Ontology:
Fundamentals, Issues and the State-of-the-Art

Linguistics

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References
2. What is an Ontology?
2.1 Ontology: The Term

“Ontology” (with capital “O”) in philosophy

- from the Greek \( \text{οντολογία} \)
  - \( \text{oν} \), genitive \( \text{oντς} \): of being (part of \( \text{εινάι} \): to be) = ontos
  - \( -\text{λογία} \): science, study, theory = logos
- the study of being or existence.
- A branch of metaphysics (Greek: \( \text{μετα} \) (meta) = "after", \( \text{φυσικα} \) (physika) = "those on nature")
  - concerned with explaining the nature of the world.
  - It is the study of being or reality.
2.1 Ontology: The Term

“Ontology” (with capital “O”) in philosophy

- It seeks to describe or posit the basic categories and relationships of being or existence to define entities and types of entities within its framework.

- Any ontology must give an account of which words refer to entities, which do not, why, and what categories result.
2.2 Definitions

Varieties of definitions

- Evolution (Gómez-Pérez et al. (2004: 6ff.))
2.2 Definitions

Gómez-Pérez et al. (2004: 8f.)
- Ontologies aim to capture consensual knowledge in a generic way.
- They may be reused and shared across software applications and by groups of people.

Knowledge System Lab. at Stanford University
- An ontology is an explicit specification of some topic.
- It is a formal and declarative representation which includes:
  - the vocabulary (or names) for referring to the terms in that subject area and
  - the logical statements that describe
    - what the terms are,
    - how they are related to each other, and
    - how they can or cannot be related to each other.
2.2 Definitions


- “An ontology defines the basic terms and relations comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary”
  - The terms that are explicitly defined in it
  - The knowledge that can be inferred from it
2.2 Definitions


- “An ontology is an explicit specification of a conceptualization”
  - The most quoted in the literature and by the ontology community
2.2 Definitions


- “Ontologies are defined as a formal specification of a shared conceptualization”

  - Slightly modified version of Gruber’s definition
2.2 Definitions


“An ontology is a formal, explicit specification of a shared conceptualization of a domain of interest”

- Conceptualization: An abstract model of some phenomena in the world by having identified the relevant concepts of that phenomena
- Explicit: types of concepts and the constraints are explicitly defined
- Formal: machine-readable
- Shared: consensual knowledge
2.2 Definitions


- “A logical theory which gives an explicit, partial account of a conceptualization”
  - Conceptualization: The ideas of the world that a person or a group of people can have
  - Formalization of the notion of conceptualization
  - Introduction of logical theory

- Ontology (with capital “O”) vs. ontology (with small “o”)
2.2 Definitions


- “A set of logical axioms designed to account for the intended meaning of a vocabulary”
2.2 Definitions


- “It [an ontology] provides the means for describing explicitly the conceptualization behind the knowledge represented in a knowledge base.”
  - Extracting the ontology from a knowledge base
  - Following a bottom-up strategy
  - By means of an abstraction process
2.2 Definitions


- “An ontology is a hierarchically structured set of terms for describing a domain that can be used as a skeletal foundation for a knowledge base.”
  - The same ontology can be used for building several knowledge bases
  - Merging and sharing the knowledge bases and inference mechanisms become easier.
2.2 Definitions


- Taxonomies are considered full ontologies
- They also provide a consensual conceptualization of a given domain
  - UNSPSC, e-cl@ss, RosettaNet, Yahoo Directory, ...
- Light-weight ontologies vs. heavy-weight ontologies
  - Light-weight ontologies:
    - Ontologies that are mainly taxonomies
  - Heavy-weight ontologies:
    - Ontologies that model the domain in a deeper way and provide more restrictions on domain semantics
2.2 Definitions


- “An ontology may take a variety of forms, but it will necessarily include a vocabulary of terms and some specification of their meaning.”
  - “This includes definitions and an indication of how concepts are inter-related which collectively impose a structure on the domain and constrain the possible interpretations of terms”

- To popularize ontologies in other disciplines
  - Used for different purposes:
    - natural language processing, knowledge management, e-commerce, intelligent integration of information, the Semantic Web, etc.
  - Used different communities
    - Knowledge engineering, database and software engineering
2.3 Ontology in the Classical Tradition

The classical tradition

- The world is defined in terms of categories on the basis of genus and differentiae (Aristotle).
  - Genus: the category to which something belongs
  - Differentiae: the properties that uniquely distinguish the category members from their parent and form one another.

- Example
  - Adult = grown-up human
    - Man = male adult
    - Woman = female adult
  - Child = young human
    - Boy = male child
    - Girl = female child
2.3 Ontology in the Classical Tradition

Classical taxonomy or hierarchy [Vossen (2003: 467)]

- Relations: asymmetric, transitive and reflexive
- Monotonic hierarchy
  - The class membership principle: All members of a class share the properties that defines the class
- Default inheritance hierarchy
  - Default values can be overwritten by specific types (penguins vs. birds)
Multiple classifications and multiple inheritance

- Not trees
- but a tangled network
- Lattice structure
  - It is more efficient than the tree.
  - It does not force one to order the introduction of distinctions at different levels.
    - It can be used to merge taxonomies with different but compatible structures.
    - ANSI Ad Hoc Group on Ontology Standards
  - It introduces a (very) large number of internal nodes for feature combinations that have no natural human interpretation.
2.3 Ontology in the Classical Tradition

Lattice structure with multiple classifications [Vossen (2003: 468)]
## 2.4 온톨로지와 시멘틱 웹

<table>
<thead>
<tr>
<th>정의</th>
<th>온톨로지</th>
<th>웹 온톨로지</th>
</tr>
</thead>
<tbody>
<tr>
<td>공유된 개념화에 대한 형식적이고도 명확하게 명세화하는 것</td>
<td>웹에 나타난 지식을 표현하고, 공유하며, 재사용할 수 있도록 하는 온톨로지</td>
<td></td>
</tr>
<tr>
<td>지식 또는 정보의 체계화와 응용화 등에 관련된 모든 분야</td>
<td>Semantic Web, E-Commerce, Agent, Web Service 등 웹 관련 분야</td>
<td></td>
</tr>
<tr>
<td>특정한 온톨로지 구축 언어 없음</td>
<td>Web Ontology Language (RDF, DAML+OIL, OWL...)</td>
<td></td>
</tr>
<tr>
<td>단어, 어휘(개념), 전문용어...</td>
<td>웹의 정보를 공유할 수 있는 단어, 어휘, 전문용어 등</td>
<td></td>
</tr>
<tr>
<td>WordNet, CYC, UMLS, EDR, Lexical FreeNet, ETRI CoNet...</td>
<td>실험적 수준 (기존 온톨로지의 변환)</td>
<td></td>
</tr>
</tbody>
</table>
2.4 Ontology and the Semantic Web

- 웹 온톨로지(Web Ontology)
  - Ontology Language를 이용한 구축
    - XML을 기반으로 한 Ontology Languages
  - 온톨로지에서 정의된 의미관계, 개념관계, 속성은 웹 온톨로지에서는 Object Property, Data-type Property로 표현됨
3. Types of Ontologies
3.1 Some Terminologies

- **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

- **Top-level Ontology or Upper Ontology**
  - 매우 일반적인 개념을 기술하게 되고,
  - 이미 구축되어 있는 온톨로지의 최상위 개념이 연결될 수 있는 일반개념을 제공
3.1 Some Terminologies

- **Object ontology vs. Task ontology**
  - **Object Ontology**: An ontology on “things” and “events”
  - **Task Ontology**: An ontology on “doing”

- **Task Ontology**
  - 업무 온톨로지 (Task Ontology)는 진단이나 일정짜기, 판매 등 일반적인 업무나 행위에 대한 어휘를 기술한다. 여기에서도 상위 온톨로지에서 정의된 용어들을 특화하게 되는데, 동일한 영역이거나 동일한 영역이 아니라도 일반적으로 업무수행과 관련된 문제를 해결하는 용어들을 포함한다.
3.1 Some Terminologies

Application Ontology

- Application-dependent
- It contains all the definitions needed to model the knowledge required for a particular application

응용 온톨로지 (Application Ontology)는 특정 응용분야에서 요구되는 지식을 모형화하는 데 필요한 모든 정의들을 기술한다. 응용 온톨로지는 혼히 영역 온톨로지와 업무 온톨로지의 어휘들을 해당 응용분야에 맞게 특화하게 된다.
3.1 Some Terminologies

- **Heavy-weight ontology vs. Light-weight ontology**
  - **Heavy-weight ontology:**
    - fully described ontology
    - including concept definitions and relations, in particular in a logical way
  - **Light-weight ontology:**
    - partially described ontology
    - including typically only is-a relations
3.2 Classification

Mizoguchi et al. (1995)

- Content Ontologies
  - Domain Ontologies
    - Object Ontologies: scanner, printer, etc.
    - Activity Ontologies: give birth, etc.
    - Field Ontologies:
  - Task Ontologies
    - Generic Nouns Ontologies: Goal, Schedule
    - Generic Verbs Ontologies: to assign, to classify
    - Generic Adjectives Ontologies: assigned
  - General/Common Ontologies
    - Thing, Event, Time, Space
    - Causality, Behaviour, Function, etc.

- Communication (tell & ask) Ontologies
- Indexing Ontologies
- Meta-Ontologies
3.2 Classification

Van Heilst et al. (1997)

- Amount and type of structure
  - Knowledge Modeling Ontologies
  - Information Ontologies (DB)
  - Lexicons

- Issue of the conceptualization
  - Domain Ontologies: Reusable
  - Application Ontologies: Not reusable
  - Representation Ontologies: Conceptualization of KR formalism
  - Generic Ontologies: Reusable across domains
3.2 Classification

Guarino (1994:9):

- Top-level Ontology
- Domain Ontology
- Task Ontology
- Application Ontology
3.2 Classification

Richness of Internal Structure

- Glossary
- Taxonomy
- Thesaurus
- Catalog
- WordNet
- Ontology

Ontological precision
3.3 Comparisons

Ontology-related Notions

Front-End
- Topic Maps
- Navigation
- Information Retrieval
- Sharing of Knowledge
- Query Expansion

Back-End
- Semantic Networks
- Consistency Checking
- Reasoning
- Context Awareness
- Predicate Logic

Ontologies

Extended ER-Models (Entity Relationship)

Queries

Thesauri

Taxonomies
3.3 Comparisons

**Taxonomy**

- Segmentation, classification and ordering of elements into a classification system according to their relationships between each other.

![Diagram of classification system with nodes: Object, Person, Topic, Document, Student, Researcher, Semantics, Doctoral Student, Ph.D. Student, F-Logic, Ontology.]
3.3 Comparisons

**Thesaurus**
- Terminology for specific domain
- Graph with primitives, 2 fixed relationships (similar, synonym)
- originate from bibliography

![Diagram of thesaurus terms and relationships]

- Object
  - Person
    - Student
      - Doctoral Student
    - Researcher
      - Ph.D. Student
  - Topic
    - Semantics
      - F-Logic
      - Ontology
- Document
  - synonym
  - similar
3.3 Comparisons

- Topic Map (typically for navigation and visualization)
  - Topics (nodes), relationships and occurrences (to documents)
3.3 Comparisons

- Ontology
  - Representation Language: Predicate Logic
  - Standards: RDF(S), OWL

Graphical representation of ontologies and their relationships:
- Person
- Topic
- Document
- Student
- Researcher
- Semantics
- F-Logic
- Ontology

Rules:
- T described_in D
- D is_about T
- P writes D
- D is_about T
- P knows T

Affiliations:
- Tel: +49 721 608 6592
- Affiliation: AIFB
- York Sure

Knowledge representation:
- knows
- describes_in
- writes
- is_about
- subTopicOf
- similar
3.3 Comparisons

An ontology is a formal, explicit specification of a shared conceptualization of a domain of interest.
4. Languages for Building Ontologies
4.1 Languages for Building Ontologies

Languages for Building Ontologies

- HTML (HyperText Markup language)
- XML (eXtensible Markup Language)
- XOL (Xml-based Ontology Exchange Language)
- SHOE (Simple HTML Ontology Extension)
- OML (Ontology Markup Language)
- RDF(S) (Resource Description Framework (Schema))
- DAML (DARPA Agent Markup Language)
- OIL (Ontology Inference Layer)
- OWL (Web Ontology Language)

국내의 온톨로지 언어 연구 대부분을 차지함

OWL
OIL
DAML+OIL
RDF(S)
XML
### Expressivity of Languages for Building Ontologies

<table>
<thead>
<tr>
<th>Expressivity</th>
<th>KIF/S CL</th>
<th>OKBC</th>
<th>F-Logic</th>
<th>LOOM</th>
<th>RDF/S</th>
<th>OWL</th>
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<td>Built-in Functions, Equations, Formulae</td>
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<tr>
<td>Instances / Individuals / Facts</td>
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</tr>
</tbody>
</table>
4.3 Evolution of the Language

- **1990**: Human Understandable data
- **2000**: Structure Understandable data
- **2003-**: Computer Understandable data

**HTML**
- Presentation
- 메타데이터

**XML**
- Syntactic
- 메타데이터

**OWL**
- Semantic
- 메타데이터
4.4 Evolution of the Technologies

Evolution of the Ontology-related Technologies

- **Taxonomy**
  - 시소러스
  - 온톨로지

- **HTML**
  - XML
  - OWL

- **Entity**
  - Relation
  - Event

- **DAML+OIL** 기반
  - OWL 기반
  - SWRL 기반
4.5 Evolution of the Web Standardization

WWW

XML, Web Service

Next-Generation Web: Semantic Web


WWW is invented by Tim Berners-Lee

First WWW Browser

W3C Take-Off: MIT, INRIA, EKIO

XML

RDF/RDFS

OWL/SWRL

Inference/Reasoning

Proof/Trust

DAML-Time

FOAF

SOUPA

온톨로지

IT

XML, Web Service

Web Service

Next-Generation Web: Semantic Web

*Web ware

Semantic Web
4.6 An Example

온톨로지 기술언어인 OWL (Web Ontology Language)로 기술

```xml
<owl:Class rdf:ID="대학교_구성원"/>

<owl:Class rdf:ID="교수">
  <rdfs:subClassOf rdf:resource="#대학교_구성원"/>
</owl:Class>
<owl:Class rdf:ID="부교수">
  <rdfs:subClassOf rdf:resource="#대학교_구성원"/>
</owl:Class>
<owl:Class rdf:ID="조교수">
  <rdfs:subClassOf rdf:resource="#대학교_구성원"/>
</owl:Class>

<owl:ObjectProperty rdf:ID="involve">
  <rdfs:domain rdf:resource="#강의"/>
  <rdfs:range rdf:resource="#대학교_구성원"/>
</owl:ObjectProperty>

<owl:ObjectProperty rdf:ID="isTaughBy">
  <rdfs:subPropertyOf rdf:resource="#involve"/>
  <rdfs:domain rdf:resource="#강의"/>
  <rdfs:range rdf:resource="#대학교_구성원"/>
</owl:ObjectProperty>
```
5. Ontology Tools
# 5. Ontology Editor Survey Results


<table>
<thead>
<tr>
<th>Tool</th>
<th>Release Date</th>
<th>More Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apollo</td>
<td>9/20/02</td>
<td><a href="http://apollo.open.ac.uk/index.html">http://apollo.open.ac.uk/index.html</a></td>
</tr>
<tr>
<td>CoGITaNT</td>
<td>9/14/02</td>
<td><a href="http://cogitant.sourceforge.net/">http://cogitant.sourceforge.net/</a></td>
</tr>
<tr>
<td>Coherence</td>
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<td><a href="http://www.unicorn.com/pr-overview.htm">http://www.unicorn.com/pr-overview.htm</a></td>
</tr>
<tr>
<td>COPORUM OntoBuilder</td>
<td>8/1/02</td>
<td><a href="http://ontoserver.cognit.no/">http://ontoserver.cognit.no/</a></td>
</tr>
<tr>
<td>DAMLImp (API)</td>
<td>7/15/02</td>
<td><a href="http://codip.grci.com/Tools/Components.html">http://codip.grci.com/Tools/Components.html</a></td>
</tr>
<tr>
<td>Differential Ontology Editor (DOE)</td>
<td>9/1/02</td>
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</tr>
<tr>
<td>Disciple Learning Agent Shell</td>
<td>4/1/02</td>
<td><a href="http://lalab.gmu.edu/">http://lalab.gmu.edu/</a></td>
</tr>
<tr>
<td>Enterprise Semantic Platform (ESP) including Knowledge Toolkit</td>
<td>11/30/02 (expected)</td>
<td><a href="http://www.semagix.com/">http://www.semagix.com/</a></td>
</tr>
<tr>
<td>EOR</td>
<td>7/10/01</td>
<td><a href="http://eor.dublincore.org/index.html">http://eor.dublincore.org/index.html</a></td>
</tr>
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</table>
## 5. Ontology Editor Survey Results

<table>
<thead>
<tr>
<th>Editor Name</th>
<th>Release Date</th>
<th>Website Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>ExClaim &amp; CommonKADS Workbench</td>
<td>12/1/01</td>
<td><a href="http://www.ici.ro/ici/expoeng/prodici/prod_12_22/pag_excl0.htm">http://www.ici.ro/ici/expoeng/prodici/prod_12_22/pag_excl0.htm</a></td>
</tr>
<tr>
<td>GALEN Case Environment (GCE)</td>
<td>8/1/02</td>
<td><a href="http://www.kermanog.com/">http://www.kermanog.com/</a></td>
</tr>
<tr>
<td>JOE</td>
<td>7/21/99</td>
<td><a href="http://www.cse.sc.edu/research/cit/demos/java/joe/">http://www.cse.sc.edu/research/cit/demos/java/joe/</a></td>
</tr>
<tr>
<td>KAON (including OIModeller)</td>
<td>9/25/02</td>
<td><a href="http://kaon.semanticweb.org/">http://kaon.semanticweb.org/</a></td>
</tr>
<tr>
<td>KBE -- Knowledge Base Editor (for Zeus AgentBuilding Toolkit)</td>
<td>3/22/00</td>
<td><a href="http://www.isis.vanderbilt.edu/Projects/micants/Tech/Demos/KBE/">http://www.isis.vanderbilt.edu/Projects/micants/Tech/Demos/KBE/</a></td>
</tr>
<tr>
<td>LinKFactory Workbench</td>
<td>7/1/02</td>
<td><a href="http://www.landc.be/">http://www.landc.be/</a></td>
</tr>
<tr>
<td>OilEd</td>
<td>4/12/02</td>
<td><a href="http://oiled.man.ac.uk/">http://oiled.man.ac.uk/</a></td>
</tr>
<tr>
<td>OLR3 Schema Editor</td>
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</table>
### 5. Ontology Editor Survey Results

<table>
<thead>
<tr>
<th>Tool Name</th>
<th>Date</th>
<th>URLs</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><a href="http://www.ontologos.com">http://www.ontologos.com</a></td>
</tr>
<tr>
<td>OntoEdit</td>
<td>8/6/02</td>
<td><a href="http://www.ontoprise.de/com/ontoedit.htm">http://www.ontoprise.de/com/ontoedit.htm</a></td>
</tr>
<tr>
<td>PC Pack 4</td>
<td>4/27/2001 (predecessor)</td>
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<td>RDFAuthor</td>
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<td><a href="http://rdfweb.org/people/damian/RDFAuthor/">http://rdfweb.org/people/damian/RDFAuthor/</a></td>
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<tr>
<td>RDFedt</td>
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<tr>
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<td><a href="http://www.semtalk.com/">http://www.semtalk.com/</a></td>
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</tbody>
</table>
## 5. Ontology Editor Survey Results

<table>
<thead>
<tr>
<th>Editor</th>
<th>Date</th>
<th>Website</th>
</tr>
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<tbody>
<tr>
<td>SymOntos</td>
<td>4/1/02</td>
<td><a href="http://www.symontos.org">http://www.symontos.org</a></td>
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<tr>
<td>Taxonomy Builder</td>
<td>8/1/02</td>
<td><a href="http://www.semansys.com/about_composer.html">http://www.semansys.com/about_composer.html</a></td>
</tr>
<tr>
<td>TOPKAT</td>
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<td><a href="http://www.ai.i.ed.ac.uk/~jkk/topkat.html">http://www.ai.i.ed.ac.uk/~jkk/topkat.html</a></td>
</tr>
<tr>
<td>WebODE</td>
<td>7/10/02</td>
<td><a href="http://delicias.dia.fi.upm.es/webODE/">http://delicias.dia.fi.upm.es/webODE/</a></td>
</tr>
</tbody>
</table>
5. Protégé 3.1 beta
5. OntoStudio
6. The Most Outstanding Ontologies
6.1 Ontology in KR/AI/CS

Evolution

- Simple knowledge representation system (e.g. conceptual networks) → More complex knowledge representation formalisms (KL-ONE)

Knowledge representation systems

- Collins and Quillian (1969):
  - Differences in response time
  - Traversing more nodes in the so-called conceptual networks requires more processing
6.1 Ontology in KR/AI/CS

Early work in knowledge representation

- Focus on conceptual primitive
  - Shank (1973): Conceptual dependency structure

- Focus on the actual representation formalism and mechanism
  - KL-ONE: Brachman and Schmolze (1985)
    - Complex facts, relations, and properties can be expressed

- Supports description logics
6.1 Ontology in KR/AI/CS

- Standardizing knowledge representation formalisms
  - Knowledge Interchange Format (KIF, Genesereth (1991))
  - Frame Ontology in KIF (Gruber (1992))
  - The OKBC (Open Knowledge Base Connectivity) Ontology (Chaudhri et al. (1998))
6.1 Ontology in KR/AI/CS

Building KR systems

- Extremely labour-intensive and complex tasks
- DL used in small systems for specific domains
  - Complex schemata for cars: Rychtyckyj (1996)
  - Traffic control: Gaizauskas and Humphrey (1997)
6.1 Ontology in KR/AI/CS

Large Ontologies: Cyc (Lenat and Guha (1990))

- A formalized representation of a vast quantity of fundamental human knowledge
- Facts, rules of thumb, and heuristics for reasoning about the objects and events of every-day life
- Stored in a formal representation language CycL
6.1 Ontology in KR/AI/CS

**Trends**
- Completeness in coverage is more important than the richness of knowledge
- Large-scale vocabularies with very limited reasoning are preferred.

**Recent development**
- RDF(S) Knowledge Representation Ontology
- OIL Knowledge Representation Ontology
- DAML+OIL Knowledge Representation Ontology
- OWL Knowledge Representation Ontology
6.2 Ontology in Linguistics

The differences of foci
- Cognitive model and AI
  - The classes and types as categories that organize our mental knowledge and processing capacity
- Linguistic approaches
  - The meanings of words

Two main approaches in the linguistic tradition
- Semantic features or meaning components
  - Words are associated with features that predict syntactic structures or behaviour
- Lexical semantic networks
  - Words are defined in terms of relations to each other
Semantic features or meaning components

- A limited set of abstract semantic features for describing linguistic phenomena
  - Syntactic alternation (Levin (1993))
  - Logical metonymy (Pustejovsky (1999))

- Experimental NLP lexicons
  - ACQUILEX (Brisco, Copestake & de Paiva (1993))
  - CORELEX (Buitelaar (1998))
  - DELIS (Heid et al. (1995))
  - MikroKosmos lexical database (Mahesh & Nirenburg (1995a, b))

- PENMAN Upper Model
  - Bateman (1990) and Bateman et al. (1994)
6.2 Ontology in Linguistics

Lexical semantic networks
- Mainly on verbs
- Diagnostic frames and lexical semantic relations (Cruse (1986))
- WordNet 2.1 (Miller et al. (1990), Fellbaum (1998))
- EuroWordNet (Vossen (1998))
- The EDR database (Yokoi (1996))
6.2 Ontology in Linguistics

Linguistic Approaches

- Use and extension of linguistic concepts
- Partially abstract and partially general
- **Pros: understandable**
- **Cons: limitation to the linguistic world**
- **Examples**
  - Penman Upper Model,
  - WordNet,
  - EuroWordNet (using Inter Language Index (ILI))
  - The MikroKosmos ontology,
  - SENSUS ontology, etc.
6.2 Ontology in Linguistics

Lexicon, thesaurus and dictionaries are close to ontology
- Plenty of concepts and their relations
- Lack of formal system

Difference between linguistic knowledge and object knowledge
- Linguistic knowledge: grammar, categories ...
- Object knowledge: knowledge about target (ontology)
- Two knowledges are dependent to each other
6.2 Ontology in Linguistics

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
6.2 Ontology in Linguistics: PUM

Class Hierarchy
6.2 Ontology in Linguistics: WordNet

WordNet: A lexical reference system

- Princeton 대학교의 George A. Miller (1986) 시작
- "Link-based electronic dictionary"
  - 명사, 동사, 형용사, 부사의 의미를 개념-의미 관계와 어휘 관계를 통해 일련의 다른 단어와 연결해 표상한 의미망(Semantic Network)
  - 각각의 품사 범주들은 상이한 의미 속성을 반영하도록 달리 처리됨

Concepts (WN v1.6 ca. 130,000)

- synset
  - Noun: 94,000 entries
  - Verb: 10,000 entries
  - Adjective: 20,000 entries
  - Adverbs: 4,500 entries

Relations

- synonym
- hypernym/hyponym (is-a)
- holonym/meronym (a-part-of)
6.3 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
6.3 Top-level Ontology: 3 Approaches

- **Formal Approaches**
  - Logical formalization
  - Fully Abstract

- **Linguistic Approaches**
  - Use and extension of linguistic concepts
  - Partially abstract and partially general

- **Empirical Approaches**
  - Use and extension of everyday concepts
  - Mostly general
6.3 Top-level Ontology: Formal Approaches

Formal Approaches

- Logical formalization
- Fully Abstract
- **Pros:** clean
- **Cons:** hardly understandable
- e.g., Sowa’s top-level ontology, DOLCE
6.3 Top-level Ontology: Formal Approaches

- Sowa’s top-level ontology
  - Physical / Abstract
  - Independent / Relative / Mediating
  - Continuant / Occurrent
6.3 Top-level Ontology: Formal Approaches

- DOLCE (A Descriptive Ontology for Linguistic and Cognitive Engineering)
- Intended to a reference system for top-level ontology
- Logical definition
- DOLCE is an ontology of particulars
- Particular (DOLCE) vs. Universal
  - Particular:
    - Ontology about things, phenomena, quality, etc.
    - Particulars are entities which have no instances.
    - Its domain of discourse is restricted to them.
  - Universal:
    - Ontology for describing particulars like categories and attributes
    - Universals are entities that can have instances
    - Properties and relations (corresponding to predicates in a logical language) are usually considered as universals.
6.3 Top-level Ontology: Formal Approaches

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
Hierarchy of Concepts
6.3 Top-level Ontology: Empirical Approaches

Empirical Approaches

- Use and extension of everyday concepts
- Mostly general
- Pros: understandable and applicable to all the world
- Cons: lack of solid foundation
- e.g. SUMO, Cyc, EDR
6.3 Top-level Ontology: SUMO

SUMO

- Suggested Upper Merged Ontology
- created as part of the IEEE Standard Upper Ontology Working Group (Ian Niles).
- The goal of this Working Group is to develop a standard upper ontology that will promote
  - data interoperability,
  - information search and retrieval,
  - automated inferencing, and
  - natural language processing.
- The SUMO has been translated into various representation formats, but the language of development is a variant of KIF (a version of the first-order predicate calculus).
6.3 Top-level Ontology: SUMO

- SUMO contains terms chosen to cover the most general concepts needed to represent the world.
- Approximately 4,000 assertions – including over 800 rules – define its 1,000 concepts.
- SUMO terms are mapped to all 100,000 WordNet synonym sets.
- The structural relations defined in SUMO, in particular “subclass,” are basic for defining any ontology, including SUMO itself.
6.4 Domain Ontologies

- E-commerce ontologies
- Medical ontologies
- Engineering ontologies
- Enterprise ontologies
- Chemistry ontologies
- Knowledge management ontologies
Part 2 Issues and the State-of-the-Art
1. Building Ontologies
1. Building Ontologies

- **1. Building Ontologies**
  - Building Ontologies
    - **Building Ontologies Purpose Setting**
    - **Domain Setting of Ontology**
    - **Gathering and Analyzing Domain Information**
    - **Semantic Web Language Determination**
    - **Ontology Internal Structure Design**
    - **Ontology Tool Determination**
    - **Construction of Ontology**
    - **Evaluation of Ontology**
      - **Evaluation by Application**
      - **Evaluation by Expert**
    - **Ontology Version Management**
      - **Ontology Effectiveness**
      - **Ontology Version Management**
      - **Construction Tool Usage Decision**
    - **Maintenance of Ontology**
1.1 Basic Approaches

3 Approaches to constructing ontologies

- **Top-down**
  - Thing
  - Person
  - Material
  - Process

- **Bottom-up**
  - Generalize

- **Middle-out**
  - Specialize
1.2 A New Hybrid-Approach

A New Approach: Hybrid-Approach

- **Top-down**
- **Bottom-up**
- **Middle-out**

**Middle-into**

- generalize
- specialize

- specialize
- generalize

- specialize
2. Composition
2. Composition

### Composing ontologies
- Goal: guide and speed the task of ontology construction
- Method:
  - Composing theories
- Tools: Loom, etc.

Adapted from: the list of current and expected feature of the Ontosaurus Ontology Server
3. Pruning
3. Pruning

Pruning ontologies

- **Goal:** helps a designer to delete terms that are not needed for a given domain
- **Subtask:**
  - Removal or generalisation of the pieces of knowledge using the terms to prune
  - Illustration:

![Diagram showing pruning process](image)
4. Extraction
4. Extraction

Ontology extraction

- Goal: speed the enumeration and organization of the hundreds or thousands terms needed to model a domain
- Example:
  - Extracting a domain-specific ontology from a broad coverage ontology.
  - Illustration:

```
Select Relevant Terms
Link Seed Terms
Extract Selected Subset
(a) (b) (c)
```
5. Merging
5. Merging

**Ontology merging**

- Goal: helps a designer to augment an ontology or a knowledge base by extracting and incorporating selected parts from independently developed ontologies (cf. figure below).
- Example:
  - Merging parts of one ontology into another.

![Ontology A](ontologia.png) ![Ontology B](ontologia.png)

Ontology a'
5. Merging

Ontology Merging

- Problems:
  - The extraction and merging operation presents a variety of technical challenges.
  - Different naming conventions
    - they may refer to the same underlying concept with different names, or different concepts with same name.
  - Isolation
    - Because ontologies are richly interconnected, the process of extracting only selected concepts requires deciding how to isolate the desired portions from the remainder of the ontology.
  - Axioms and Definitions
    - The axioms and definitions written in the context of the originating ontology must be reinterpreted and made consistent with those in the receiving context.
5. Merging

- **Ontology Merging**
  - Some of these problems can be solved pragmatically.
  - Different Naming Conventions
    - The problem with naming conventions is solved in the Ontosaurus using a mapping table that can translate between common naming conventions. The problem of name mismatch between ontologies can be solved by mapping concepts in both ontologies to a common reference ontology (e.g. SENSUS) and using the reference ontology for name alignment.
  - The problem of different definitions can be resolved by merging the definitions and allowing the user to resolve conflicts when they arise.
  - The problems with lifting axioms from one context to another, however, is considerably harder and requires fundamental advances in the theory of contexts.
    - The development of the theory of contexts on further development of the formal theory of contexts with the goal of
      - (1) providing formal understanding of the process of combining ontologies, and
      - (2) pragmatically making the merging of ontologies efficient.
6. Ontology
Validation/Evaluation
6. Ontology Validation

Ontology validation

Subtask:

- Identifying and editing undefined terms, and keeping agenda mechanism (as in: Expect and its future extensions)
- Identifying conflicts and inconsistencies
- Verify the completeness of the ontology
  
  Subtasks:
  
  - Verify that all referenced terms are defined
  - Verify that all instances of a term in a partition belong to exactly one of the partition subclasses
  - Verify that all subsumption relations implicit in the definitions have been made explicit

- Identify semantic differences between two terms in different ontologies
  (e.g.: identifying similar terms in different ontologies, identifying the same term in different versions of an ontology)
7. Standardization
7. Standardization

Merging different paradigms

- NLP is moving towards inferencing systems that exploit common-sense knowledge (semantics).
- Small-scale information systems can become efficient when more general bits and pieces of information are (re-)used.
7. Standardization

Standardization of the content of ontologies

- Advantages
  - Different disciplines can benefit from the same ontology
  - Existing ontologies can be reused
  - Ontologies can be compared or evaluated

- Organizations
  - EAGLES (Expert Advisory Group on Language Engineering Standards)
    - http://www.ilc.cnr.it/EAGLES/home.html
  - ANSI Ad Hoc Group on Ontology Standards
    - http://www-ksl.stanford.edu/onto-std/
8. Issues, Projects, Research Groups and Some Useful Pointers
8.1 Ontology Research (in Korea)

- **Word Network**
- **Ontology**
- **Semantic Network**
- **Thesaurus**
- **Dictionary/Encyclopedia**
- **Taxonomy/Classification**
- **Controlled Vocabulary**

---

**Conceptual Ontologies**
- Korean WordNet: U-WIN, CoreNet, KorLex...
- Korean Thesaurus: Omron Information Thesaurus...
- Existing Thesaurus: Using Korean Ontology..."controlled vocabulary" using existing Thesaurus...

---

**Web Ontologies**
- KT Web Services: Using Korean Ontology (Currently under development)
- KISTI Knowledge-based R&D Knowledge-based Ontology: Using existing services (Currently under development)
- Geographic/Construction/Tour Information... Ontology: (Experimental level)
- JOsitional 표준상품 온톨로지: (Web Ontology is not)

---

**Ontology-based Basic Services**
- KISTI Knowledge-based Basic Services: KT Basic Services
- Financial Information and Financial Institutions: Related Services...

---

**Ontology-based Basic Services**
- Ontology-based Basic Services: (Web Ontology) Semantic Web-related Logic Services, Meaning Note Technology
- Semantic Web-based Tool Development
- Semantics Web-based Basic Services: Most of
8.1 Ontology Research (in Korea)

- **국가 IT 온톨로지 인프라 기술개발**
  - 연구책임자: 최기선 (KAIST)
  - 참여연구기관: 산업체(코리아 와이즈넛, 솔트룩스), 연구기관 (ETRI, KAIST), 대학교 (숭실대학교, 경북대학교, 영남대학교, 부산대학교, POSTECH, 충남대학교), 외국 (Univ. College Dublin, Univ. of Karlsruhe)
  - 정보통신부 (정보통신연구진흥원)
  - 2006-

- **언어중립적 온톨로지**
  - 연구책임자: 채희락 (HUFS)
  - 2차 BK21 (한국학술진흥재단)
  - 2006-
8.2 Ontology Research (Semantic Web)

Ontology Research (Semantic Web)

- Ontology Language
- Ontology Editor
- Ontology Construction
- Ontology Application
- Ontology Versioning
- Ontology Inference
- Ontology Semantic Annotation
- Ontology Evaluation

Ontology Query Language: RDQL, SWRL
Ontology Web Service: OWL-S

Protégé, OilEd, SWOOP, OntoBuilder, OntoEdit, SymOntoX...
Multi-function Editor (in present)
Evaluation of Ontology Editor (in present)

Reuse of the existing resource: WordNet...
Language-based Ontology Building
Tool-based Ontology Building
Ontology Merging/Integration/Division
Ontology Information Extraction

Semantic Search Engine
Knowledge Management System
Product Search System
Information Generation
Multi Agent System
Design System (hardware, architecture...)

Rule-based Inference
DL-based Inference
Inference Engine-Based Inference...

XML, RDF, RDFs, DAML+OIL, OWL
8.3 Research World-Wide

Reference
- Knowledge Annotation Initiative of the Knowledge Acquisition Community (KA)
- [http://hcs.science.uva.nl/usr/richard/ka2/research-topic.html#ontologies](http://hcs.science.uva.nl/usr/richard/ka2/research-topic.html#ontologies)

Research-groups
- KSI-Stanford University,
- SWI-University of Amsterdam,
- AIFB-University of Karlsruhe,
- LIA-Technical University of Madrid,
- ISI-University of Southern California,
- National Research Council-Italy,
- Boeing,
- LRI-University of Paris-Sud,
- IRIT-University Paul Sabatier,
- KMi-Open University,
- SMI-Stanford,
- Osaka University,
- AIG-University of Nottingham,
- Unilever,
- University of Murcia,
- IRST
8.3 Research World-Wide

Researchers:

- Peter Clark, Boeing (USA)
- Natalya Fridman Noy, Northeastern University (USA)
- Carole D. Hafner, Northeastern University (USA)
- Mike Uschold, Boeing (USA)
- Asun Gomez-Perez, Technical University Madrid (Spain)
- Mariano Fernandez (Technical University Madrid, Spain)
- Adam Farquhar, Stanford University (USA)
- Nicola Guarino, National Research Council (Italy)
- Richard Benjamins, University of Amsterdam (the Netherlands)
- Ashok K. Goel, Georgia Tech (USA)
- Bill Swartout, University of Southern California/ISI (USA)
- Bob Wielinga, University of Amsterdam (the Netherlands)
- Chantal Reynaud, Lab of Research in Informatics (France)
- Chris Welty (Vassar College)
- Cristiano Castelfranchi (Italy)
- Derek Sleeman, University of Aberdeen (UK)
- Dieter Fensel, University of Karlsruhe (Germany)
- Rudi Studer, University of Karlsruhe (Germany)
- Ed Hovy, University of Southern California (USA)
- Enric Plaza, IIIA, Spain
- Enrico Motta, Open University (UK)
- Frank Puppe, University of Wuerzburg (Germany)
- Gertjan van Heijst, Knowledge Centre CIBIT (the Netherlands)
- Guus Schreiber, University of Amsterdam (the Netherlands)
- Hans Akkermans, Free University Amsterdam (Netherlands)
- John Bateman, Steling University (United Kingdom)
- John Gennari, UC-Irvine (USA)
- Joost Breuker, University of Amsterdam (the Netherlands)
- Kris Van Marcke, Bolesian (Belgium)
- Mark A. Musen, Stanford (USA)
- Masahiro Hori, IBM, (Japan)
- Michael Gruninger, University of Toronto (Canada)
- Nathalie Aussenac, University of Toulouse (France)
- Nigel Shadbolt, University of Nottingham (UK)
- Rodrigo Martinez Bejar, University of Murcia (Spain)
- Jose Palma, University of Murcia (Spain)
- Riichiro Mizoguchi, Osaka University (Japan)
- Vipul Kashyap, Applied Research at Bellcore, (USA)
- Pim Borst, Unilever (the Netherlands)
8.4 Related Topics

- Related-topics
  - Problem-solving methods,
  - software engineering,
  - knowledge management,
  - knowledge representation,
  - knowledge modeling,
  - intelligent information integration,
  - description-logics,

- Sub-topics
  - Theoretical foundations,
  - Methodologies,
  - Software applications

- Journals:
  - Knowledge Engineering Review (special issue: 1998, 13(1))
  - IEEE-Intelligent Systems (special issue: 1999, February)
  - Data and Knowledge Engineering
Projects

- Almost all projects are referred to at http://www.cs.utexas.edu/users/mfkb/related.html,
- including Ontolingua, Plinius, Kactus, Methontology, Generalized Upper Model, Sensus Ontology, HPKB, Wordnet, (KA)2, GRASP, Onto2agent, and many others

Application-areas:

- knowledge management,
- knowledge representation,
- natural language understanding

Products:

- the Ontology Server (Stanford, Madrid, Nijmegen),
- ODE,
- VOID (the Kactus toolkit),
8.6 Some Useful Pointers

- **Bibliographies:**
  - http://www.kr.org/top/bibliography.html

- **Mailing-lists:**
  - ontology@cs.umbc.edu,
  - kaw@swi.psy.uva.nl

- **Webpages:**
  - http://www.medg.lcs.mit.edu/doyle/top/

- **International-funding-agencies:** EC-Esprit

- **National-funding-agencies:** DARPA (USA), NWO (NL)
8.6 Some Useful Pointers

Some Ongoing KBS/Ontology Projects and Groups

- Mailing Lists
- Conceptual Graphs -
  - Archive (Recent emails)
  - Archive (Ancient emails)
  - Subscription information
- KAW - Knowledge Aquisition Mailing List.
- KAW-PSM - Knowledge Aquisition: Problem-Solving Methods mailing list.
- Knowledge and Information Systems - Journal.
- Mail Archives - for Interlingua, KQML, MADEFAST, Ontolingua, and SRKB.
- onto-std and ontology mailing lists - the former for the ANSI Ad Hoc Group on Ontology Standards, the latter for general AI discussions on ontologies.
- Subscription Information - for KAW, Conceptual Graphs, KQML, Knowledge Sharing, and Interlingua.
8.6 Some Useful Pointers

On-Line Proceedings

- **KAW’96** - Proceedings (1996, Banff, Canada).
  
  http://ksi.cpsc.ucalgary.ca/KAW/KAW96/KAW96Proc.html

  
  http://www.aifb.uni-karlsruhe.de/WBS/dfe/PSM/main.html

- **ProKSI’97** - workshop report from the 2nd workshop on Product Knowledge Sharing and Integration.
  
  http://www.ai.cs.uni-magdeburg.de/~proksi/ProKSI-97/

  
  http://www.aifb.uni-karlsruhe.de/WBS/dfe/dlfl

- **IJCAI’97 Workshop on Problem-Solving Methods** - proceedings.
  
  http://www.aifb.uni-karlsruhe.de/WBS/dfe/PSM/main.html

  

- **ECAI’98 Workshop on Applications of Ontologies and Problem-Solving Methods**
  
  http://delicias.dia.fi.upm.es/WORKSHOP/ECAI98/papers.html

- **V&V Workshop ’98** - The 1998 European Meeting on Validation and Verification of KBSs.
  
  http://www.cs.vu.nl/~frankh/VVKR98>V&V

  
  http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-10
8.6 Some Useful Pointers

On-Line Proceedings

- **CommonSense’98** - Proc. 4th Symposium on Logical Formalizations of Common Sense Reasoning.
  http://www.dcs.qmw.ac.uk/research/krr/events/CS98/
- **IJCAI’99 Workshop on Ontologies an Problem-Solving Methods.**
  http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-18/
- **IJCAI’99 Workshop on Knowledge Management and Organizational Memories.**
  http://www.inria.fr/acacia/WORKSHOPS/IJCAI99-OM/proceedings.html
- **KAW’99** - papers from the 1999 workshop.
  http://sern.ucalgary.ca/KSI/KAW/KAW99/papers.html
  http://ol2000.aifb.uni-karlsruhe.de/
- **IJCAI’2001 Workshop on the IEEE Standard Upper Ontology** (Aug 6, 2001)
  http://reliant.teknowledge.com/IJCAI01/index.html
  http://www.ceur-ws.org/Vol-44/
  http://lsdis.cs.uga.edu/SemNSF/
- **Proceedings of the EKAW’04 Workshop on Core Ontologies in Ontology Engineering** (2004)
  http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-118/
- **Advancing Domain Vocabularies - MMI Workshop** (2005) - focusing on mapping and serving domain vocabularies.
  http://marinemetadata.org/examples/mmihostedwork/ontologieswork/mmiworkshop05 name=mmi-workshop
8.6 Some Useful Pointers

Some useful pointers on ontologies

- Cyc: http://www.cyc.com/
- MikroKosmos: http://crl.nmsu.edu/Research/Projects/mikro/
- WordNet: http://wordnet.princeton.edu/
- EDR: http://www.iijnet.or.jp/edr/
- LDC (Linguistic Data Consortium): http://www.ldc.upenn.edu/
- ELDA (European Language Resource Association): http://www.elra.info/
- Description Logic: http://www.dl.kr.org/
(Selected) References

- 신효필 (2004), 지식기반 (Knowledge Base)으로서의 온톨로지 (Ontology)와 시맨틱 웹 (Semantic Web). 한국정보처리학회 학회지 11:64-75.
- 이경일 (2006), 온톨로지 응용, 한국인지과학회 추계학술대회 특강 발표자료.
- 최기선 (2006), 국가 IT 온톨로지 구축, CoreOnto 워크샵 발표자료.
- 한국과학기술원 전문용어언어공학연구센터 (2005), CoreNet - 한국어 어휘의미망. 대전: KAIST Press.
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