

## Ontologies - A Very General Overview

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## Preamble

- the meaning of the term "ontology" in computing is different its meaning in philosophy
  - there is a connection, though
- initially, understand the term "ontology" in computing as a **"standard vocabulary"**

## Overview

- context and motivation for ontologies
- definitions
- ontologies for humans, ontologies for machines
- examples: WordNet and CYC; investigation
- stating/expressing an ontology
- reasoning within an ontology
- levels of abstraction; types of ontologies
- ontologies and domain descriptions
- conjecture: ontologies are necessarily required
- ontologies, meta-data, meta-data standard, RDF

## Dialogues between humans and machines

Type of dialogue	Role of Software System (Machine)	Example
human-human (via a software)	acts as a notice board, with some "nice" editing features; it does not need to understand anything of the phrases exchanged by the human agents through it	editor
human-software	may act as a structured repository of data, providing query facilities more or less independent of the meaning of the stored data; the human must know the structure of data and map that structure to meaning	database
human-software	may act as an agent who has some knowledge of a part of "the world" and who is able to communicate a part of that knowledge in response to the human's questions; the human and the software must share the same understanding of the domain (part of "the world")	semantic web
software-software	acts as an agent who has some knowledge of a part of "the world" and who is able to communicate a part of that knowledge in response to another software agent's questions; the two software agents must share the same understanding of the domain (part of "the world")	agents and the semantic grid

## Ontologies - Motivation

- truism: many agents can understand each other only if they share a common language (syntax and semantics)

## Ontology - Definitions

- a **shared** and **common/unitary** understanding of a domain that can be **communicated** between people and heterogeneous software systems (Fensel, 2001)
- a shared and common language (or a standard language) for a specific domain
  - vocabulary
  - syntax / grammar

## Ontologies - Examples

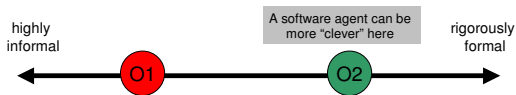
- in medicine ...
- in computing ...
- in the financial sector ...
- in the context of local governmental councils ...
- in museums ...
- *level of abstraction*

## Ontologies – Who Uses Them?

- humans
  - informal
- software agents
  - machine readable (interpretable) - formal

## From Informal to Formal

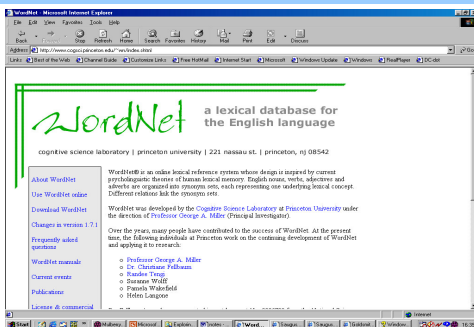
- there is a continuum between informal and formal
  - informally (sic!): the better the quality of the reasoning/processing that a software agent can perform within an ontology, the more formal the ontology is
  - the degree of formality of an ontology increases with its expressive power regarded from the point of view of software agents



## Ontologies - Examples

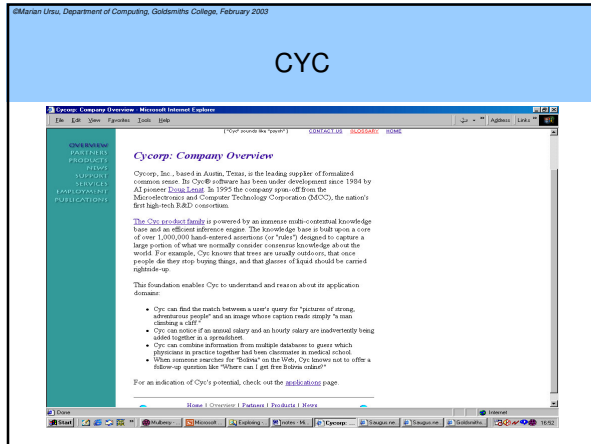
- WordNet
  - informal
  - thesaurus for natural language terms, explained in natural language
- CYC
  - formal
  - theories for common sense knowledge

## WordNet



## WordNet

- <http://www.cogsci.princeton.edu/~wn/>
- explore and discuss its features



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## CYC - Applications

- applications currently available or in development
  - [Integration of Heterogeneous Databases](#)
  - [Knowledge-Enhanced Retrieval of Captioned Information](#)
  - [Guided Integration of Structured Terminology \(GIST\)](#)
  - [Distributed AI](#)
  - [WWW Information Retrieval](#)
- potential applications
  - Online brokering of goods and services
  - "Smart" interfaces
  - Intelligent character simulation for games
  - Enhanced virtual reality
  - Improved machine translation
  - Improved speech recognition
  - Sophisticated user modelling
  - Semantic data mining

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## CYC

- explore and discuss:
  - [Knowledge-Enhanced Retrieval of Captioned Information](#)
  - [WWW Information Retrieval](#)
  - [Integration of Heterogeneous Databases](#)
  - [Guided Integration of Structured Terminology \(GIST\)](#)
  - [Distributed AI](#)

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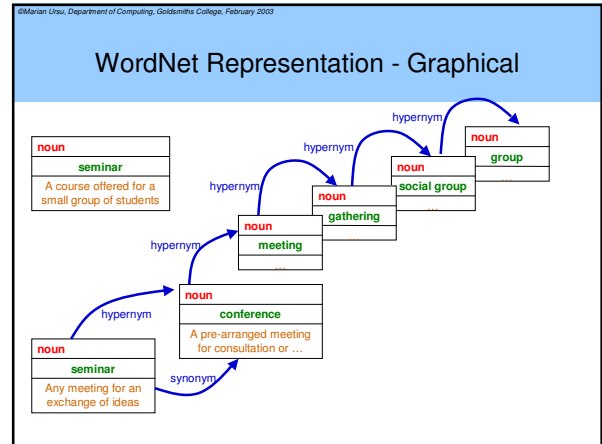
## Stating/Expressing an Ontology; Reasoning

- informal ontology
  - a limited set of pre-defined categories and relationships and abundant natural language annotations
  - limited capabilities for automatic inferences/reasoning
- formal ontology
  - a formal language; for example, a subset of first order predicate logic
  - good capabilities for automatic inferences/reasoning

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## Informal Ontology - Language

- example: WordNet (simplified)
  - some pre-defined categories:
    - Noun: name; explanation
    - Verb: name; explanation
    - Adjective: name; explanation
    - Adverb: name; explanation
  - some pre-defined relationships
    - Synonym
    - Hypernym (X is a kind of ...)
    - Hyponym (... is a kind of X)
  - pre-defined terms are "understood" by the system



## WordNet Representation - Relational DB

**nouns**

Name	Meaning	Description
seminar	1	any meeting for an exchange of ideas
seminar	2	a course offered for a small group of students
conference	1	a pre-arranged meeting for consultation or ...
meeting	1	...
gathering	1	...
social group	1	...
group	1	...
...	...	...

**hypernyms**

Name	Meaning	Name	Meaning
seminar	1	conference	1
conference	1	meeting	1
meeting	1	gathering	1
gathering	1	social group	1
social group	1	group	1
...	...	...	...

**synonyms**

Name	Meaning	Name	Meaning
seminar	1	conference	1
...	...	...	...

## WordNet - Reasoning Capabilities

- find all the explanations for a given noun (name)
- find all the level one synonyms for a certain noun
- find all the level one hypernyms for a certain noun
- find all the hypernyms for a certain noun
- ...
- *quite poor*

## Formal Ontology - Formal Language

- declarative
- a subset of natural language, but much better structured, to the extent that machines can make inferences — can reason — with its expressions
  - to infer/reason means to deduce new expressions from existing ones
- domain categories and relationships can be introduced by means of the language

## Formal Ontology - Example

### FACTS

man(Danny)  
 man(Tony)  
 man(Marian)  
 friend-of(Danny, Tony)  
 friend-of(Marian, Danny)  
 works-for(Lew-Council, Danny)  
 works-for(Lew-Council, Tony)  
 works-for(Gold-Uni, Marian)

### RULES

person(x) IF man(x)  
 person(x) IF woman(x)  
 friend-of(x, z) IF  
 friend-of(x, y) AND  
 friend-of(y, z)  
 colleague-of(x, y) IF  
 works-for(x, z) AND  
 works-for(y, z)

### INFERENCE RULES

FROM fact(a)  
 AND rule(b IF a)  
 INFER  
 fact(b)

## Formal Ontology - Reasoning Capabilities

- find all the men
- find all the persons
- find all the friends of 'marian'
- find all the pairs of friends
- find all the friends of 'marian' who work for Lewisham Council
- are there any colleagues who do not work for the same institution?
- ...
- *quite rich*

## Formal Ontology - Definition

- a formal explicit specification of a shared and consensual conceptualisation (Fensel, 2001)
  - conceptualisation: abstract model of a part of "the world"
  - explicit: the elements of the model and the constraints on their use are explicitly described (as opposed to being implicit in someone's head or embodied in a piece of software)
  - shared and consensual: used unitarily by a group of users
  - formal: machine readable/interpretable (accompanied by inference rules)

## Ontologies vs Databases - Differences

- an ontology is usually syntactically and semantically richer than a database
  - this aspect relates to technology
- an ontology must be shared and consensual terminology
  - this aspect is beyond technology - it relates to the dynamics and interactions between social systems

## Ontology - Ambiguous Term

- a set of abstractions that can be used to describe a part of "the world"
  - is the set of pre-defined categories and relationships of WordNet an ontology?
  - or
  - is WordNet and ontology?

## Ontologies - Different Levels of Abstraction

- ontologies have different levels of abstraction
  - the set of pre-defined categories and relationships of WordNet is more generic than WordNet but they are both ontologies
  - the set of pre-defined categories and relationships of WordNet (plus the corresponding syntax) represent an ontology for the representation of thesauri for natural language (any language)
  - WordNet is an ontology for natural language representations

## Types of Ontologies - Examples

- domain ontologies
  - vocabularies for medicine, museums, government agencies
- ontologies for general and common sense knowledge
  - e.g. for mathematics (numbers, arithmetic operators), for physical descriptions (space, time) and for common sense knowledge (dangerous, avoid, ...)
- representational ontologies
  - domain (understood as above) independent; e.g. the frame ontology (Gruber 1993), for frame based (Object Oriented) representations

## Ontology - Most Frequent Use

- given an information domain such as that of museums, financial institutions or government councils, the term ontology is usually associated with the definition of the terms that can be used to describe the respective domain rather than with particular domain representations
  - making a parallel to database systems, an ontology is usually regarded as the database schema rather than the database itself (note that, in database systems, the difference between the schema/intension of the database and the extension of the database is clearly defined)

## Ontology vs Domain Description

### Ontology

```

man/1
friend-of/2 : person x person
works-for/2 : institution x person
person(x) IF man(x)
person(x) IF woman(x)
friend-of(x, z) IF
  friend-of(x, y) AND
  friend-of(y, z)
colleague-of(x, y) IF
  works-for(x, z) AND
  works-for(y, z)

```

### Domain Description

```

//FACTS
man(Danny)
man(Tony)
man(Marian)
friend-of(Danny, Tony)
friend-of(Marian, Danny)
works-for(Lew-Council, Danny)
works-for(Lew-Council, Tony)
works-for(Gold-Uni, Marian)
//PLUS THE ONTOLOGY

```

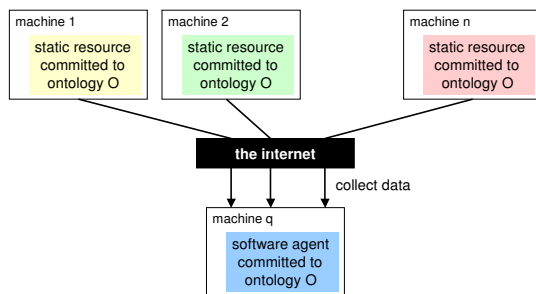
## Skeletal Methodology for Ontology Creation

- identify purpose and scope
- build ontology
  - capture
    - identify key concepts and relationships
    - produce precise unambiguous textual definitions
  - code
    - choose/commit to a representational ontology (meta-ontology)
    - choose language
    - write the code
  - integrate with existing ontologies
- evaluate
- create documentation
- refer to (Uschold and Gruninger, 1996)

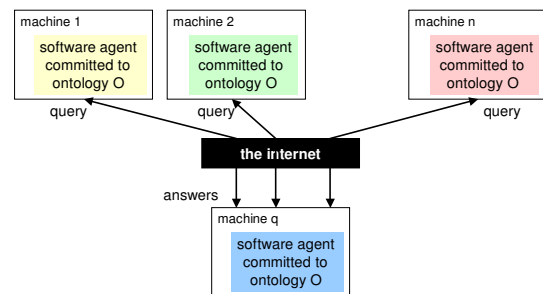
## Ontologies - Conjectures

- ontologies are needed in the context of any knowledge based or knowledge management system, whenever the issue of knowledge sharing arises
- the more refined and formal (sic!) an ontology is, the better are the capabilities for developing "intelligent" software agents
- ontologies are necessarily required for the next stage in the development of the WWW — the semantic web
  - current meta-data standards (e.g., Dublin Core and e-GMS) represent only the beginning (*will become clearer later*)

## Ontologies and the Semantic Web



## Ontologies and the Semantic Web



## Ontologies and Meta-Data

- an ontology can be used to express meta-data
- a meta-data standard/class is an (informal) ontology

## Ontology / Meta-Data Standard and RDF

- "simple":
  - RDF is a domain independent "language" for resource description
    - resource - general meaning (e.g. not restricted to the web)
    - a resource description could be regarded as being equivalent to meta-data
    - RDF is a domain independent language for meta-data descriptions
  - for a specific domain, RDF should be used together with the/a domain's ontology / meta-data standard
    - elements of the vocabulary of an ontology (elements of a meta-data standard) are used to make statements about resources
    - RDF specifies the structure in which such statements should be written

## Summary

- why ontologies
- what are ontologies
- from very informal to rigorously formal
- examples
- representations and reasoning
- types of ontologies
- ontologies and domain descriptions
- the semantic web and ontologies
- ontologies and meta-data standards
- ontologies, meta-data standards and RDF

## References

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