COMP474/6741

Ontologies

Pools: Chapter 13

Some slides from my course at @MIT, 2010

Today

- Ontologies Overview
- Ontologies History
- Ontologies Motivation
- Elements of an Ontology
- Methodologies for developing Ontologies
- Tips for developing Ontologies
- Some well known Ontologies

Ontologies

- The goal of the science of Ontologies is to study the categories that exist in a domain
- The result of this study is what it is called an **ontology**
- An ontology is a catalog of all the kind of things that we assume that exist in a domain $\mathcal{D}$ from the perspective of someone that uses the language $\mathcal{L}$ to talk about $\mathcal{D}$
- The elements in an ontology represent predicates, constants, concepts and relations that belong to a language $\mathcal{L}$ when used to communicate information about $\mathcal{D}$
- An ontology is a vocabulary

Ontologies

- Logic gives the means to obtain deductions from the information represented in an ontology
- Logic itself is semantically neutral, it is its combination with an ontology what gives to a logic formalism the capacity to express meaning, for example:

$$\frac{P \rightarrow Q \quad P}{Q}$$

This reasoning talks about nothing unless a meaning is given to each atom (P = it rains, Q = I get wet)

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Ontologies-History

- The development of ontologies starts with philosophy
- Aristotle coined the term **Category** as the word to describe the different classes that divide the things from the world
- The term *ontology* is relatively modern (XIX cent.), derives from greek *Ontos* (being) and *Logos* (word) (literally the words to talk about things)
- This term became to be used to distinguish categorization of the being from categorization of living beings in biology
- In fact many areas of science use categorization (Philosophy, biology, medicine, linguistics, ...)

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Ontologies-Motivation

Why it is interesting to use ontologies?

- **Allows to share the interpretation of the structure of the information of a domain among people/agents**
  Defining a common ontology of a domain allows any group of agents to understand each other without ambiguity, they all know what they are talking about
- **Allows to reuse knowledge**
  Describing a domain with a ontology allows to share the definition with other programs that need to use that knowledge
- **Allows to make explicit our conception of the domain**
  The task of formalizing the knowledge of a domain using an ontology helps to think about our conception of the information of the domain and helps others to understand our vision of the domain

Ontologies-Motivation

- **Separates the knowledge of the domain from the procedural and problem solving knowledge**
  Allows to separate the techniques and algorithms used to solve the problem from knowledge of the problem
- **Allows to analyze the knowledge of the domain**
  Once we have a formal description of the knowledge, it can be analyzed by means of logical formal methods (to know if it is consistent, complete, ...)

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Elements of an Ontology

- In the area of Artificial Intelligence an ontology will be an explicit formal description of the concepts of a domain (**Classes**)
- These classes will be described by **properties** that represent characteristics, attributes and relations among the classes
- Additionally these characteristics will have **constraints** (data type, cardinality, ...)
- We will have also instances (identifiable elements) that will represent the actual elements of the domain

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Development of an Ontology

- To develop an ontology for a domain requires:
  - To define the classes that the domain has
  - To organize the classes in a hierarchical taxonomy
  - To define the properties of each class and define their constraints
  - To assign values to the properties to define instances

Methodologies for developing Ontologies

- There is not a unique methodology to develop ontologies, we will use an informal one:
  "Ontology Development 101: A Guide to Creating Your First Ontology", Noy & McGuinness, (2000)
- We have to notice that:
  1. There is no *correct* way to model a domain. The best solution depends on the actual application/problem
  2. The development of an ontology is an iterative process
  3. The elements in the ontology should be close to the concepts and relations used to describe the domain (usually are names and verbs that appear in sentences describing the domain)

Phases of development of an Ontology

- **Phase 1:** Determine the domain and the coverage of the ontology
  - How much of the domain will cover the ontology?
  - What will be the use of the ontology?
  - What kind of questions will have the ontology to answer?
  - Who will use and maintain the ontology?
- **Phase 2:** Consider the reuse of existing ontologies

  An ontology is developed to communicate domain knowledge hence the ability to share the description is one of the goals. It is not necessary to repeat a development that is already done, if an ontology about our domain exists we can add it to our ontology to reduce development time

Phases of development of an Ontology

- **Phase 3:** Enumerate the important terms in the ontology

  A list of terms that are used to describe elements of the domain has to be collected, one easy way to do this is to find sentences that can be used to ask questions about the domain or to explain information of the domain to somebody.

  - What properties have these terms?
  - What do we want to say about them?

Phases of development of an Ontology

- **Phase 4:** Define the classes and their hierarchy

  We can use different approaches

  - **Top down:** The more general concepts are defined and then specialized
  - **Bottom up:** The more specific concepts are defined and then grouped by their common properties generalizing
  - **A combination of both:** The more relevant concepts are defined and specialized and generalized to complete the ontology

  None of these approaches are essentially better and it depends on the domain

Phases of development of an Ontology

- **Phase 5:** Define the properties of the classes
  - The structure of the classes has to be described
  - A list of characteristics will be collected and it will be determined to which classes corresponds each characteristic
  - There are many kinds of properties
    - Descriptive properties, qualities
    - Identifying properties, names
    - Composing parts
    - Relations to instances of other classes
  - A property should be assigned to the more general class and the other classes will inherit it

Phases of development of an Ontology

- **Phase 6:** Define the characteristics of the properties
  - Cardinality (number of values allowed)
  - data type, values
  - Default value
  - Mandatory
  - If it is a relation define cardinality and range
- **Phase 7:** Create instances

  If it is necessary (sometime it will be) create the base instances that will need the domain ontology

Tips for developing Ontologies (1/3)

- Do not include singular and plural names of the same term (the best policy is to use only singular or plural names)
- A name is not the class, the distinction between the name and the class has to be clear. We can have synonyms, but all refer to the same class
- Make sure that the hierarchy is well built and correct
- Be careful with the transitive relations
- Avoid cycles in the hierarchy

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Tips for developing Ontologies (2/3)

- The classes from a level in the hierarchy should have the same generality
- There is no criteria for the number of classes in a level, but experience indicates that a number between two and twelve is the usual, more classes indicates that more structure is needed
- When to add more classes?
  It is hard to use hierarchies that are too wide or too deep, a compromise should be the best, some tips are:
  - The new classes have additional properties that the superclass has not
  - They have different constraints than the superclass
  - They appear in different relations than the superclass

Tips for developing Ontologies (3/3)

- How to decide when to use a property or a new class?
  Sometimes an attribute is important enough to consider that different values correspond to different classes
- How to decide what level is the level of the instances?
  It is necessary to assess the minimum level of granularity needed for the domain
- Limit the coverage of the ontology
  - It is not necessary that the ontology includes all the possible classes from the domain, only enough to cover the necessities of the problem
  - It is also not necessary to include all possible attributes/constraints/relations

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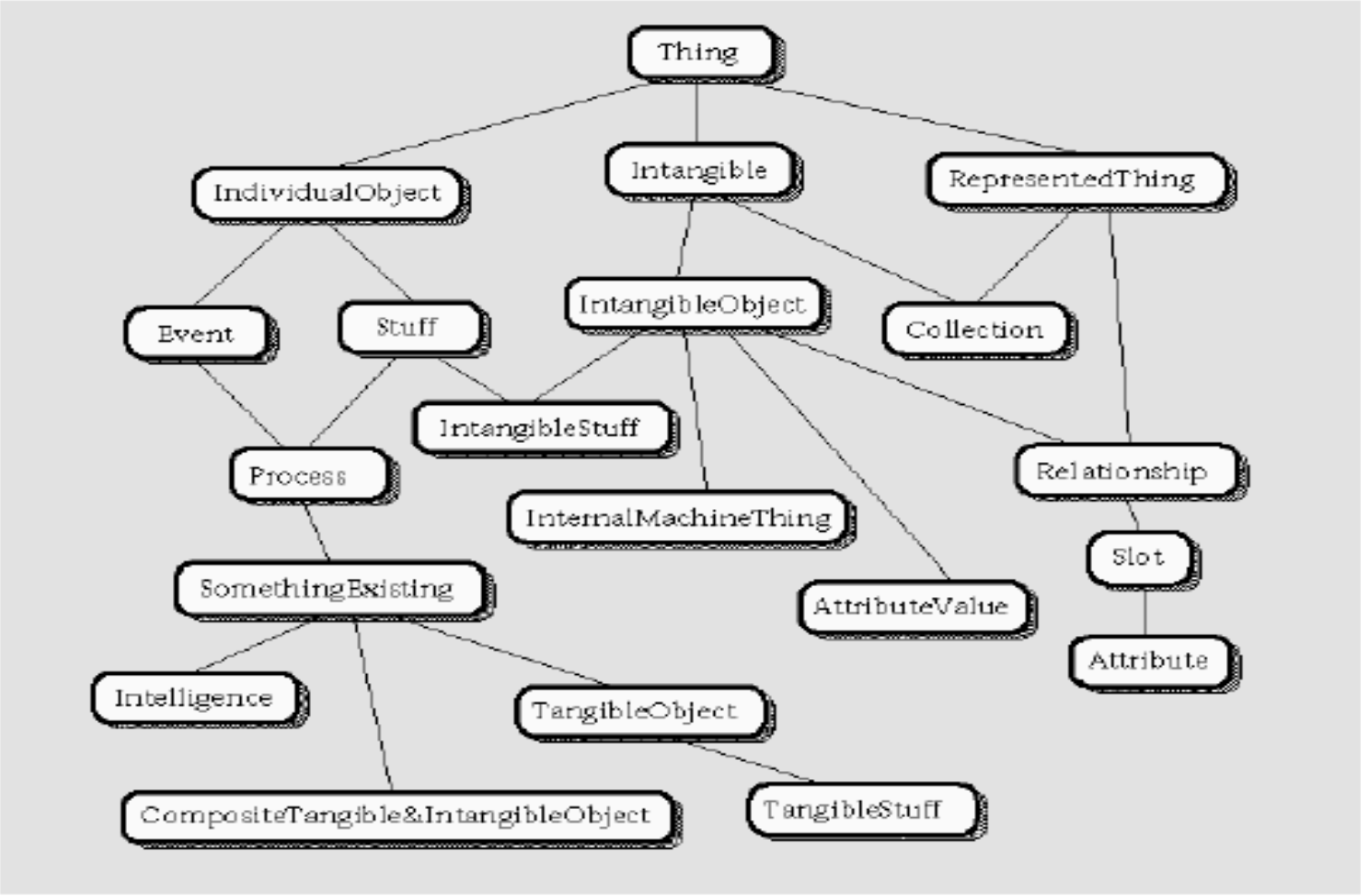
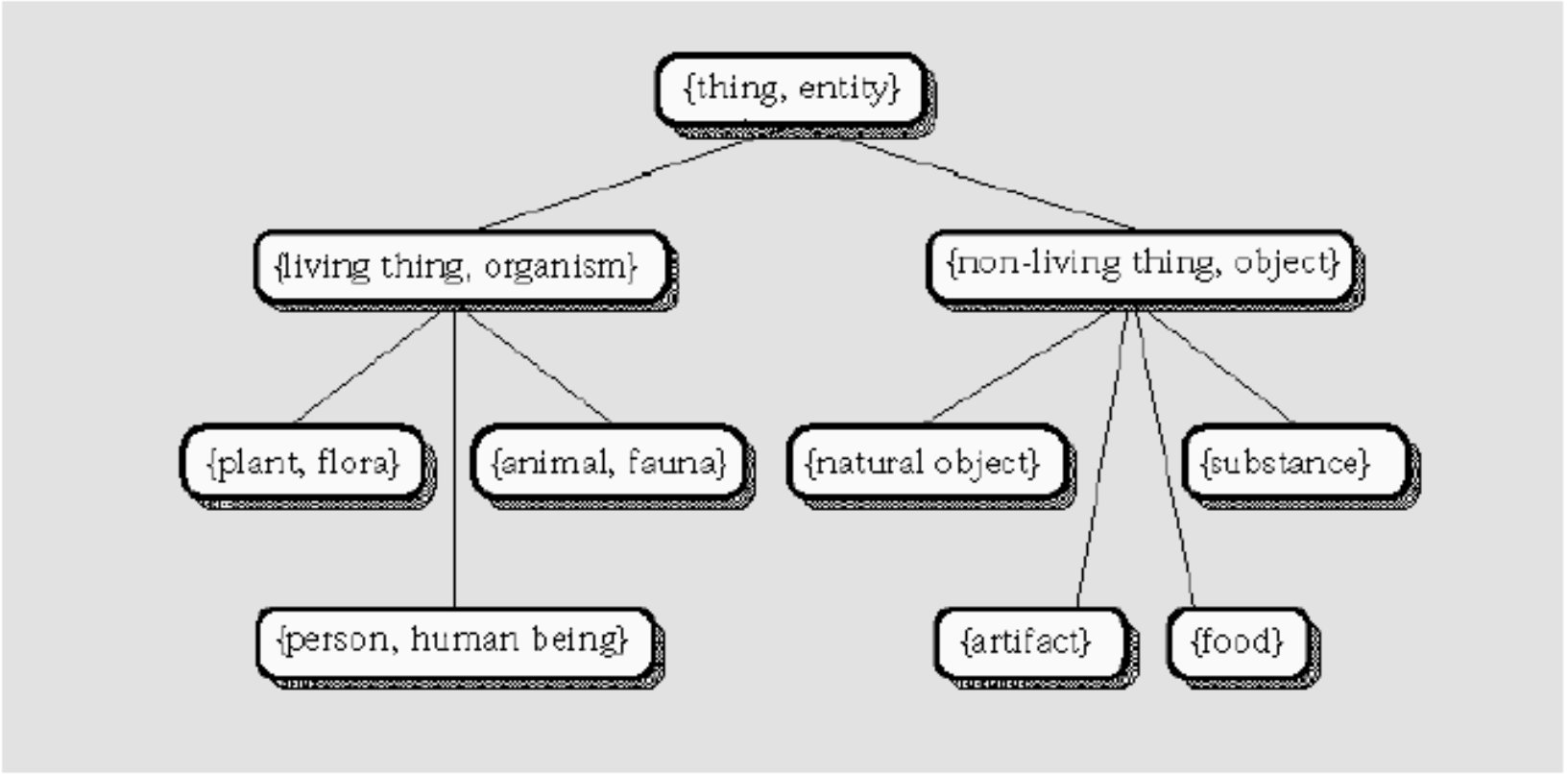
CYC (1985)/OpenCYC (2003) Douglas Lenat

- Example of general ontology
- Goal: Formalization of common sense knowledge
- Hundreds of thousands of concepts, millions of facts about the concepts
- Language CYCL (subset of predicate calculus)
- Specific subsets (micro theories)
- sw.opencyc.org


Thing
IndividualObject
Intangible
RepresentedThing
Event
Stuff
IntangibleObject
Collection
IntangibleStuff
Process
Relationship
InternalMachineThing
Slot
SomethingExisting
AttributeValue
Attribute
Intelligence
TangibleObject
CompositeTangible&IntangibleObject
TangibleStuff

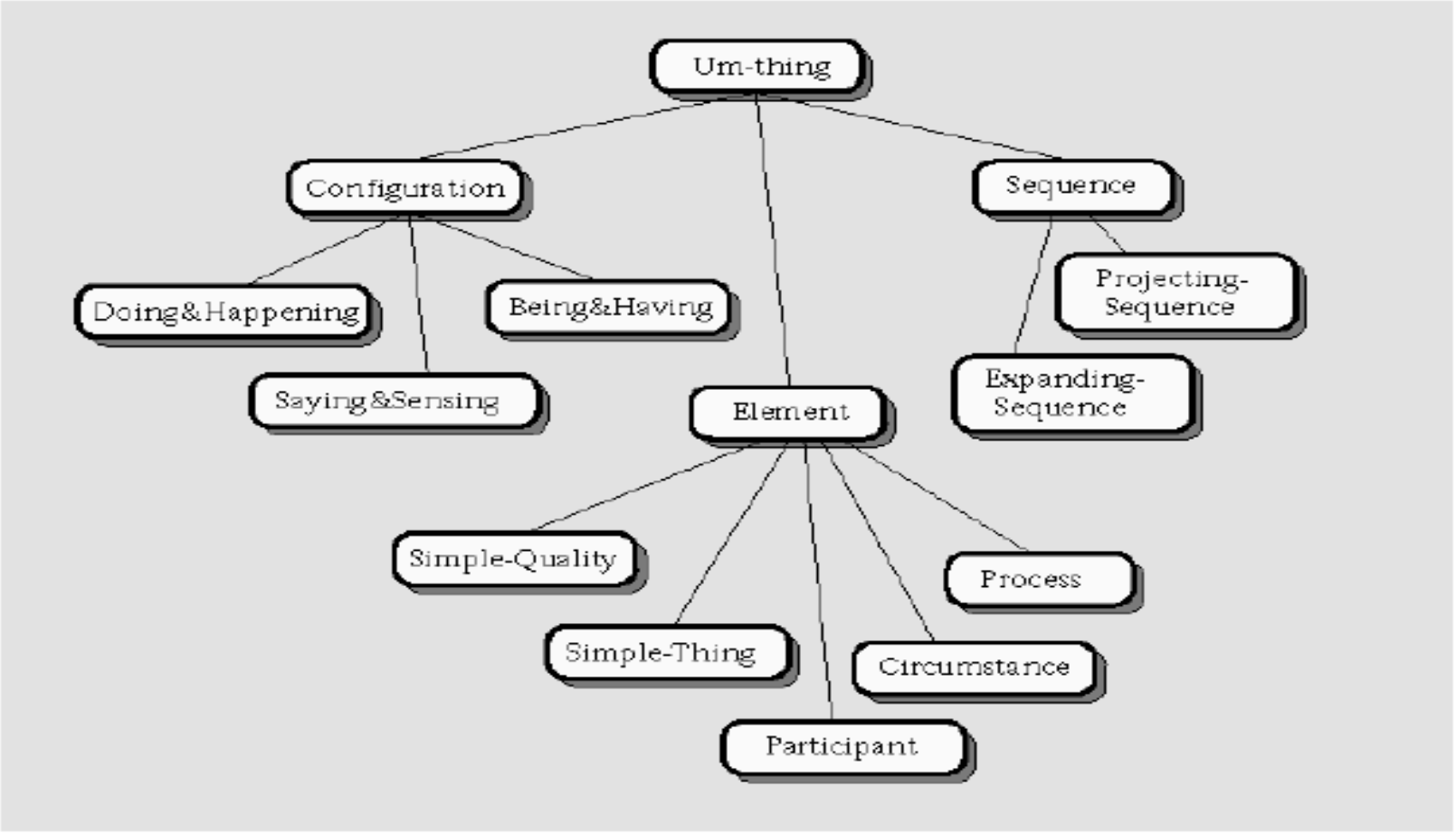
WORDNET (1990)

- Example of application oriented ontology
- Lexical ontology (Organized by semantic categories, tagged with syntactic categories)
- 95.500 words, 70.100 senses
- Semantic networks
- Initially for english language, now developed for many languages
- www.wordvis.com


{thing, entity}
{living thing, organism}
{non-living thing, object}
{plant, flora}
{animal, fauna}
{natural object}
{substance}
{person, human being}
{artifact}
{food}

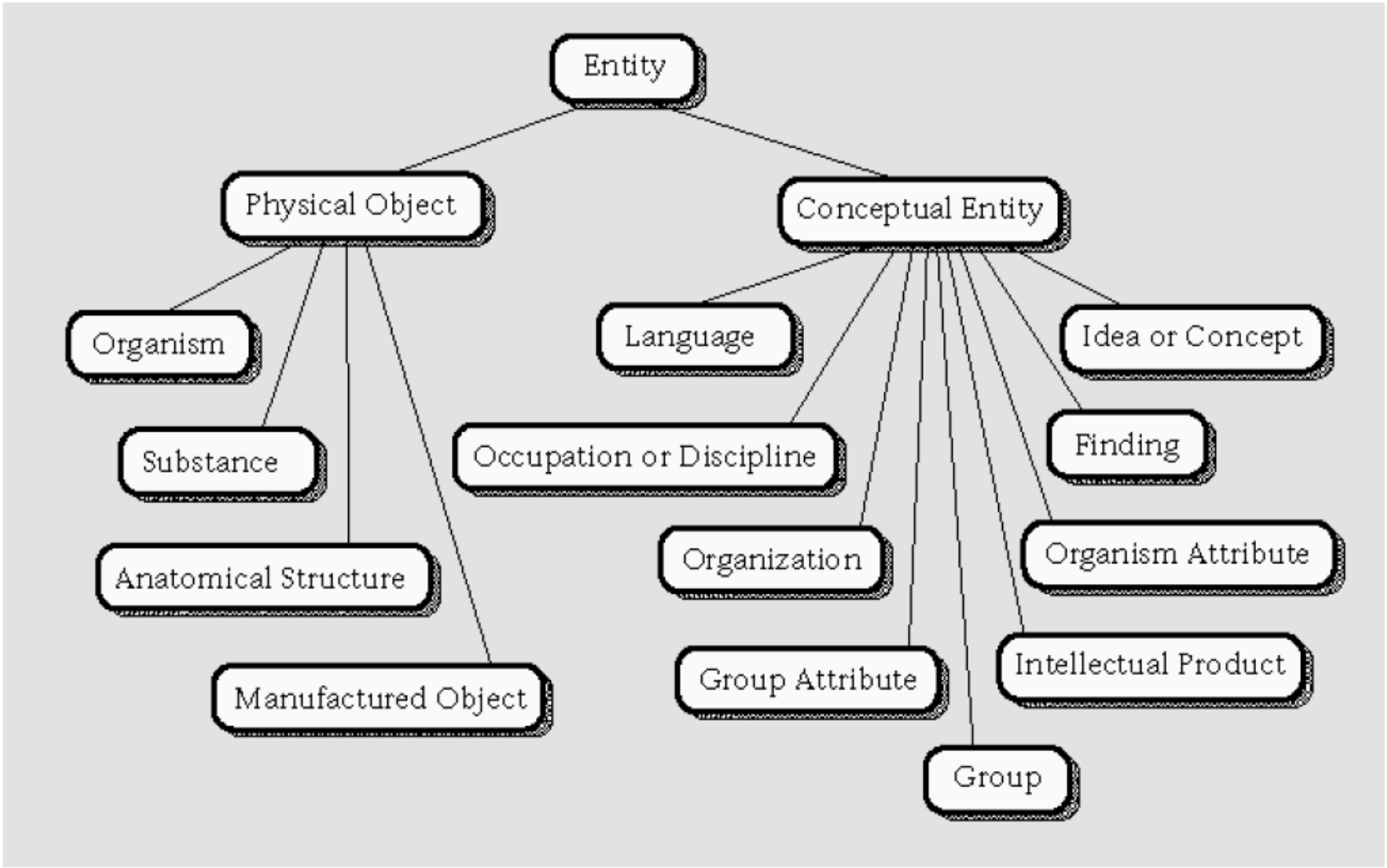
Generalized Upper Model (1994)

- Example of Upper otology
- Lexical ontology (multilanguage, it is only a hierarchy of concepts)
- 250 Concepts
- LOOM (Predicate calculus)


Um-thing
Configuration
Sequence
Doing&Happening
Being&Having
Saying&Sensing
Element
Projecting-Sequence
Expanding-Sequence
Simple-Quality
Simple-Thing
Participant
Circumstance
Process

Unified Medical Language System (1993)

- Example of domain ontology
- Ontology of biomedical terms
- 135 semantic types, 51 semantic relations, 252.982 concepts
- Semantic networks


Entity
Physical Object
Conceptual Entity
Organism
Substance
Anatomical Structure
Manufactured Object
Language
Occupation or Discipline
Organization
Group Attribute
Group
Idea or Concept
Finding
Organism Attribute
Intellectual Product

DAML+OIL/OWL repositories- Semantic Web

- Ontologies for the semantic web
- Hundreds of public ontologies developed in DAML+OIL/OWL
- `http://www.daml.org/ontologies/`
- Any subject:
  - academic department, Actors, address book, airport, Bibliography, Biology, Chemistry, Clothing, Weather, ...

DAML+OIL/OWL - Example

```
<daml:Ontology>
 <daml:Class ID="Animal" />

 <daml:Class ID="ATerrestrial">
  <rdfs:SubclassOf rdf:Resource="#Animal" />
 </daml:Class>

 <daml:Class ID="AAerial">
  <rdfs:SubclassOf rdf:Resource="#Animal" />
  <daml:DisjointWith rdf:Resource="#ATerrestrial" />
 </daml:Class>

 <daml:Class ID="AAquatic">
  <rdfs:SubclassOf rdf:Resource="#Animal" />
 </daml:Class>

 <daml:Class ID="AAnphibious">
  <rdfs:SubclassOf rdf:Resource="#Animal" />
  <daml:Intersectionof>
   <daml:Class rdf:Resource="#ATerrestrial" />
   <daml:Class rdf:Resource="#AAquatic" />
  </daml:IntersectionOf>
 </daml:Class>
</daml:Ontology>
```

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