Ontological Engineering and the Semantic Web

Asunción Gómez-Pérez
Mariano Fernández-López
Oscar Corcho
asun@fi.upm.es, mfernandez.eps@ceu.es, ocorcho@cs.man.ac.uk
Grupo de Ontologías
Laboratorio de Inteligencia Artificial
Facultad de Informática
Universidad Politécnica de Madrid
Campus de Montegancedo sn,
28660 Boadilla del Monte, Madrid, Spain

Table of Contents

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The Role of Ontologies in the Semantic Web

Asunción Gómez-Pérez
Mariano Fernández-López
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asun@fi.upm.es, mfernandez.eps@ceu.es, ocorcho@cs.man.ac.uk
Grupo de Ontologías
Laboratorio de Inteligencia Artificial
Facultad de Informática
Universidad Politécnica de Madrid
Campus de Montegancedo sn,
28660 Boadilla del Monte, Madrid, Spain

Main References

Gómez-Pérez, A.; Fernández-López, M.; Corcho, O. **Ontological Engineering.** *Springer Verlag. 2003*

http://www.ontoweb.org

Deliverables
•D1.1
•D1.2
•D1.3
•D1.4
•D1.5

http://knowledgeweb.semanticweb.org

Research deliverables
Industry deliverables

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.

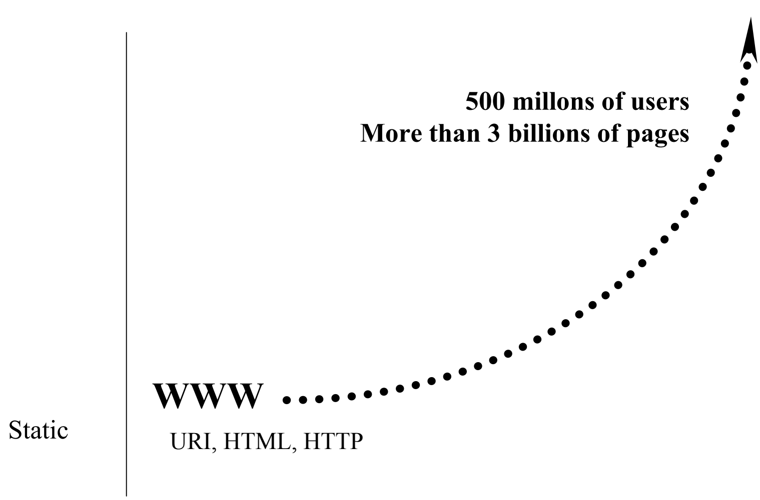
Gruber, T. *A translation Approach to portable ontology specifications.* **Knowledge Acquisition**. Vol. 5. 1993. 199-220.

Uschold, M.; Grüninger, M. *ONTOLOGIES: Principles, Methods and Applications.* **Knowledge Engineering Review**. Vol. 11; N. 2; June 1996.

Acknowledgements

- Asunción Gómez-Pérez and Mariano Fernández-López
  - Most of the slides have been done jointly with them
- Alan Rector (University of Manchester)
  - Conclusion

The problem: Information overload on the Web



The current Web is based on HTML

Arab

الاسم: الهندسة فىعلم التطو ر
المؤلفون: آسنسيون غومزبيرز
السّعر: $74.95
المنتج: الكتاب

```
<b>الاسم:</b><BR> الهندسة فىعلم التطو ر
<b>المؤلفون:</b><BR> آسنسيون غومزبيرز
$74.95 <b>السّعر:</b><BR>
<b>الكتاب:</b><BR> المنتج
```

Japanese

タイトル: 存在論工学
著者: アスンスィオン　ゴメスペレス
価格: $74.95
産品: 本

```
<b>タイトル:</b> 存在論工学<BR>
<b>著者:</b> アスンスィオン　ゴメスペレス... <BR>
<b>価格:</b> $74.95<BR>
<b>産品:</b> 本<BR>
```

Norwegian

Skjøte: Ontological Ingeniørarbeid
Forfatter: Overtakelse Gómez-Pérez...
Pris: 74.95€
Produkt: Bok

```
<b>Skjøte:</b> Ontological Ingeniørarbeid<BR>
<b>Forfatter:</b> Overtakelse Gómez-Pérez... <BR>
<b>Pris:</b> 74.95€<BR>
<b>Produkt:</b> Bok<BR>
```

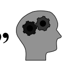
English

Title: Ontological Engineering
Authors: Asunción Gómez-Pérez...
Price: $74.95
Product: Book

```
<b>Title:</b> Ontological Engineering <BR>
<b>Authors:</b>  Asunción Gómez-Pérez... <BR>
<b>Price:</b> $74.95<BR>
<b>Product:</b> Book<BR>
```

.- HTML is useful for browsing the information
.- Content is language-dependent
.- High cost for keeping the information up-to-date

XML allows the creation of metada with “meaning”



Arab

الاسم: الهندسة فىعلم التطو ر
المؤلفون: آسنسيون غومزبيرز
السّعر: $74.95
المنتج: الكتاب

```
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<الكتاب>المنتج</الكتاب>
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English

Title: Ontological Engineering
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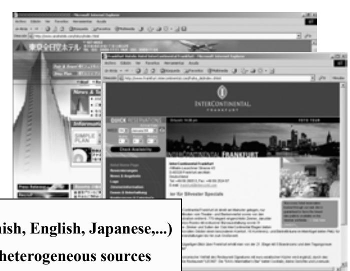
```
<Title>Ontological Engineering</Title>
<Author>Asunción Gómez-Pérez...</Author>
<Price>$74.95</Price>
<Product>Book</Product>
```

¿What do the tags mean for the machine?

The problem of choosing information

.- Find the information
.- Extract relevant information
.- Interpretation by human users
.- Sinthesis

The problem of content agregation: From Madrid to Tokyo



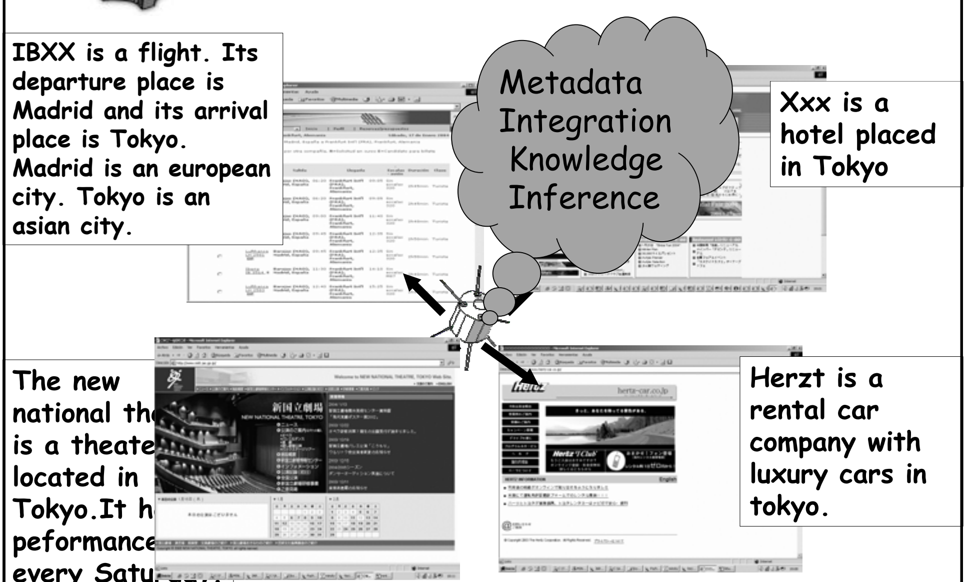
.- Content in different languages (Spanish, English, Japanese,...)
.- Find out relevant information from heterogeneous sources
  .- Extract
  .- Interpretation
  .- Agregation
.- Consistency of the information

What was the Web intended to be?

"... a goal of the Web was that, if the interaction between person and hypertext could be so intuitive that the machine-readable information space gave an accurate representation of the state of people's thoughts, interactions, and work patterns, then machine analysis could become a very powerful management tool, seeing patterns in our work and facilitating our working together through the typical problems which beset the management of large organizations."

[Berners-Lee 1996]

Why not make the computers do the work?



What is the Semantic Web?

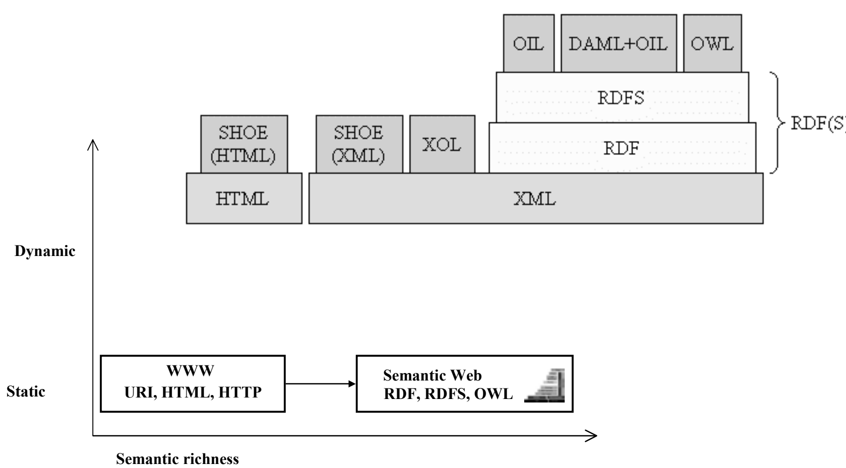
"The Semantic Web is an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation. It is based on the idea of having data on the Web defined and linked such that it can be used for more effective discovery, automation, integration, and reuse across various applications."

Ontologies

Annotation

Hendler, J., Berners-Lee, T., and Miller, E.
Integrating Applications on the Semantic Web, 2002,
http://www.w3.org/2002/07/swint.html

Semantic Web Languages



Ontologies and Metadata

Ontologies

xmlns:rdf='http://www.w3.org/1999/02/22-rdf-syntax-ns#'
xmlns:NS0='http://www.esperonto.net/semanticportal/RDFS/Person_Ontology#'
xmlns:NS1='http://www.esperonto.net/semanticportal/RDFS/Organization_Ontology#'

Person — Belongs_To → Organization
Organization — Has_contact_Person → Person
Associate Prof. — Subclass of → Person
Partner — Subclass of → Organization

[redacted] [redacted]

Annotation (RDF)

<rdf:Description rdf:about='Asunción Gómez-Pérez'>
<rdf:type rdf:resource='Associate Prof'/>
<NS0:**Full_Name**>A_GomezPerez</NS0:**Full_Name**>
<NS0:**Belongs_To**>UPM</NS0: **Belongs_To** >
<NS0:**e-mail**>asun@fi.upm.es</NS0:**e-mail**>

<rdf:Description rdf:about='UPM'>
<rdf:type rdf:resource='Partner'/>
<NS1:**Acronym**>UPM</NS1:**Acronym**>
<NS1:**Has_Contact_Person**>Asunción Gómez-Pérez
</NS1:**Has_Contact_Person** >

Web Page

Full Name	Asuncion Gomez-Perez
e-mail	asun@fi.upm.es
Photo	

Asunción Gómez-Pérez is contact person UPM (Partner).
Asunción Gómez-Pérez belongs to UPM (Partner).

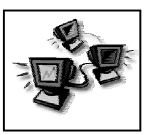
Full Name	Universidad Politécnica de Madrid
Acronym	UPM
Logo	

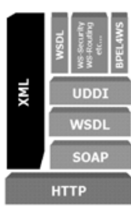
UPM has contact person Asunción Gómez-Pérez (Associate Professor).
UPM participates in Esperonto (Project).
UPM team is formed by :

URL **http://www.esperonto.net** **http://www.esperonto.net**

Web Services

Peer Web for information exchange between machines





To describe control flows
To register Services
Service Access Interfaz
Communication Protocol

[redacted]

Dynamic — **Web Services UDDI, WSDL, SOAP**

Declaratively described Program Access Interfaces that are accessible through the Web

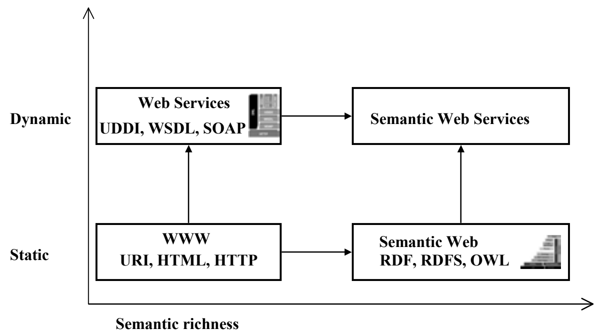
Static — **WWW URI, HTML, HTTP** → **Semantic Web RDF, RDFS, OWL**

Semantic richness

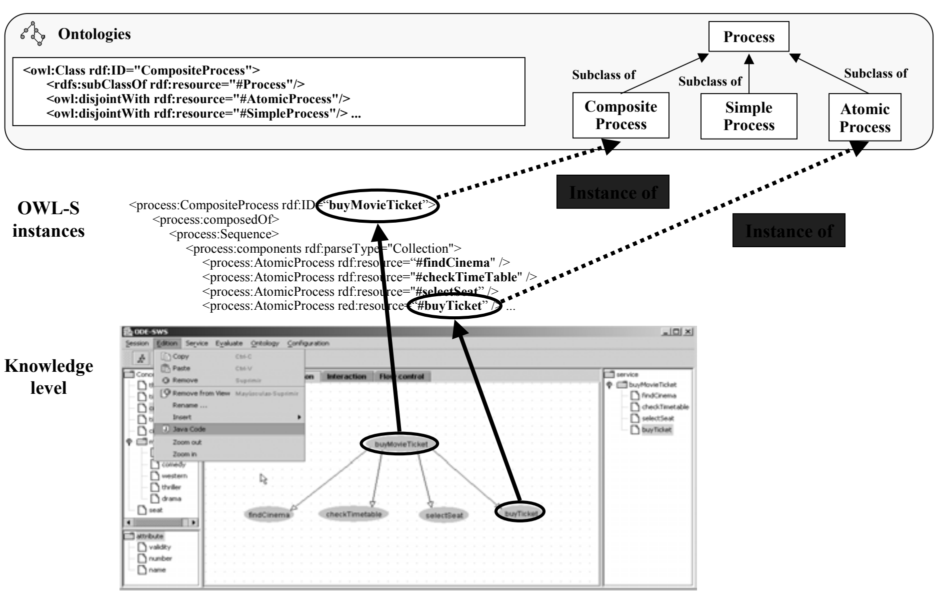
The Semantic Web and the Semantic Web Services

Web Services that describe their properties and capabilities using

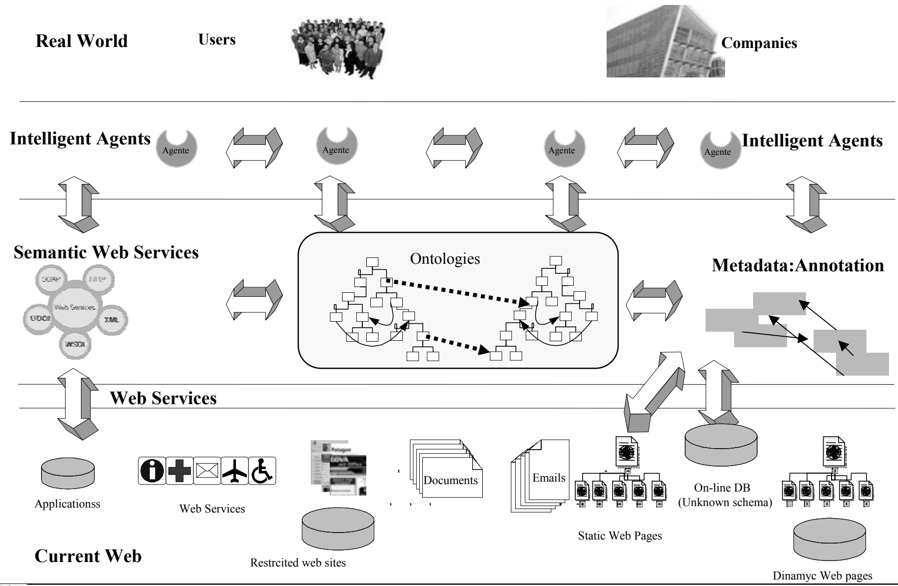
the vocabulary of an ontology, and they are expressed in some semantic markup language



Semantic Web Services



A Semantic Web Scenario



Ontological Engineering for the Semantic Web

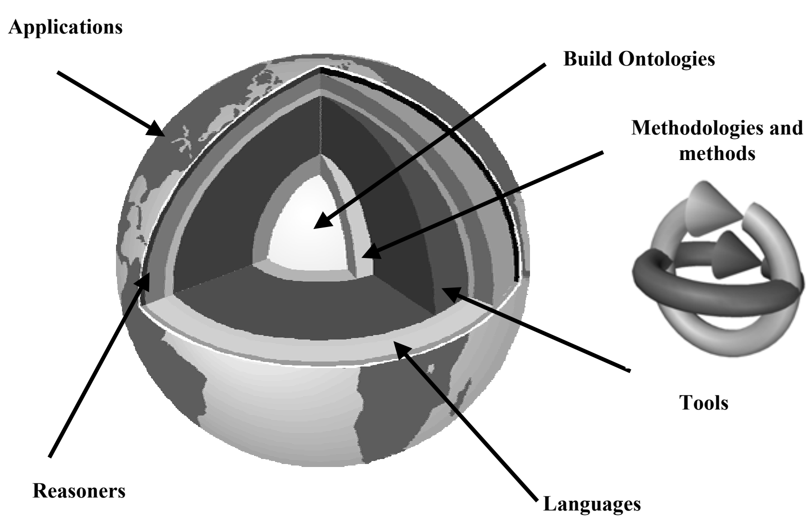


Table of Contents

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Theoretical Foundations of Ontologies

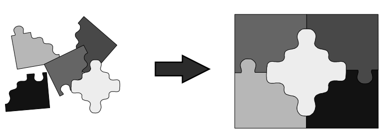
Asunción Gómez-Pérez
Mariano Fernández-López
Oscar Corcho
asun@fi.upm.es, mfernandez.eps@ceu.es, ocorcho@cs.man.ac.uk
Grupo de Ontologías
Laboratorio de Inteligencia Artificial
Facultad de Informática
Universidad Politécnica de Madrid
Campus de Montegancedo sn,
28660 Boadilla del Monte, Madrid, Spain

Outline

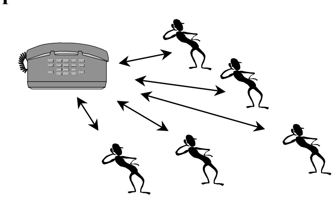
The Knowledge Sharing Initiative
Definitions of Ontologies
Modeling of Ontologies
Types of Ontologies
Libraries of Ontologies
Ontological Commitments

Reuse and Sharing

Reuse means to build new applications assembling components already built



Sharing is when different applications use the some resources



Advantages:

- **Less money**
- **Less time**
- **Less resources**

Areas:

- **Software**
- **Knowledge**
- **Communications**
- **Interfaces**
- **---**

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.

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.

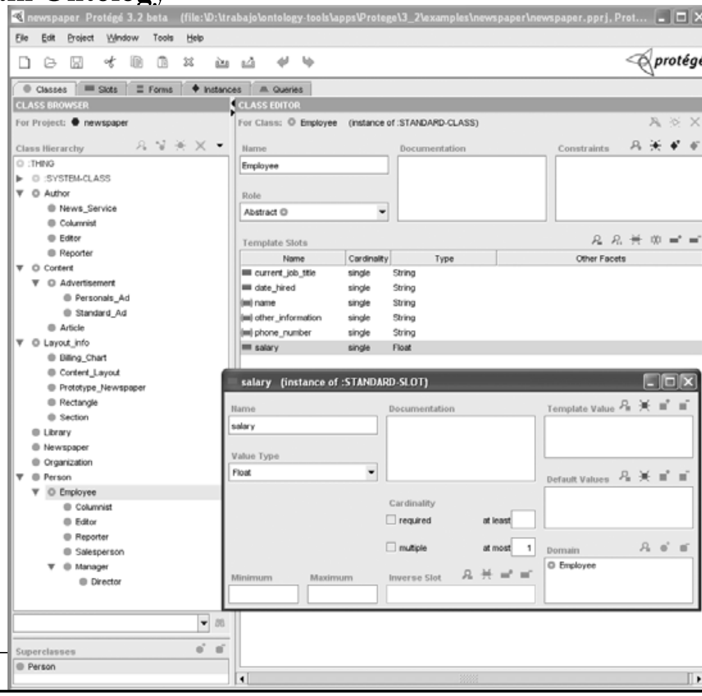
Outline

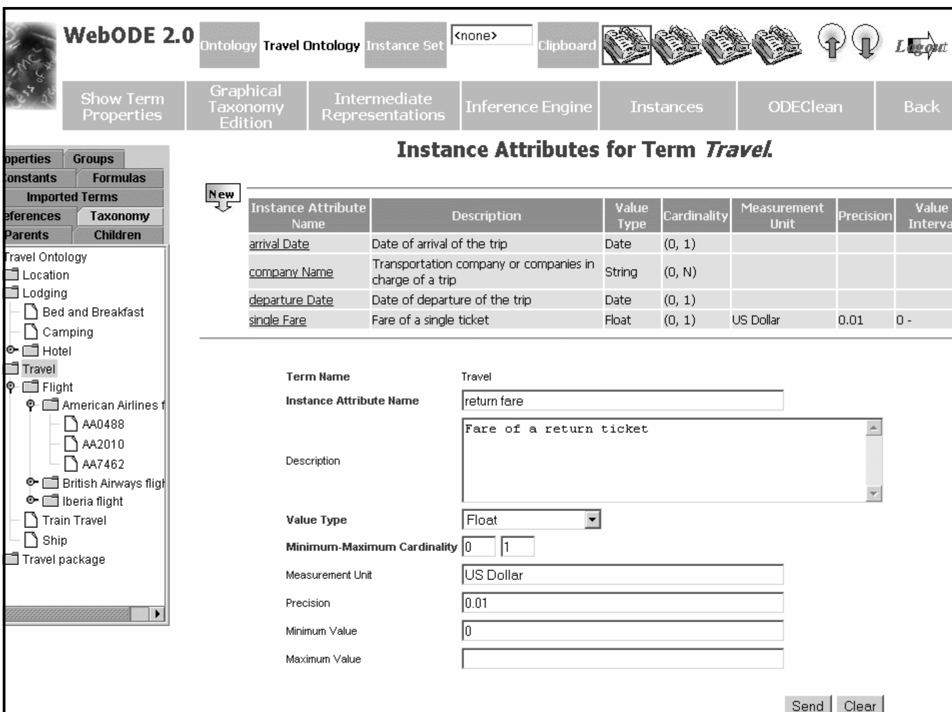
- The Knowledge Sharing Initiative
- Definitions of Ontologies
- Modeling of Ontologies
- Types of Ontologies
- Libraries of Ontologies
- Ontological Commitments

Definitions of Ontologies (I)

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 RE, Finin T, Gruber TR, Senator T, Swartout WR (1991) *Enabling technology for knowledge sharing*. **AI Magazine** 12(3):36–56
2. "An ontology is an explicit specification of a conceptualization"	Gruber TR (1993a) *A translation approach to portable ontology specification*. **Knowledge Acquisition** 5(2):199–220
3. "An ontology is a formal, explicit specification of a shared conceptualization"	Studer R, Benjamins VR, Fensel D (1998) *Knowledge Engineering: Principles and Methods.* **IEEE Transactions on Data and Knowledge Engineering** 25(1-2):161–197
4. "A logical theory which gives on explicit, partial account of a conceptualization"	Guarino N, Giaretta P (1995) *Ontologies and Knowledge Bases: Towards a Terminological Clarification*. In: Mars N (ed) **Towards Very Large Knowledge Bases: Knowledge Building and Knowledge Sharing (KBKS'95)**. University of Twente, Enschede, The Netherlands. IOS Press, Amsterdam, The Netherlands, pp 25–32
5. "A set of logical axioms designed to account for the intended meaning of a vocabulary"	Guarino N (1998) *Formal Ontology in Information Systems*. In: Guarino N (ed) 1st International Conference on **Formal Ontology in Information Systems (FOIS'98)**. Trento, Italy. IOS Press, Amsterdam, pp 3–15

Example of Domain Ontology





Outline

The Knowledge Sharing Initiative
Definitions of Ontologies
Modeling of Ontologies
- Components
- Principles
- Approaches

Types of Ontologies
Libraries of Ontologies
Ontological Commitments

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: $C_1 \times C_2 \times \ldots \times C_{n-1} \text{-->} C_n$

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

Instances Elements

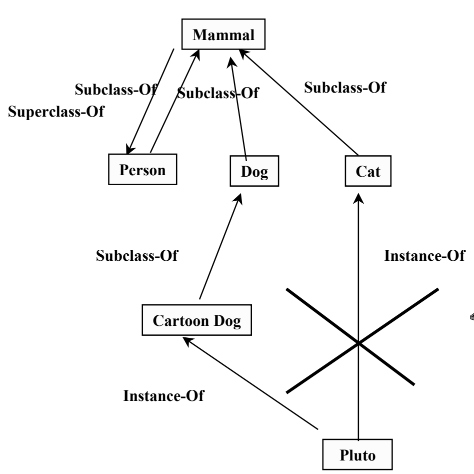
Axioms Sentences which are always true

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

Vocabulary

- "Class" ≈ "Concept" ≈ "Category" ≈ "Type"
- "Instance" ≈ "Individual"
- "Entity" ≈ "object", Class or individual
- "Property" ≈ "Slot" ≈ "Relation" ≈ "Relationtype" ≈ "Attribute" ≈ Semantic link type" ≈ "Role"
  - but be careful about "role"
    - Means "property" in DL-speak
    - Means "role played" in most ontologies
      - E.g. "doctor role", "student role" …

How to build taxonomies (I)

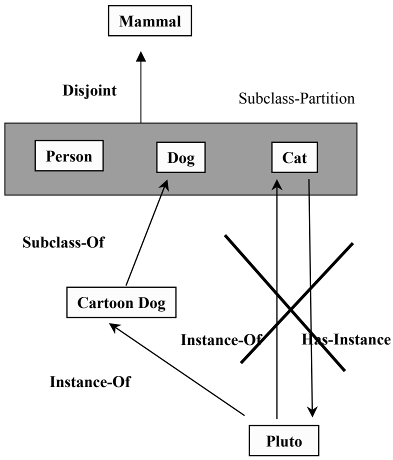


A. Gómez-Pérez. *Evaluation of Ontologies.* **International Journal of Intelligent Systems.** Vol. 16, Nº3. March 2001. PP391-410

Pluto could be an instance of cat and dog

Semantic Error

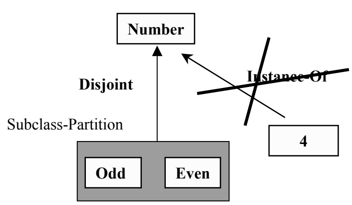
How to build taxonomies (II)



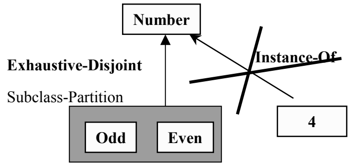
A. Gómez-Pérez. *Evaluation of Ontologies.* **International Journal of Intelligent Systems.** Vol. 16, Nº3. March 2001. PP391-410

Pluto cannot be simultaneously a class of Cat and Dog because they are disjoint

How to build taxonomies (III)



Four is an instance of Even



Four is an instance of something in the partition

A. Gómez-Pérez. *Evaluation of Ontologies.* **International Journal of Intelligent Systems.** Vol. 16, Nº3. March 2001. PP391-410

What Does an Ontology Look Like? (I)

Lightweight Ontologies :

- **Include Concepts with Properties and Taxonomies**
- **Do not include Axioms nor Constraints**

Heavyweight Ontologies :

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

What Does an Ontology Look Like? (II)

Highly informal: → in natural language

An html ontology for linking documents

Semi-informal: → in a restricted and structured form of natural language

Example

Semi-formal: → in an artificial and formally defined language

Example

Rigorously formal: → in a language with formal semantics, theorems and proofs of such properties as soundness and completeness

Example

Uschold, M.; Grüninger, M. *ONTOLOGIES: Principles, Methods and Applications.* **Knowledge Engineering Review**. Vol. 11; N. 2; June 1996.

Principles for the Design of Ontologies (I)

Clarity:

To communicate the intended meaning of defined terms

Coherence:

To sanction inferences that are consistent with definitions

Extendibility:

To anticipate the use of the shared vocabulary

Minimal Encoding Bias:

To be independent of the symbolic level

Minimal Ontological Commitments:

To make as few claims as possible about the world

• Gruber, T.; *Towards Principles for the Design of Ontologies.* **KSL-93-04.** Knowledge Systems Laboratory. Stanford University. 1993

Principles. Clarity

An ontology should communicate effectively the intended meaning of defined terms. Definitions should be objective. Definitions can be stated on formal axioms, and a complete definition (defined by necessary and sufficient conditions) is preferred over a partial definition (defined by only necessary or sufficient conditions). . .

No Clarity → :def

```
(define-class Travel (?travel)
   "A journey from place to place"
:axiom-def
 (and (Superclass-Of Travel Flight)
      (Subclass-Of Travel Thing)
      (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)))
```

Principles. Clarity

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

Clarity → :iff-def

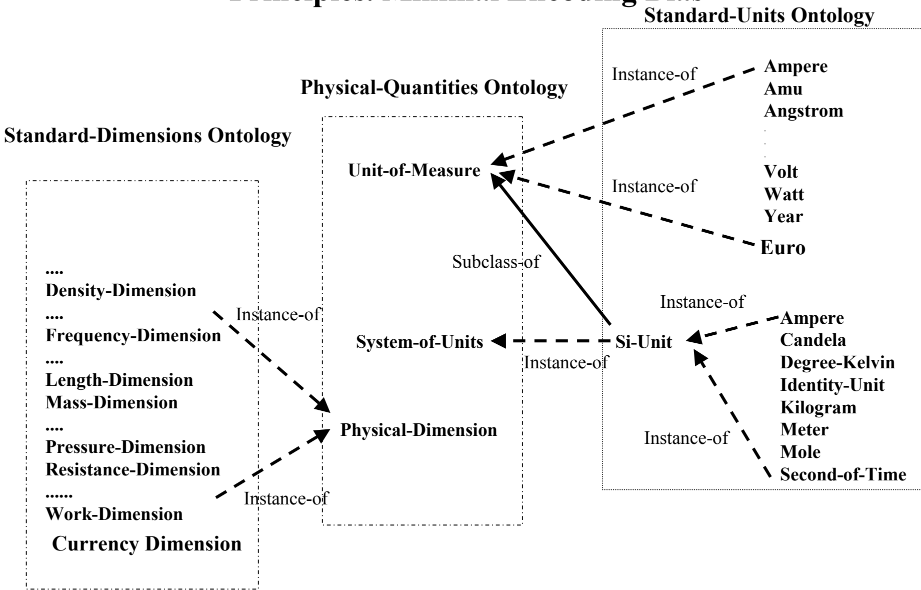
Principles. Minimal Encoding Bias

"The conceptualization should be specified at the knowledge level without depending on a particular symbol-level encoding".

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

No minimal Encoding Bias → Number

Principles. Minimal Encoding Bias



Principles. Minimal Encoding Bias

```
(singleFare ?travel Number)
```

should be substituted by:

```
(singleFare ?travel CurrencyQuantity)
```

Principles. Extensibility

> *"One should be able to define new terms for special uses based on the existing vocabulary, in a way that does not require the revision of the existing definitions".*

- **Currency dimension**
- **Definition of currencies**
- **Relationship between currencies**

```
(define-individual Euro (Unit-of-Measure)
   "An Euro is the currency on the European Union"
:= (* 0,96 USDollar)
:axiom-def
  (= (Quantity.dimension Euro) CurrencyDimension))
```


Principles. Coherence

> *"An ontology should be coherent: that is, it should sanction inferences that are consistent with the definitions. […] If a sentence that can be inferred from the axioms contradicts a definition or example given informally, then the ontology is incoherent".*

```
(define-axiom No-Train-between-USA-and-Europe
   "It is not possible to travel by train between the USA and Europe"
:= (forall (?travel)
    (forall (?city1)
     (forall (?city2)
      (=> (and (Travel ?travel)
               (arrivalPlace ?travel ?city1)
               (departurePlace ?travel ?city2)
               (or (and (EuropeanLocation ?city1)
                        (USALocation ?city2))
                   (and (EuropeanLocation ?city2)
                        (USALocation ?city1) )))
          (not (TrainTravel ?travel)))))))
(define-instance Madrid (EuropeanLocation))
(define-instance NewYork (USALocation))
```


Principles. Minimal Ontological Commitments

"Since ontological commitment is based on the consistent use of the vocabulary, ontological commitment can be minimized by specifying the weakest theory and defining only those terms that are essential to the communication of knowledge consistent with the theory"

```
(define-class Travel (?travel)
   "A journey from place to place"
:axiom-def
 ( .... )
:iff-def
  (and (arrivalDate ?travel Date)
       (departureDate ?travel Date))
:def
  (and (singleFare ?travel Number)
       (companyName ?travel String)))
```

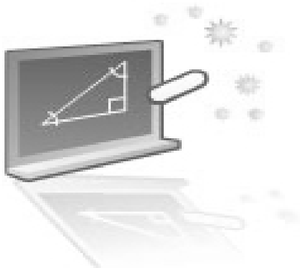
- **What is a date?**
- **Absolute/relative date?**
- **could be an interval?**
- **date= month + year**
- **date= day + month +year**
- **date = month +day +year**

Principles for the Design of Ontologies (II)

- **The representation of disjoint and exhaustive knowledge.** If the set of subclasses of a concept are disjoint, we can define a disjoint decomposition. The decomposition is exhaustive if it defines the superconcept completely.
- **To improve the understandability and reusability of the ontology,** we should implement the ontology trying to minimize the syntactic distance between sibling concepts.
- **The standardization of names.** To ease the understanding of the ontology the same naming conventions should be used to name related terms.

Arpírez JC, Gómez-Pérez A, Lozano A, Pinto HS (1998) *(ONTO)^{2}Agent: An ontology-based WWW broker to select ontologies*. In: Gómez-Pérez A, Benjamins RV (eds) **ECAI'98 Workshop on Applications of Ontologies and Problem-Solving Methods**. Brighton, United Kingdom, pp 16–24

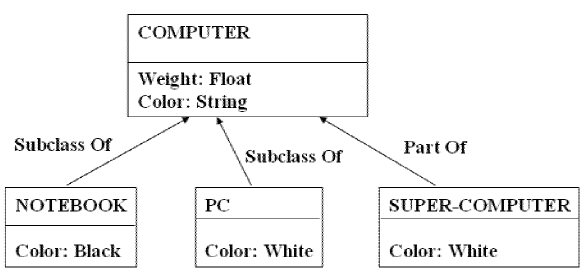
Exercise: design principles



•**Objective**
- •**Get a better understanding of ontology design principles**

•**Tasks**
- •**Analyse a formalisation and find a set of violations of ontology design principles**

Find at least five violations of design principles

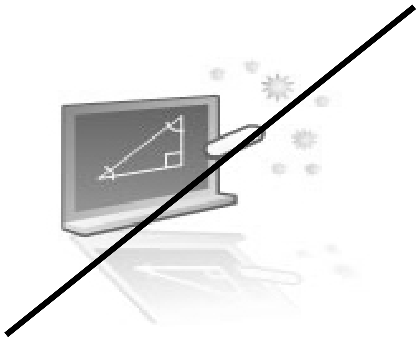


$\exists x\ (computer(x) \vee \neg computer(x))$

$\forall x\ (notebook(x) \rightarrow \exists y\ (float(y) \wedge computer(x) \wedge weight(x, y)\ y < 6))$

$\exists x\ (notebook(x) \wedge weight(x, 9))$

Design principles



Approaches for Modeling Ontologies

- **Using frames and first order logic**
- **Using description logic**
- **Using UML**
- **Using the entity relationship model**

Using Frames and First Order Logic for Modeling Ontologies

```
(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)))
```

```
(define-function Pays (?room ?discount) :-> ?finalPrice
   "Price of the room after applying the discount"
:def (and (Room ?room) (Number ?discount)
        (Number ?finalPrice)
        (Price ?room ?price))
:lambda-body
        (- ?price (/ (* ?price ?discount) 100)))
```

```
(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))))))
```

```
(define-instance AA7462-Feb-08-2002 (AA7462)
:def ((singleFare AA7462-Feb-08-2002 300)
     (departureDate AA7462-Feb-08-2002 Feb8-2002)
     (arrivalPlace AA7462-Feb-08-2002 Seattle)))
```


Using Description Logics for Modeling Ontologies

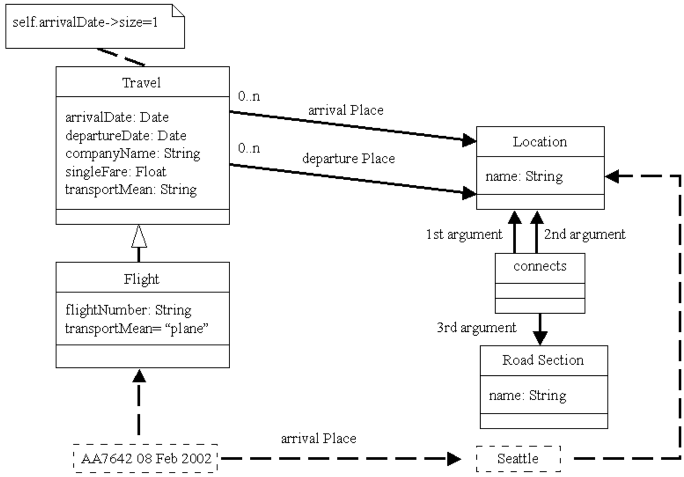
```
(defconcept Travel
  "A journey from place to place"
:is-primitive
 (:and
   (:all arrivalDate Date)(:exactly 1 arrivalDate)
   (:all departureDate Date)(:exactly 1
departureDate)
   (:all companyName String)
   (:all singleFare Number)(:at-most singleFare 1)))
```

```
(defrelation Pays
:is
 (:function (?room ?Discount)
  (- (Price ?room) (/(*(Price ?room) ?Discount) 100)))
:domains (Room Number)
:range Number)
```

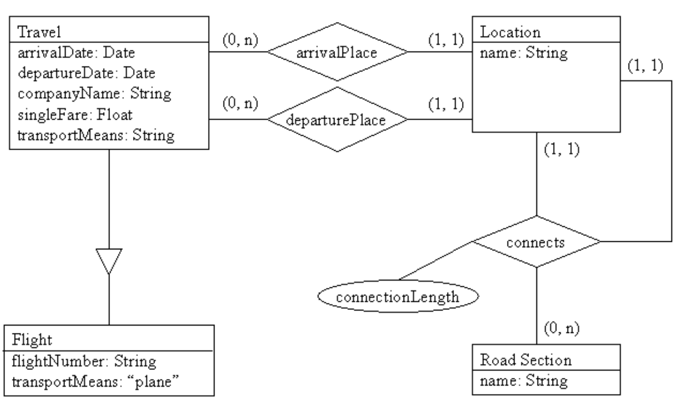
```
(defrelation connects
  "A road connects two different cities"
:arity 3
:domains (Location Location)
:range RoadSection
:predicate
 ((?city1 ?city2 ?road)
  (:not (part-of ?city1 ?city2))
  (:not (part-of ?city2 ?city1))
  (:or (:and (start ?road ?city1)(end ?road ?city2))
      (:and (start ?road ?city2)(end ?road ?city1)))))
```

```
(tellm (AA7462 AA7462-08-Feb-2002)
     (singleFare AA7462-08-Feb-2002 300)
     (departureDate AA7462-08-Feb-2002 Feb8-2002)
     (arrivalPlace AA7462-08-Feb-2002 Seattle))
```

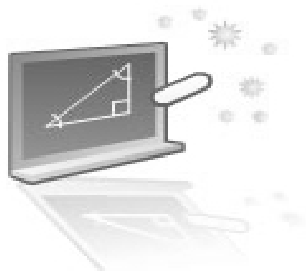
Using UML for Modeling Ontologies



Using the Entity Relationship Model for Modeling Ontologies



Exercise



•**Objective**
- •**Analyse the advantages and disadvantages of using the entity-relationship model for developing ontologies, and start realising about the needs for achieving a shared understanding of a domain**

•**Tasks**
- •**Create an entity-relationship model for the domain of pets (in small groups)**
- •**Then try to share it with other 2 groups to come up with a common shared model**
- •**Explain it to each group**

Approaches. Conclusions

- **The formalism and the language limit the kind of knowledge that can be represented**
- **All the aforementioned formalisms allow representing: classes, organized in class taxonomies, attributes, and binary relations**
- **Only AI formalisms are specially prepared to model formal axioms either as independent components in the ontology or embedded in other components**
- **A domain model is not necessarily an ontology only because it is written in Ontolingua or OWL, for the same reasons that we cannot say that a program is a knowledge-based system because it is written in Prolog**
- **Although some languages are more appropriate than others to represent ontologies, a model is an ontology only if it is agreed and machine readable**

Outline

The Knowledge Sharing Initiative
Definitions of Ontologies
Modeling of Ontologies
Types of Ontologies
Libraries of Ontologies
Ontological Commitments

A semantic continuum

Pump: "a device for moving a gas or liquid from one place or container to another"

(pump has
(superclasses (…))

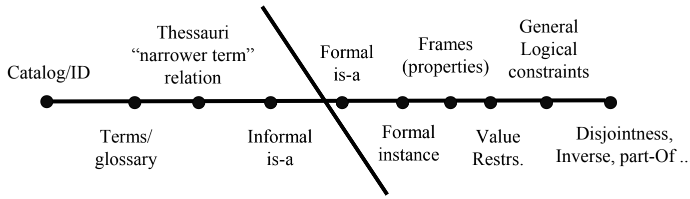
Shared human consensus	Text descriptions	Semantics hardwired; used at runtime	Semantics processed and used at runtime
Implicit	Informal (explicit)	Formal (for humans)	Formal (for machines)

→ Further to the right →

- Less ambiguity
- Better inter-operation
- More robust – less hardwiring
- More difficult

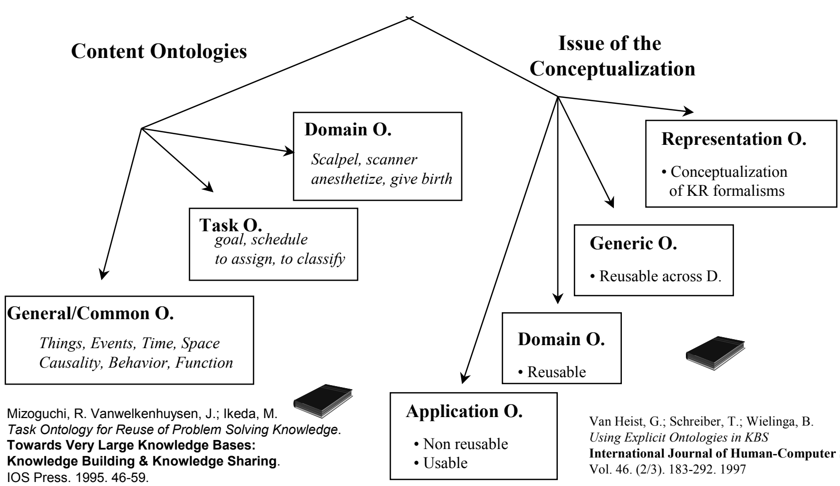
Uschold M

Types of Ontologies
Lassila and McGuiness Classification



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.

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

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

•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*

•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)

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

•OIL knowledge representation ontology
(http://www.ontoknowledge.org/oil/rdf-schema/2000/11/10-oil-standard)

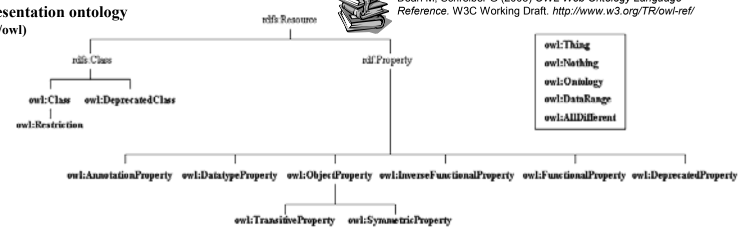
Horrocks I, Fensel D, Harmelen F, Decker S, Erdmann M, Klein M (2000) *OIL in a Nutshell*. In: Dieng R, Corby O (eds) 12th International Conference in Knowledge Engineering and Knowledge Management (EKAW'00). Juan-Les-Pins, France. (Lecture Notes in Artificial Intelligence LNAI 1937) Springer-Verlag, Berlin, Germany, pp 1–16

•DAML+OIL knowledge representation ontology
(http://www.daml.org/2001/03/daml+oil)

Horrocks I, van Harmelen F (eds) (2001) *Reference Description of the DAML+OIL (March 2001) Ontology Markup Language*. Technical report. *http://www.daml.org/2001/03/reference.html*

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

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 of universals and particulars, and DOLCE, DOLCE-Lite-Plus (http://www.loa-cnr.it/DOLCE.html)

•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

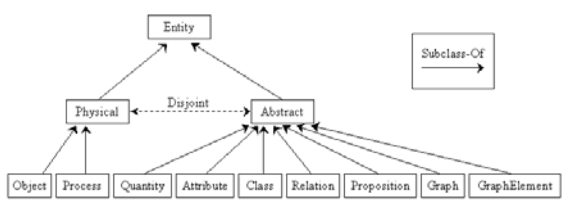
•Gangemi A, Guarino N, Oltramari A (2001) *Conceptual analysis of lexical taxonomies: the case of Wordnet top-level*. In: Smith B, Welty C (eds) International Conference on Formal Ontology in Information Systems (FOIS'01). Ogunquit, Maine. ACM Press, New York, pp 3–15

•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) and th
(http://suo.ieee.org/, http://suo.ieee.org/SUO/SUMO/index.html)

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

Linguistic Ontologies

•**WordNet** **(http://www.hum.uva.nl/~ewn/gwa.htm)**

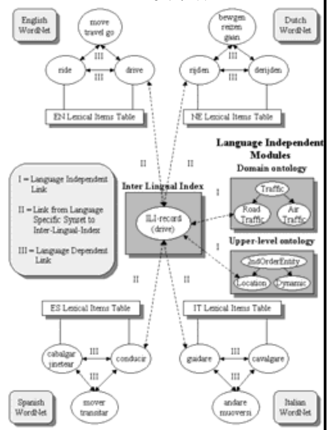
•Miller GA (1995) *WordNet: a lexical database for English*. Communications of the ACM 38(11):39–41

•Miller GA, Beckwith R, Fellbaum C, Gross D, Miller K (1990) *Introduction to WordNet: An on-line lexical database*. International Journal of Lexicography 3(4):235–244

•**EuroWordNet** **(http://www.hum.uva.nl/~ewn/)**

•Vossen P (ed) (1999) *EuroWordNet General Document. Version 3.* http://www.hum.uva.nl/ewn/

•Vossen P (ed) (1998) *EuroWordNet: A Multilingual Database with Lexical Semantic Networks*. Kluwer Academic Publishers, Dordrecht, The Netherlands



•**The Generalized Upper Model**
(http://www.darmstadt.gmd.de/publish/komet/gen-um/newUM.html)

Bateman JA, Fabris G, Magnini B (1995) *The Generalized Upper Model Knowledge Base: Organization and Use*. In: Mars N (ed) Second International Conference on Building and Sharing of Very Large-Scale Knowledge Bases (KBKS '95). University of Twente, Enschede, The Netherlands. IOS Press, Amsterdam, The Netherlands, pp 60–72

•**The Mikrokosmos ontology** **(http://crl.nmsu.edu/mikro [user and password are required])**

•Mahesh K (1996) *Ontology development for machine translation: Ideology and Methodology*. Technical Report MCCS-96-292. Computing Research Laboratory, New Mexico State University, Las Cruces, New Mexico. http://citeseer.nj.nec.com/mahesh96ontology.html

•Mahesh K, Nirenburg S (1995) *Semantic classification for practical natural language processing*. In: Schwartz RP, Kwasnik BH, Beghtol C, Smith PJ, Jacob E (eds) 6th ASIS SIG/CR Classification Research Workshop: An Interdisciplinary Meeting. Chicago, Illinois, pp 79–94

•**SENSUS** **(http://www.isi.edu/natural-language/projects/ONTOLOGIES.html)**

Swartout B, Ramesh P, Knight K, Russ T (1997) *Toward Distributed Use of Large-Scale Ontologies*. In: Farquhar A, Gruninger M, Gómez-Pérez A, Uschold M, van der Vet P (eds) AAAI'97 Spring Symposium on Ontological Engineering. Stanford University, California, pp 138–148

Domain Ontologies: e-Commerce Ontologies

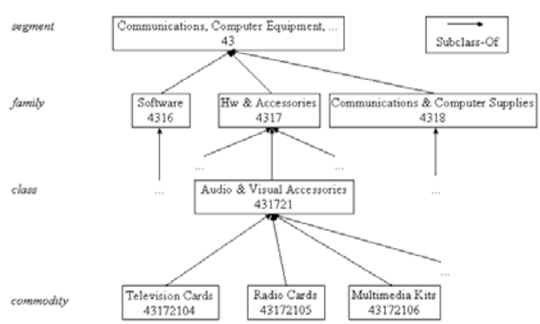
•**The United Nations Standard Products and Services Codes (UNSPSC)**
(http://www.unspsc.org/)

•**NAICS (North American Industry Classification System)**
(http://www.census.gov/epcd/www/naics.html)

•**SCTG (Standard Classification of Transported Goods)**
(http://www.statcan.ca/english/Subjects/Standard/sctg/sctg-menu.htm)

•**E-cl@ss**
(http://www.eclass.de/)

•**RosettaNet**
(http://www.rosettanet.org)



Domain Ontologies: Medical Ontologies

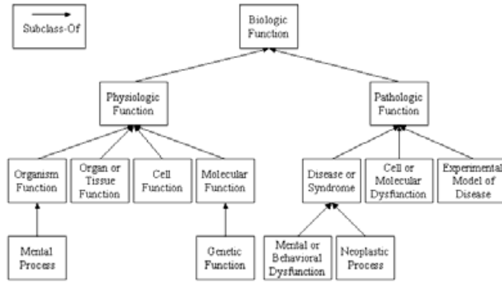
•**GALEN** (http://www.opengalen.org/)

Rector AL, Bechhofer S, Goble CA, Horrocks I, Nowlan WA, Solomon WD (1997) *The GRAIL concept modelling language for medical terminology*. Artificial Intelligence in Medicine 9:139–171

•**UMLS (Unified Medical Language System)** (http://www.nih.gov/research/umls/)

•**ON9** (http://saussure.irmkant.rm.cnr.it/ON9/index.html)

Gangemi A, Pisanelli DM, Steve G (1998) *Some Requirements and Experiences in Engineering Terminological Ontologies over the WWW*. In: Gaines BR, Musen MA (eds) 11th International Workshop on Knowledge Acquisition, Modeling and Management (KAW'98). Banff, Canada, SHARE10:1–20



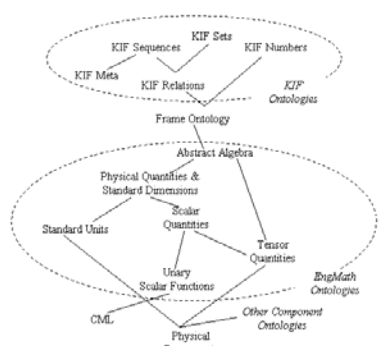
Domain Ontologies: Engineering Ontologies

•**EngMath**

Gruber TR, Olsen G (1994) *An ontology for Engineering Mathematics*. In: Doyle J, Torasso P, Sandewall E (eds) Fourth International Conference on Principles of Knowledge Representation and Reasoning. Bonn, Germany. Morgan Kaufmann Publishers, San Francisco, California, pp 258–269

•**PhysSys**

Borst WN (1997) *Construction of Engineering Ontologies*. Centre for Telematica and Information Technology, University of Tweenty. Enschede, The Netherlands



Domain Ontologies: Enterprise Ontologies

•**Enterprise Ontology** (http://www.aiai.ed.ac.uk/~entprise/enterprise/ontology.html)

Uschold M, King M, Moralee S, Zorgios Y (1998) *The Enterprise Ontology*. The Knowledg Engineering Review 13(1):31–89

•**TOVE** (http://www.eil.utoronto.ca/tove/toveont.html)

Fox MS (1992) *The TOVE Project: A Common-sense Model of the Enterprise*. In: Belli F, Radermacher FJ (eds) Industrial and Engineering Applications of Artificial Intelligence and Expert Systems. (Lecture Notes in Artificial Intelligence LNAI 604) Springer-Verlag, Berlin, Germany, pp 25–34

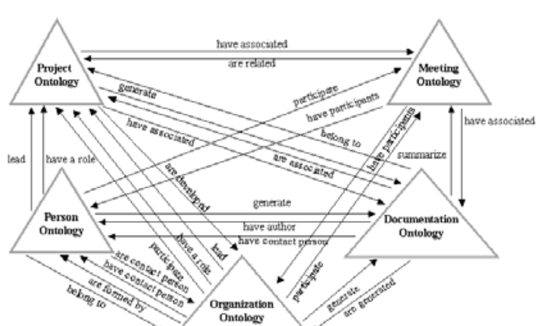
- Enterprise Ontologies
  - Enterprise Design Ontology
  - Project Ontology
  - Material Flow Ontology
  - Business Process Ontology
- Derivative Ontologies
  - Transportation Ontology
  - Inventory Ontology
  - Quality Ontology
  - Product Design Ontology
  - Goals Ontology
  - Scheduling Ontology
  - Operating Strategies Ontology
  - Product Requirements Ontology
  - Information Resource Ontology
  - Intended Action Ontology
  - Electro Mechanical Product Ontology
- Core Ontologies
  - Product Ontology
  - Service Ontology
  - Activity Ontology
  - Organization Ontology
  - Resource Ontology

Domain Ontologies: Knowledge Management Ontologies

•**(KA)^2 ontologies** (http://ka2portal.aifb.uni-karlsruhe.de)

Decker S, Erdmann M, Fensel D, Studer R (1999) *Ontobroker: Ontology Based Access to Distributed and Semi-Structured Information*. In: Meersman R, Tari Z, Stevens S (eds) Semantic Issues in Multimedia Systems (DS-8), Rotorua, New Zealand. Kluwer Academic Publisher, Boston, Massachusetts. pp 351–369

•**R&D projects** (http://www.esperonto.net/)



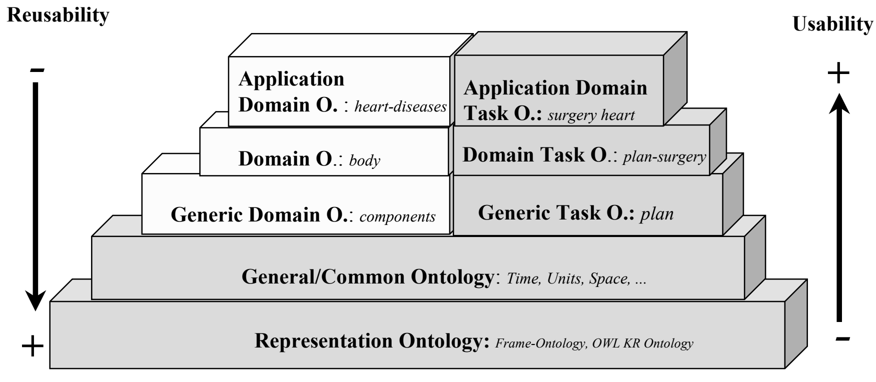
Outline

The Knowledge Sharing Initiative
Definitions of Ontologies
Modeling of Ontologies
Types of Ontologies
Libraries of Ontologies
Ontological Commitments

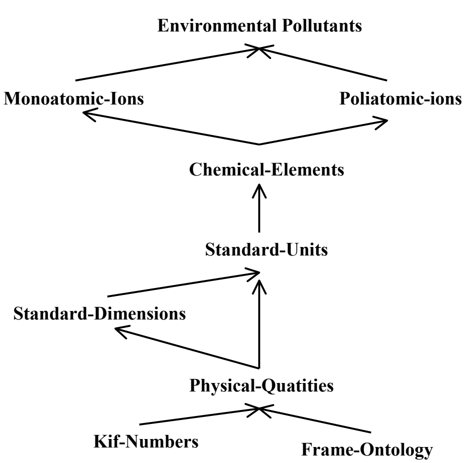
Libraries of Ontologies (I)

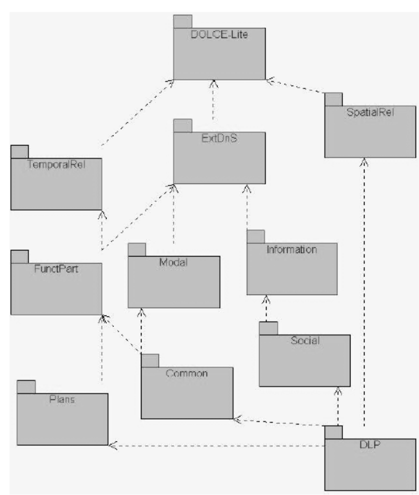
OWL ontologies	
Protégé ontology library	**http://protege.stanford.edu/download/ontologies.html**
OWL ontology library	**http://www.daml.org/ontologies/**
SWOOGLE	**http://swoogle.umbc.edu/**
Oyster	**http://oyster.ontoware.org/oyster/oyster.html**
Other ontologies	
SHOE ontology library	**http://www.cs.umd.edu/projects/plus/SHOE/onts/index.html**
Ontolingua ontology library	**http://ontolingua.stanford.edu/**
WebOnto ontology library	**http://webonto.open.ac.uk**
WebODE ontology library	**http://webode.dia.fi.upm.es/**
$(KA)^2$ ontology library	**http://ka2portal.aifb.uni-karlsruhe.de/**

Libraries of Ontologies (II)

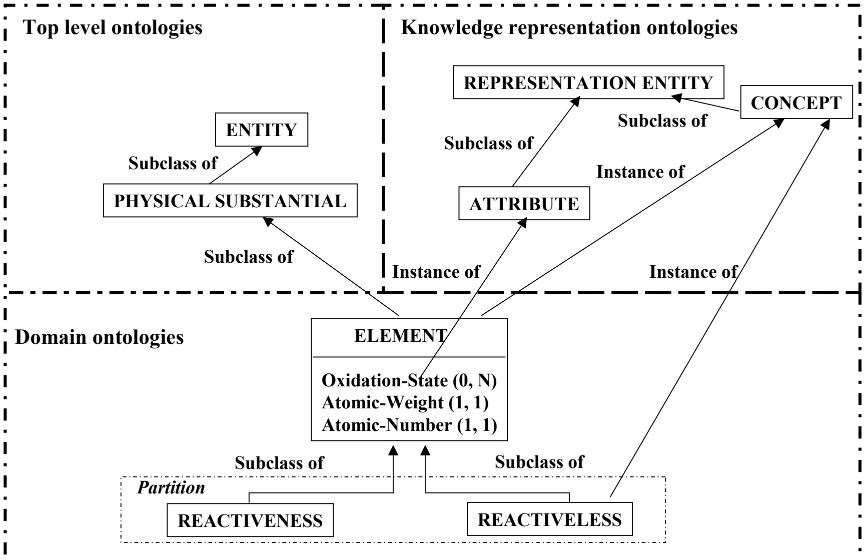


Relationship between Ontologies in the Library

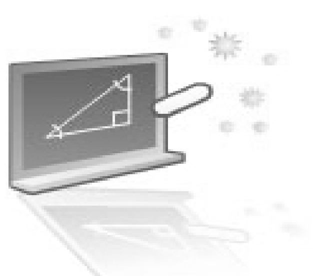




How to Reuse Ontologies from a Library



Exercise



- **Objective**
  - **Learn how to use upper-level, middle-level and domain ontologies for the development of other domain ontologies**
- **Tasks**
  - **Browse existing ontology libraries and analyse their classifications**
  - **Select terms from existing ontology libraries and use them to connect the terms in our domain ontology**
  - **Look and “shop” for terms in Swoogle or Oyster**

Outline

- The Knowledge Sharing Initiative
- Definitions of Ontologies
- Modeling of Ontologies
- Types of Ontologies
- Libraries of Ontologies
- Ontological Commitments

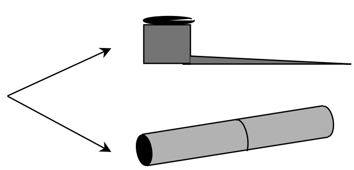
Ontological Commitments

Agreements to use the vocabulary in a coherent and consistent manner (Gruber)

Connection between the ontology vocabulary and the meaning of the terms of such vocabulary

An agent commits (conforms) to an ontology if it "acts" consistently with the definitions

Example: What is a pipe?



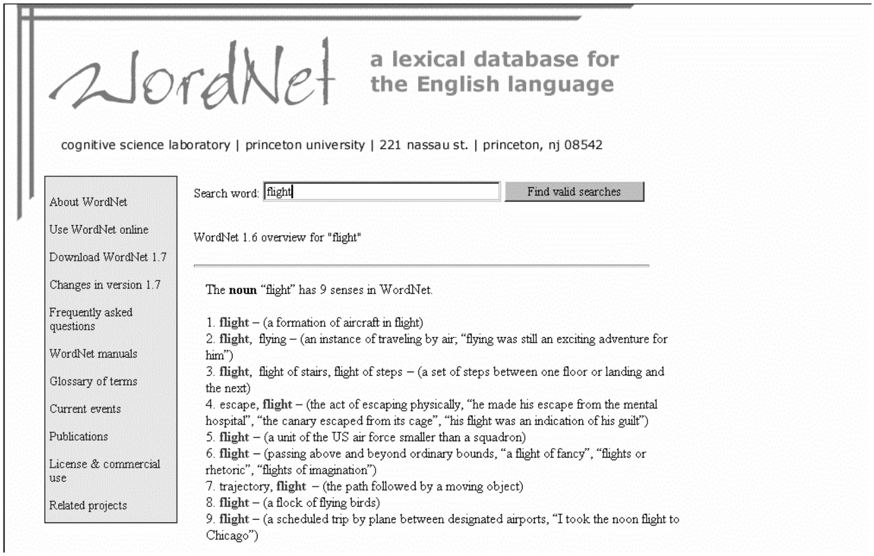
9 definitions of the term flight from WordNet

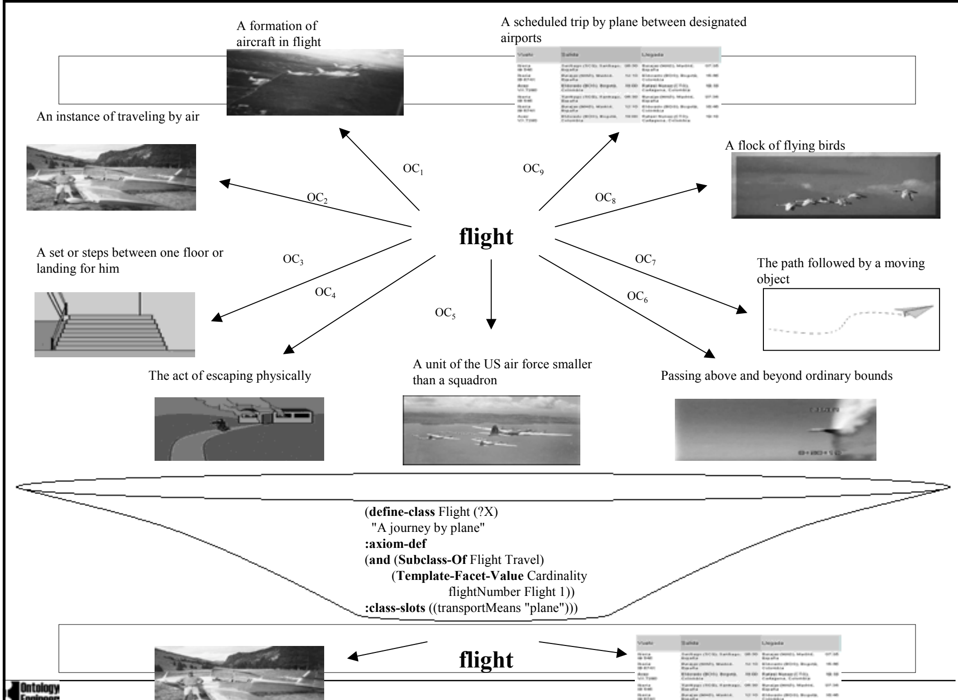
Identification of the ontological commitment

• Gruber, T.; Olsen, G. *An Ontology for Engineering Mathematics.* **Fourth International Conference on Principles of Knowledge Representation and Reasoning**. Ed by Doyle and Torasso. Morgan Kaufmann. 1994. Also as KSL-94-18.

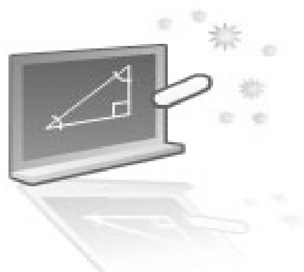
• Guarino, N.; Carrara, M.; Giaretta, P. *Formalizing Ontological Commitments.* **12th National Conference on Artificial Intelligence. AAAI**-94. 1994. 560-567

Ontological Commitments





Exercise



- **Objective**
  - **Be aware of the existence of ontological commitments and make agreements on them**
- **Tasks**
  - **Agree on the meaning of terms used in the domain model developed**

Conclusions. What is an Ontology?

Shared understanding of a domain

Repository of vocabulary

- Formal definitions
- Informal definitions

Conclusion. An Ontology should be just the Beginning