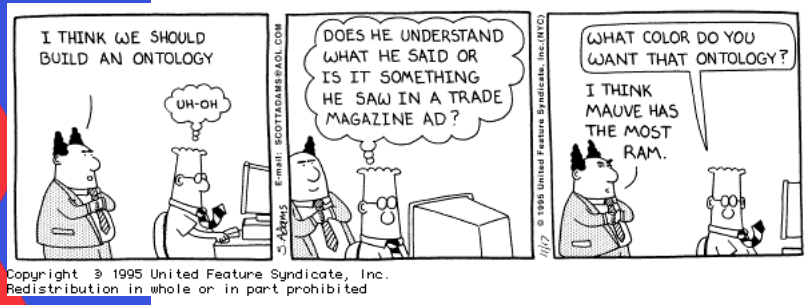
Ontology Engineering



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07/02/2018
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About all the material that we will use

- The material used in these sessions has been elaborated by Oscar Corcho by reusing existing materials from several OEG members:
  - Asunción Gómez-Pérez
  - María Poveda
  - Mari Carmen Suárez de Figueroa Baonza
  - Mariano Fernández-López
  - etc.

Session objective

You should be able to define what ontologies are and understand what their main components are

Table of Contents

- Definition of ontologies
- A bit of history
- Ontology components
- Types of ontologies

Open question

- How many of you have heard about the word "ontology"?
  - For those who have heard about it…
    - What is an ontology?
- Same for "vocabulary"
  - What is a vocabulary?

Vocabularies (ontologies)

Vocabularies *define concepts and relations used to describe and represent a domain of interest.*

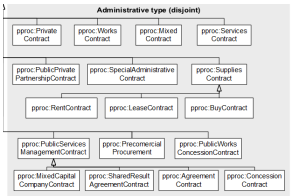
Adapted from: http://www.w3.org/standards/semanticweb/ontology

Ontology definition (I)

- What is an ontology?
  - A vocabulary, with consensus, described in a formal manner

We define terms, how they are classified, their properties, relations, etc.

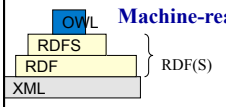
In standard Web languages such as RDF Schema / OWL



Adapted from "Soporte para desarrollo de vocabularios para datos abiertos: Un caso de uso para contaminación acústica" de Oscar Corcho, Paola Espinoza, María Poveda

Ontology definition (II)

"An ontology is a formal, explicit specification of a shared conceptualization"



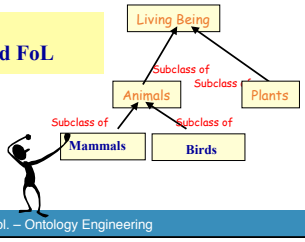
Machine-readable

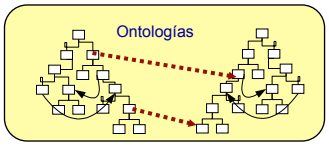
Concepts, properties relations, functions, constraints, axioms, are explicitly defined

Consensual Knowledge

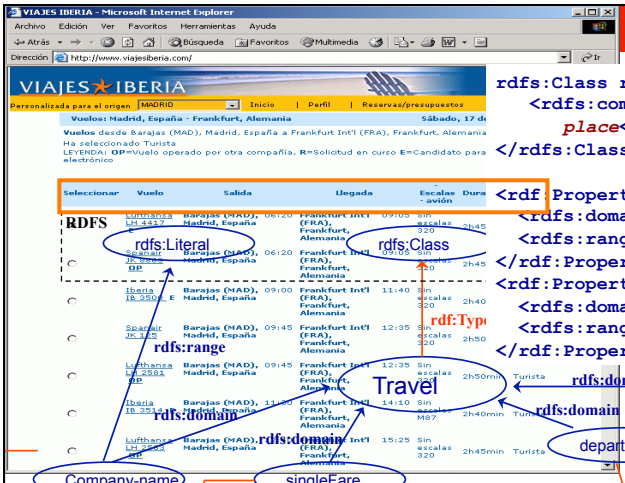
Abstract model and simplified view of some phenomenon in the world that we want to represent

Frames and FoL



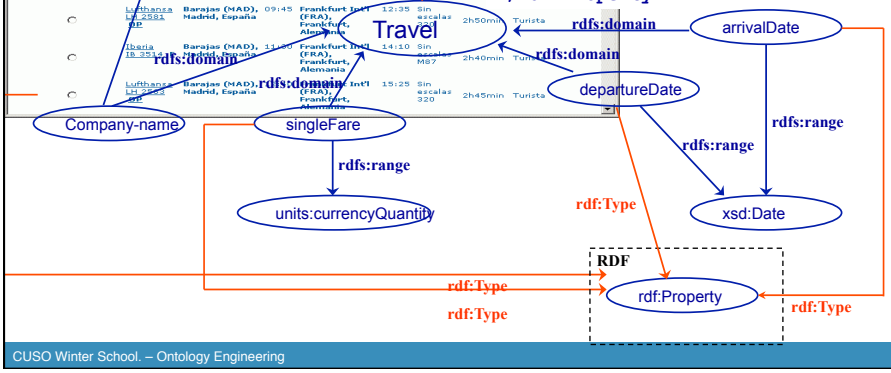


Ontology

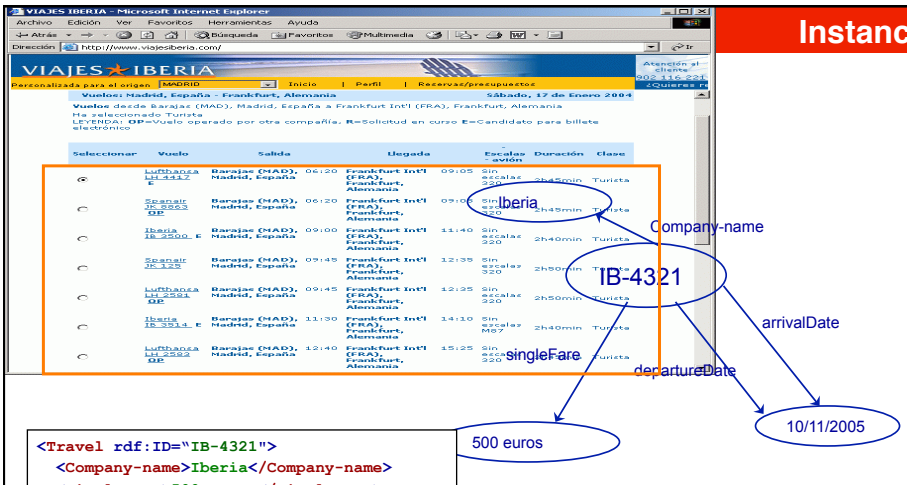



```
rdfs:Class rdf:ID="Travel">
  <rdfs:comment>A journey from place to
    place</rdfs:comment>
</rdfs:Class>

<rdf:Property rdf:ID="arrivalDate">
  <rdfs:domain rdf:resource="#Travel"/>
  <rdfs:range rdf:resource="&xsd;date"/>
</rdf:Property>
<rdf:Property rdf:ID="departureDate">
  <rdfs:domain rdf:resource="#Travel"/>
  <rdfs:range rdf:resource="&xsd;date"/>
</rdf:Property>
```

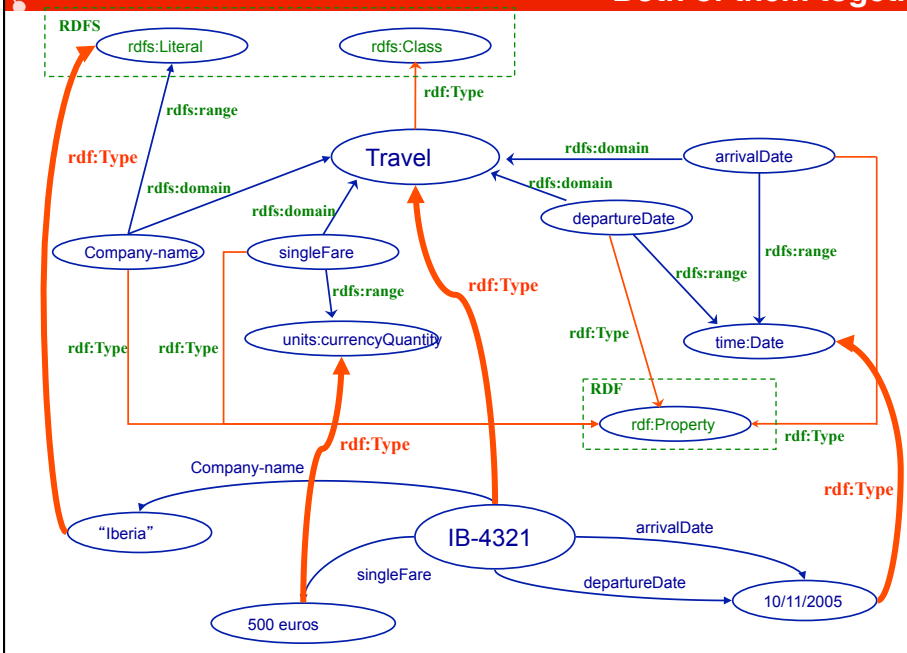


Instances




```
<Travel rdf:ID="IB-4321">
  <Company-name>Iberia</Company-name>
  <singleFare>500 Euros</singleFare>
  <departureDate rdf:datatype="&xsd;date">
     2005-11-10
  </departureDate>
 <arrivalDate rdf:datatype="&xsd;date">
     2005-11-10
  </arrivalDate>
  <arrivalPlace rdf:resource="#Paris"/>
</Travel>
```


Both of them together



Many other definitions for ontology

1. "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"

Neches, R.; Fikes, R.; Finin, T.; Gruber, T.; Patil, R.; Senator, T.; Swartout, W.R. *Enabling Technology for Knowledge Sharing.* AI Magazine. Winter 1991. 36-56.

2. "An ontology is an explicit specification of a conceptualization"

Gruber, T. *A translation Approach to portable ontology specifications.* Knowledge Acquisition. Vol. 5. 1993. 199-220.

3. 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.

B. Swartout; R. Patil; k. Knight; T. Russ. *Toward Distributed Use of Large-Scale Ontologies* Ontological Engineering. AAAI-97 Spring Symposium Series. 1997. 138-148.

4. An ontology provides the means for describing explicitly the conceptualization behind the knowledge represented in a knowledge base.

A. Bernaras;I. Laresgoiti; J. Correra. *Building and Reusing Ontologies for Electrical Network Applications* ECAI96. 12th European conference on Artificial Intelligence. Ed. John Wiley & Sons, Ltd. 298-302.

OWL (we will check it in depth later)

- OWL: Web Ontology Language
- Goal
  - Describe the semantics of information in a domain in a machine processable manner
- Based on Description Logics (*DL*)
  - Describe a domain according to its concepts (*classes*), roles (*relationships*) and individuals
    - Specific languages and sub-languages (or profiles) are characterised by the constructors and axioms that are used to declare knowledge about classes, relations and individuals

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- Definition of ontologies
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A bit of history: The knowledge Sharing Initiative

"Building new Knowledge Based Systems today usually entails constructing new knowledge bases from scratch. It could instead be done by assembling reusable components. System developers would then only need to worry about creating the specialized knowledge and reasoners new to the specific task of their systems. This new system would interoperate with existing systems, using them to perform some of its reasoning. In this way, declarative knowledge, problem-solving techniques, and reasoning services could all be shared between systems. This approach would facilitate building bigger and better systems cheaply. The infraestructure to support such sharing and reuse would lead to greater ubiquity of these systems, potentially transforming the knowledge industry ..."

Neches, R.; Fikes, R.; Finin, T.; Gruber, T.; Patil, R.; Senator, T.; Swartout, W.R. *Enabling Technology for Knowledge Sharing.* AI Magazine. Winter 1991. 36-56.

A bit of history: Reusable Knowledge Components

Ontologies

Describe domain knowledge in a generic way and provide agreed understanding of a domain

Problem Solving Methods

Describe the reasoning process of a KBS in an implementation and domain-independent manner

Interaction Problem

Representing Knowledge for the purpose of solving some problem is strongly affected by the nature of the problem and the inference strategy to be applied to the problem [Bylander et al., 88

Bylander Chandrasekaran, B. Generic Tasks in knowledge-based reasoning.: the right level of abstraction for knowledge acquisition. In B.R. Gaines and J. H. Boose, EDs *Knowledge Acquisition for Knowledge Based systems*, 65-77, London: Academic Press 1988.

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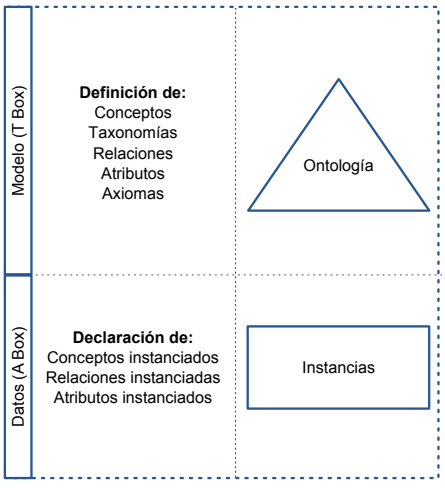
Open question

- Which components are needed to encode ontologies?

Mention as many as you think that are necessary

Ontology structure



- Two main parts:
  - **Tbox** (*Terminological KB*): axioms that define the domain:
    - Painter ⊏ Person
    - Person ≡ Man ⊔ Woman
  - **Abox** (*Assertional KB*): axioms that describe situations:
    - Picasso: Man
    - authorOf (Picasso, Guernica)
  - We can also find…
    - **RBox**
    - **EBox** (*extensional box*)

Adapted from "Ontologies: Introduction" Mari Carmen Suárez-Figueroa, Asunción Gómez-Pérez

Main Components of an Ontology

Concepts are organized in taxonomies

Relations R: $C_1 \times C_2 \times \ldots \times C_{n-1} \times C_n$

Subclass-of: Concept 1 x Concept2
Connected to: Component1 x Component2

Functions F: $C_1 \times C_2 \times \ldots \times C_{n-1} \rightarrow C_n$

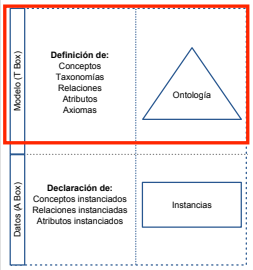
Mother-of: Person --> Women
Price of a used car: Model x Year x Kilometers --> Price

Instances Elements

Axioms Sentences which are always true

Gruber, T. *A translation Approach to portable ontology specifications.* Knowledge Acquisition. Vol. 5. 1993. 199-220.

Ontologies: Components: Concepts

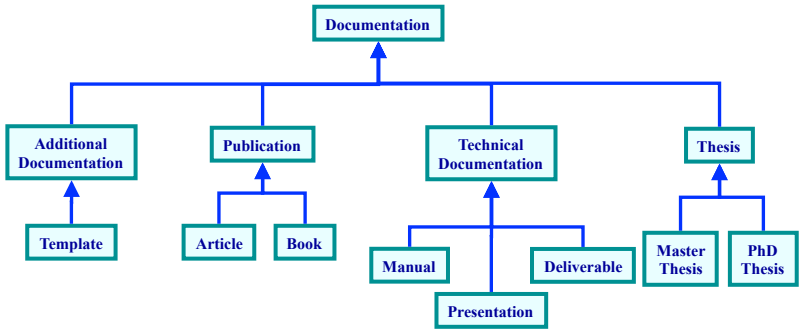


Concepts:

Documentation, Thesis, Book, Template, etc.

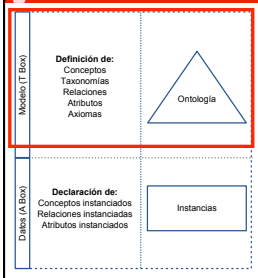
Taxonomy:

- *Article is subclass of Publication*
- *Master Thesis is subclass of Thesis*



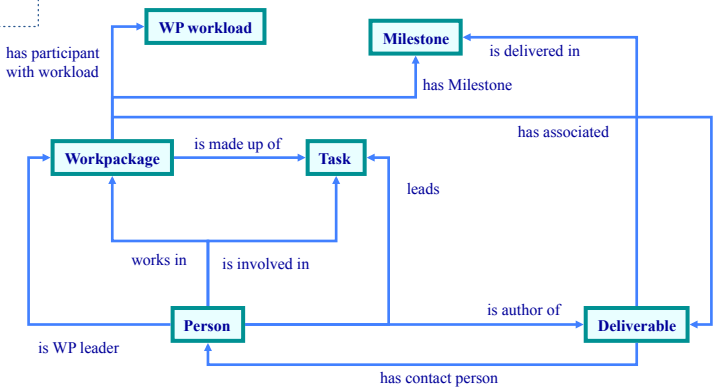
Transparencia adaptada de "Ontologies: Introduction" de Mari Carmen Suárez-Figueroa y Asunción Gómez-Pérez

Ontologies: Components: Relations



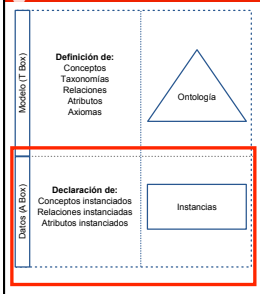
Relations:
leads, is author of, is delivered in, etc.

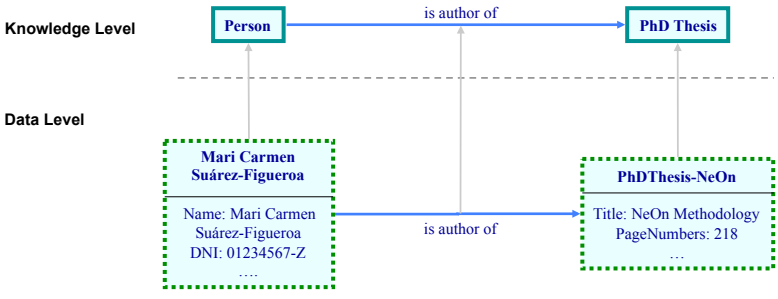
Attributes:
name, DNI, PageNumbers, etc.



Transparencia adaptada de "Ontologies: Introduction" de Mari Carmen Suárez-Figueroa y Asunción Gómez-Pérez

Ontologies: Components: Relations





Transparencia adaptada de "Ontologies: Introduction" de Mari Carmen Suárez-Figueroa y Asunción Gómez-Pérez

Where is the vocabulary/ontology?

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1200013	28/04/1992	01/01/1993	-67.052	-10.074	205.894	12
1200054	01/03/1963	01/01/1977	-69.563	-10.943	234.867	12
1200104	21/12/1938	01/01/1939	-68.748	-11.016	188.324	12
1200138	28/04/1992	01/01/1993	-67.952	-9.820	198.174	12
1200179	28/04/1992	01/01/1993	-67.674	-10.570	212.303	12
1200203	07/09/1904	01/01/1939	-72.673	-7.631	183.080	12
1200252	28/04/1992	01/01/1993	-68.745	-11.028	206.036	12
1200302	21/12/1938	01/01/1939	-70.354	-8.160	159.822	12
1200328	28/04/1992	01/01/1993	-71.951	-9.193	264.978	12
1200336	01/03/1963	01/01/1977	-72.917	-7.593	187.066	12
1200344	01/03/1963	01/01/1977	-69.260	-8.836	162.134	12
1200351	28/04/1992	01/01/1993	-72.790	-8.954	214.911	12
1200385	01/03/1963	01/01/1977	-67.188	-10.335	129.189	12
1200807	28/04/1992	01/01/1993	-67.541	-9.601	134.323	12
1200393	28/04/1992	01/01/1993	-72.742	-8.267	201.806	12
1200401	07/09/1904	01/01/1939	-67.811	-9.978	137.866	12
1200427	28/04/1992	01/01/1993	-72.648	-7.734	189.585	12
1200435	28/04/1992	01/01/1993	-70.486	-9.443	216.724	12
1200500	25/09/1904	01/01/1939	-68.656	-9.065	132.133	12
1200450	01/03/1963	01/01/1977	-67.743	-10.148	207.925	12
1200609	23/10/1912	01/01/1939	-70.756	-8.156	172.144	12
1200708	23/10/1912	01/01/1939	-68.506	-10.652	173.282	12

City	Creation date	Foundational date	Long	Lat	Alt	Nation
ID	COL1	COL2	COL3	COL4	COL5	COL6
1200013	28/04/1992	01/01/1993	-67.052	-10.074	205.894	12
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Let's create a model

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1200138	28/04/1992	01/01/1993	-67.952	-9.820	198.174	12
1200179	28/04/1992	01/01/1993	-67.674	-10.570	212.303	12
1200203	07/09/1904	01/01/1939	-72.673	-7.631	183.080	12
1200252	28/04/1992	01/01/1993	-68.745	-11.028	206.036	12
1200302	21/12/1938	01/01/1939	-70.354	-8.160	159.822	12
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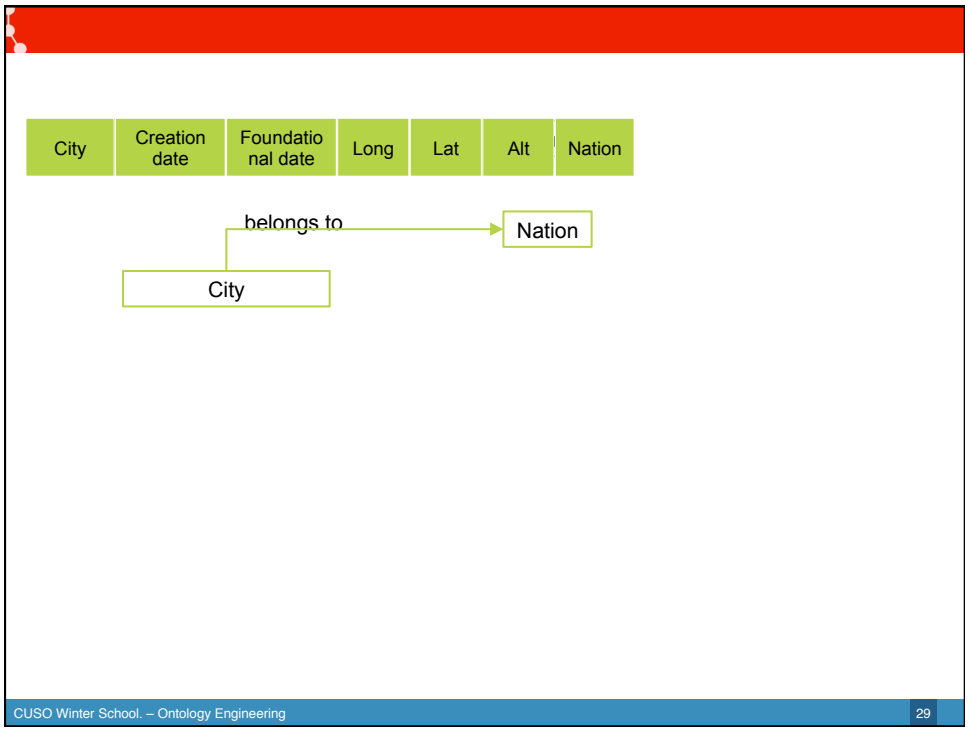
City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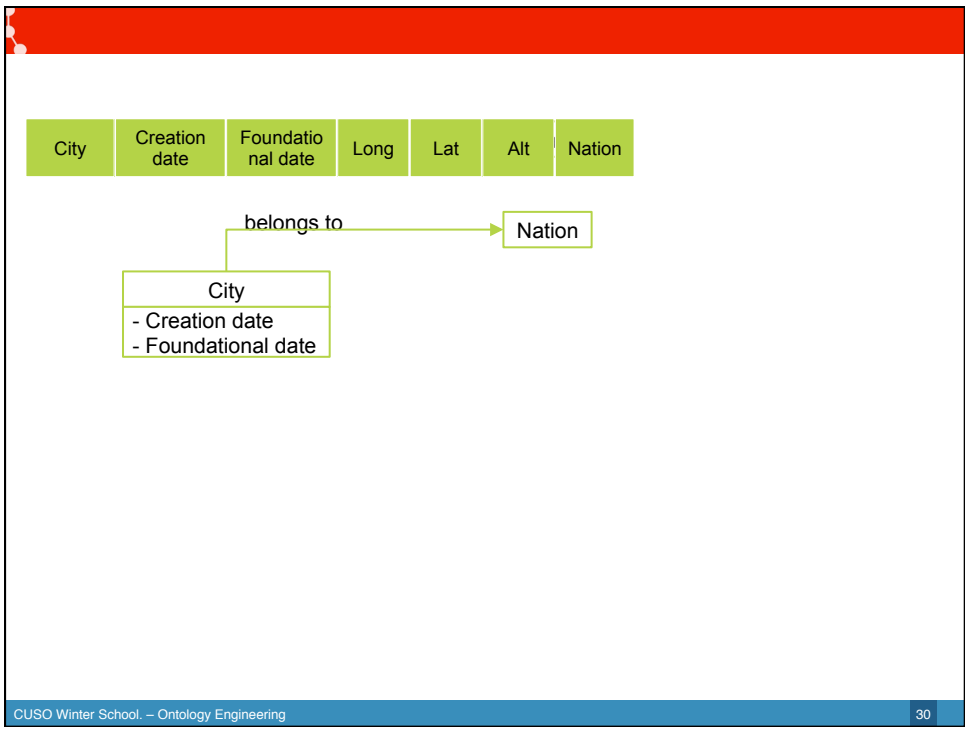
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- Foundational date
CUSO Winter School. – Ontology Engineering
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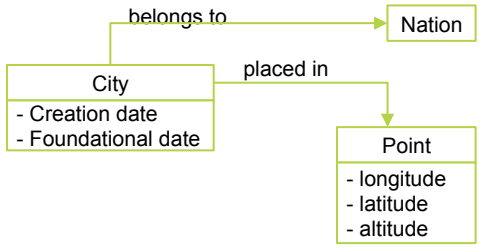
City	Creation date	Foundational date	Long	Lat	Alt	Nation



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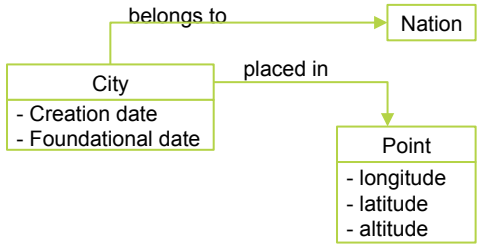

A vocabulary/ontology may represent many datasets
A dataset can be annotated with many vocabularies/ ontologies

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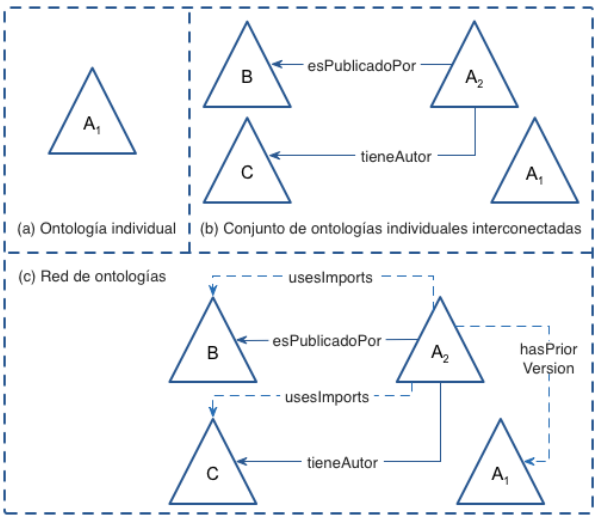
- Definition of ontologies
- A bit of history
- Ontology components
- Types of ontologies

Types of ontologies

Which kind of ontologies can we find?

Diferent architectures for an ontology



M.C. Suárez-Figueroa. *Tesis Doctoral: NeOn Methodology for Building Ontology Networks: Specification, Scheduling and Reuse.* España. Universidad Politécnica de Madrid. Junio 2010.

Types of Ontologies

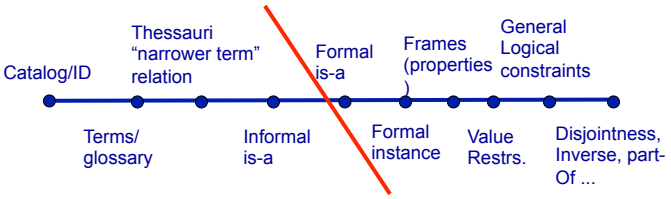
Lightweight Ontologies :

- Include Concepts with properties and Taxonomies
- Do not include axioms and constraints.

Heavyweight Ontologies :

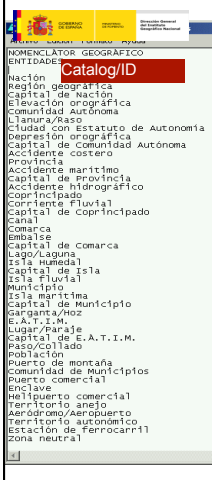
- Include all the components
- Excellent!! If they have a lot of axioms.

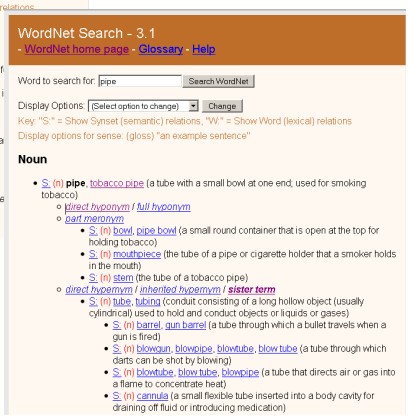
Types of Ontologies



Lassila O, McGuiness D. The Role of Frame-Based Representation on the Semantic Web. Technical Report. Knowledge Systems Laboratory. Stanford University. KSL-01-02. 2001.

Different ways of presenting terminology





Different ways of presenting terminology

Catalog/ID — Glossary — Thesaurus — Informal is-a

ID	CSI_Name
20000	Water area
20000.21000	Environmental area
20000.24020	Jurisdiction area
20000.22000	Fishing Statistical area
20000.21000.21001	Inland/marine
20000.21000.21002	Ocean
20000.21000.21003	North/South/Equatorial
20000.22000.22001	FAO statistical area
20000.22000.22002	Areal grid system

ID	CSI_Name	Parent
20000	Water area	
21000	Environmental area	20000
24020	Jurisdiction area	20000
22000	Fishing Statistical area	20000
21001	Inland/marine	21000
21002	Ocean	21000
21003	North/South/Equatorial	21000
22001	FAO statistical area	22000
22002	Areal grid system	22000

First Level	
ID	CSI_Name
20000	Water area

Second Level		
ID	First Level ID	CSI_Name
21000	20000	Environmental area
24020	20000	Jurisdiction area
22000	20000	Fishing Statistical area

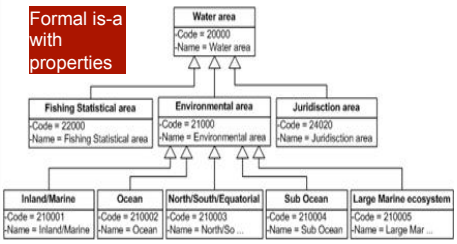
Third Level		
ID	Second Level ID	CSI_Name
21001	21000	Inland/marine
21002	21000	Ocean
21003	21000	North/South/Equatorial
22001	22000	FAO statistical area
22002	22000	Areal grid system

First Level		Second Level		Third Level	
ID	CSI_Name	ID	CSI_Name	ID	CSI_Name
20000	Water area	21000	Environmental area	21001	Inland/marine
20000	Water area	21000	Environmental area	21002	Ocean
20000	Water area	21000	Environmental area	21003	North/South/Equatorial
20000	Water area	22000	Fishing Statistical area	22001	FAO statistical area
20000	Water area	22000	Fishing Statistical area	22002	Areal grid system

Types of Ontologies

ormal is-a — Formal instance — Frames (properties) — Value Restrs. — General Logical constraints — Disjointness, Inverse, part-Of ...

Formal is-a with properties




```
(define-class Travel (?travel)
  "A journey from place to place"
:axiom-def
 (and (Superclass-Of Travel Flight)
      (Template-Facet-Value Cardinality
           arrivalDate Travel 1)
      (Template-Facet-Value Cardinality
           departureDate Travel 1)
      (Template-Facet-Value Maximum-Cardinality
           singleFare Travel 1))
:def
 (and (arrivalDate ?travel Date)
      (departureDate ?travel Date)
      (singleFare ?travel Number)
      (companyName ?travel String)))
```

Value Restrs.

```
(define-relation connects (?edge ?source ?target)
  "This relation links a source and a target by an edge. The
source and destination are considered as spatial points. The
relation has the following properties: symmetry and irreflexivity."
:def (and (SpatialPoint ?source)
          (SpatialPoint ?target)
          (Edge ?edge))
:axiom-def
((=> (connects ?edge ?source ?target)
     (connects ?edge ?target ?source)) ;symmetry
 (=> (connects ?edge ?source ?target)
     (not (or (part-of ?source ?target) ;irreflexivity
              (part-of ?target ?source))))))
```

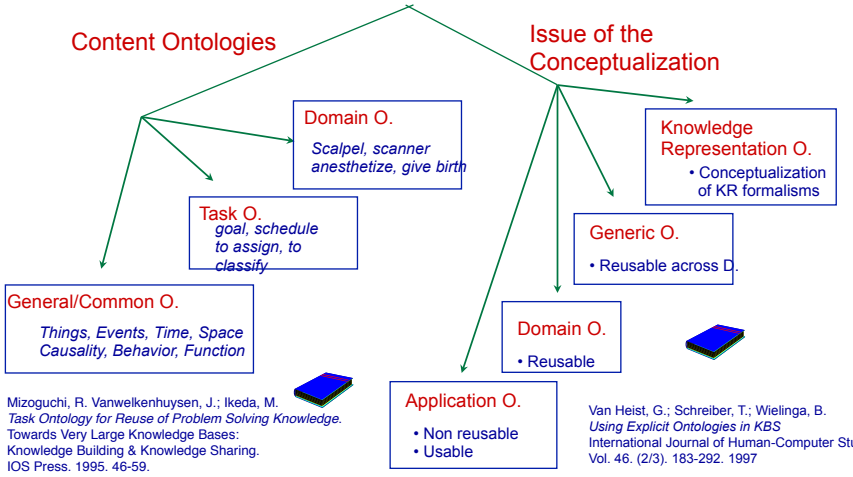
General Logical constraints

```
(define-class AmericanAirlinesFlight (?X)
:def (Flight ?X)
:axiom-def
 (Disjoint-Decomposition AmericanAirlinesFlight
          (Setof AA7462 AA2010 AA0488)))

(define-class Location (?X)
:axiom-def
 (Partition Location
      (Setof EuropeanLocation NorthAmericanLocation
           SouthAmericanLocation AsianLocation
           AfricanLocation AustralianLocation
           AntarcticLocation)))
```

Disjointness

Types of Ontologies



Mizoguchi, R. Vanwelkenhuysen, J.; Ikeda, M. *Task Ontology for Reuse of Problem Solving Knowledge.* Towards Very Large Knowledge Bases: Knowledge Building & Knowledge Sharing. IOS Press. 1995. 46-59.

Van Heist, G.; Schreiber, T.; Wielinga, B. *Using Explicit Ontologies in KBS* International Journal of Human-Computer Studies. Vol. 46. (2/3). 183-292. 1997

Knowledge Representation Ontologies

Knowledge Representation (KR) ontologies capture the representation primitives used to formalize knowledge under a given KR

•The Frame Ontology and the OKBC Ontology (http://ontolingua.stanford.edu)

•RDF and RDF Schema knowledge representation ontologies (http://www.w3.org/1999/02/22-rdf-syntax-ns http://www.w3.org/2000/01/rdf-schema)

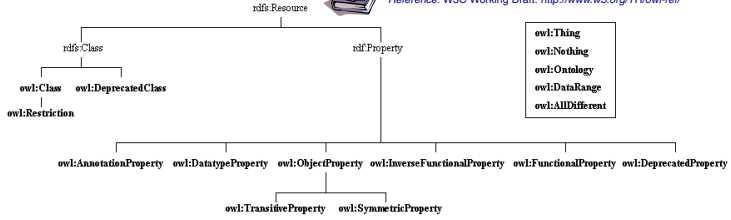
•OWL knowledge representation ontology (http://www.w3.org/2002/07/owl)

•Gruber TR (1993a) *A translation approach to portable ontology specification.* Knowledge Acquisition 5(2):199–220

•Chaudhri VK, Farquhar A, Fikes R, Karp PD, Rice JP (1998) *Open Knowledge Base Connectivity 2.0.3.* Technical Report. *http://www.ai.sri.com/~okbc/okbc-2-0-3.pdf*

Lassila O, Swick R (1999) *Resource Description Framework (RDF) Model and Syntax Specification.* W3C Recommendation. *http://www.w3.org/TR/REC-rdf-syntax/*

Dean M, Schreiber G (2003) *OWL Web Ontology Language Reference.* W3C Working Draft. *http://www.w3.org/TR/owl-ref/*



Top-level Ontologies

Top-level Ontologies or Upper-level Ontologies describe very general concepts and provide general notions under which all root terms in existing ontologies should be linked

•Top-level ontologies of universals and particulars

•Guarino N, Welty C (2000) *A Formal Ontology of Properties*. In: Dieng R, Corby O (eds) 12th International Conference in Knowledge Engineering and Knowledge Management (EKAW'00). Juan-Les-Pins, France. (Lecture Notes in Artificial Intelligence LNAI 1937) Springer-Verlag, Berlin, Germany, pp 97–112

•Gangemi A, Guarino N, Oltramari A (2001) *Conceptual analysis of lexical taxonomies: the case of Wordnet top-level*. In: Smith B, Welty C (eds) International Conference on Formal Ontology in Information Systems (FOIS'01). Ogunquit, Maine. ACM Press, New York, pp 3–15

• Sowa's top-level ontology (http://www.jfsowa.com/ontology/toplevel.htm)

Sowa JF (1999) *Knowledge Representation: Logical, Philosophical, and Computational Foundations*. Brooks Cole Publishing Co., Pacific Grove, California

•Cyc's upper ontology (http://www.cyc.com/cyc-2-1/cover.html)

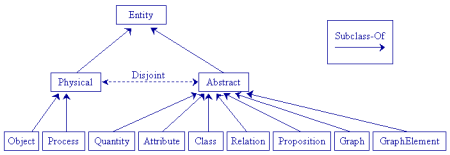
Lenat DB, Guha RV (1990) *Building Large Knowledge-based Systems: Representation and Inference in the Cyc Project*. Addison-Wesley, Boston, Massachusetts

• The Standard Upper Ontology (SUO) (http://suo.ieee.org/)

Pease RA, Niles I (2002) *IEEE Standard Upper Ontology: A Progress Report*. The Knowledge Engineering Review 17(1):65–70

•DOLCE (http://www.loa.istc.cnr.it/old/DOLCE.html)

•DUL (http://www.loa.istc.cnr.it/ontologies/DUL.owl)



General Ontologies: Time, Mereology, Topology

OVERVIEW ON GENERAL ONTOLOGIES

Gómez-Pérez A, Fernández-López M, Corcho O (2003) *Ontological Engineering*. Springer Verlag, London (section 2.2)

TIME ONTOLOGIES

Hayes PJ (1995) *A Catalog of Temporal Theories*. Technical Report UIUC-BI-AI-96-01 at the Beckman Institute and Departments of Philosophy and Computer Science University of Illinois. *http://www.ihmc.us/users/phayes/docs/timeCatalog.pdf*

Hobbs JR, Feng P (eds) (2006) *Time Ontologies in OWL*. W3C Working Draft 2. *http://www.w3.org/TR/owl-time/*

MEREOLOGY AND TOPOLOGY

Varzi A (2007) *Spatial Reasoning and Ontology: Parts, Wholes, and Locations*. In Aiello M, Pratt-Hartmann I, van Benthem J (eds) Springer-Verlag, pp 945-1038 (It also includes space modeling)

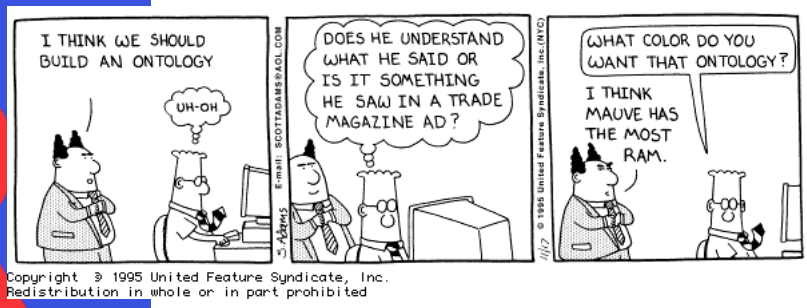
Varzi A (2003) *Mereology*. In Zalta EN, Nodelman U, Allen C (eds) Stanford Encyclopedia of Philosophy, Stanford: CSLI (on line publication) (*http://plato.stanford.edu/entries/mereology/*) (last access: 19th January 2010)

Rector A, Welty C (eds), Noy N, Wallace E (contributors) (2005) *Simple part-whole relations in OWL Ontologies*. W3C Editors Draft (http://www.w3.org/2001/sw/BestPractices/OEP/SimplePartWhole/)

HOW TO REUSE GENERAL ONTOLOGIES

•Fernández-López M, Gómez-Pérez A, Suárez-Figueroa MC (2013) *Methodological guidelines for reusing general ontologies*. Data & Knowledge Engineering 86:242-275

Ontology Engineering



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