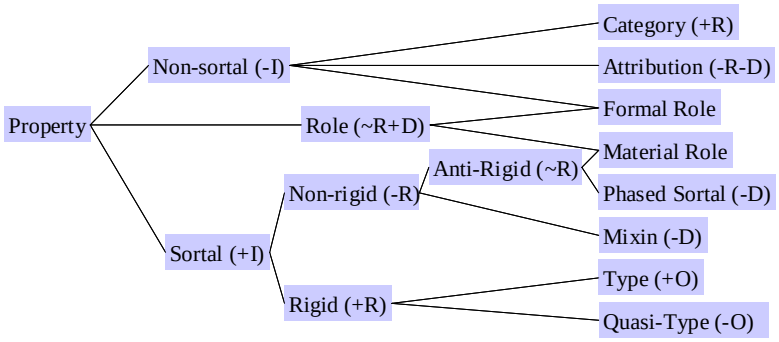


John is red.

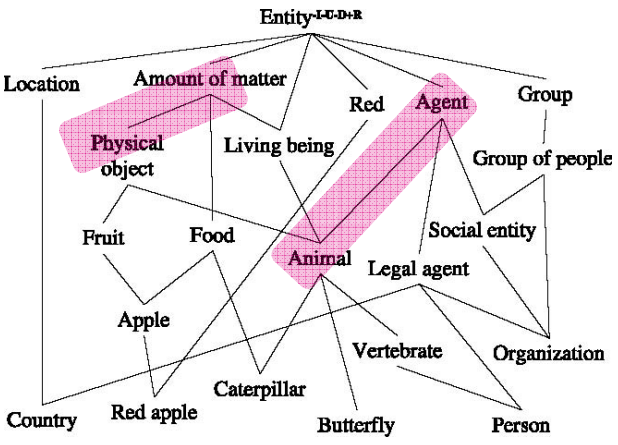


Meta ontology

- Attribute of attribute
  - Rigidity (R)
  - Identity (I)
  - Own Identity (O)
  - Dependency (D)
  - +: should be satisfied
  - -: is not satisfied
  - ~: each attribute is not satisfied

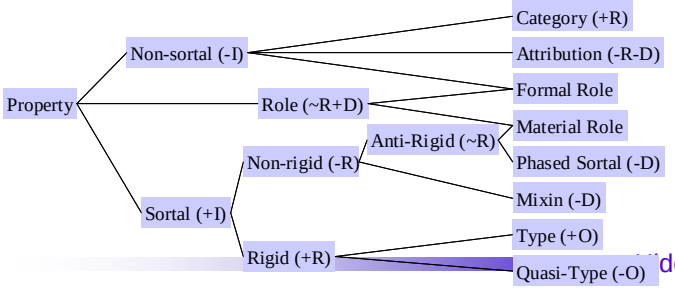


Ontology checking



+D(AGENT) cannot subsume −D(ANIMAL)

～U(AMOUNT−OF−MATTER) .cannot subsume +U(PHYSICAL−OBJECT)



Ontology checking