1. Ontologies

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28660 Boadilla del Monte, Madrid, Spain

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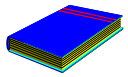
The knowledge Sharing Initiative

"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.

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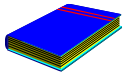
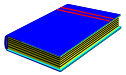
Definitions of Ontologies (I)

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

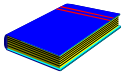
2. "An ontology is an explicit specification of a conceptualization"



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

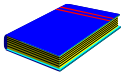
Definitions of Ontologies (II)

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.

Definitions of Ontologies (III)

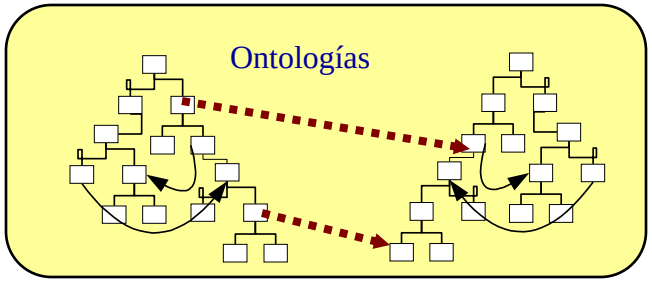
3. "An ontology is a formal, explicit specification of a shared conceptualization"

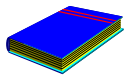
Machine-readable

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





Studer, Benjamins, Fensel. **Knowledge Engineering: Principles and Methods.** ***Data and Knowledge Engineering*****. 25 (1998) 161-197**

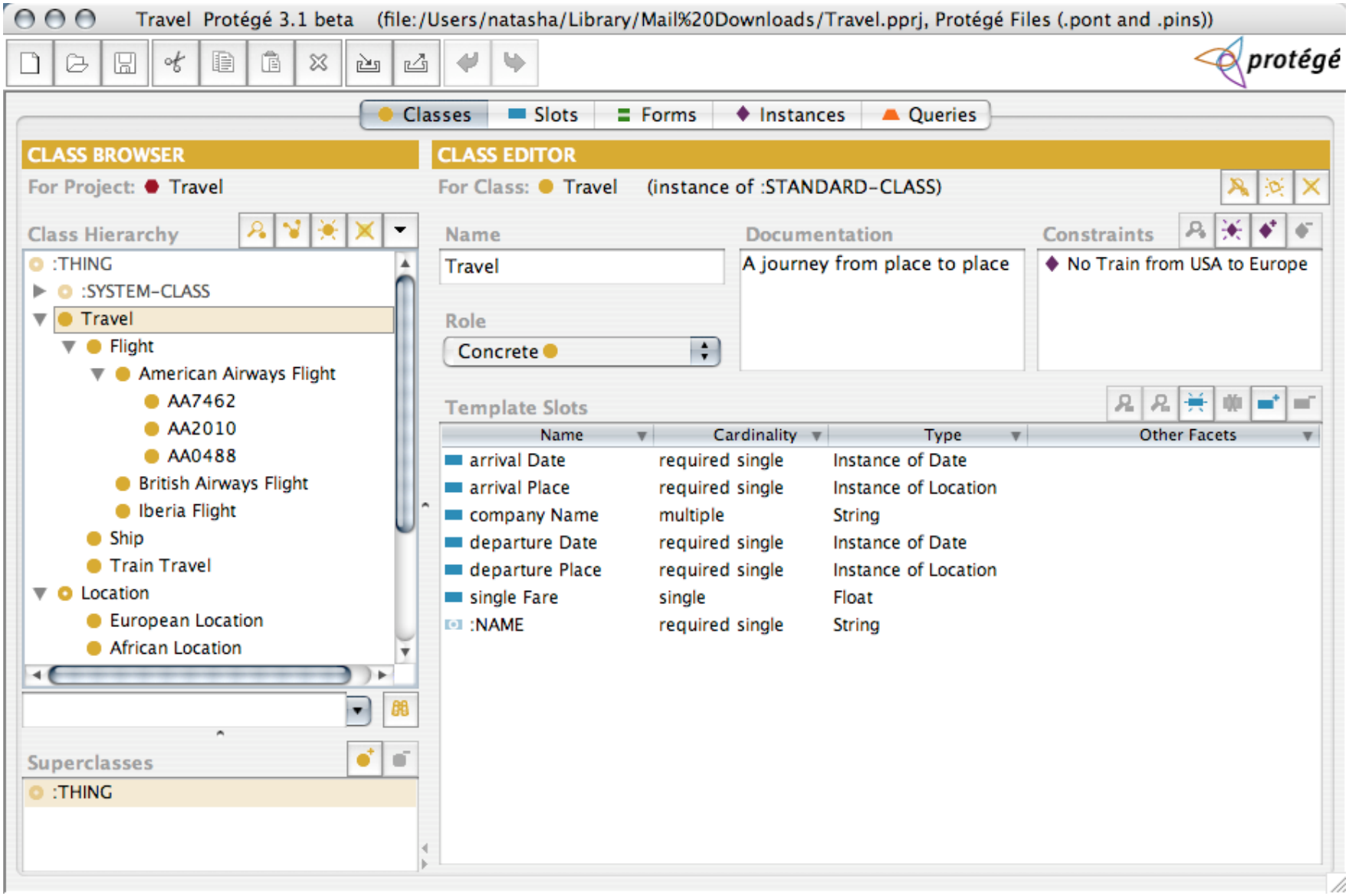
Definitions of Ontologies (IV)

Lightweight Ontologies :

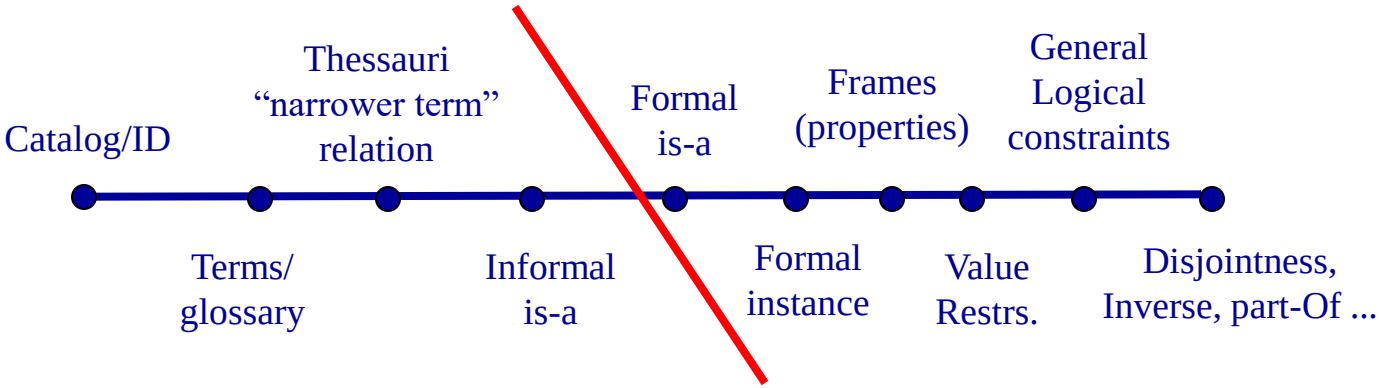
- **Include Concepts with properties and Taxonomies**
- **Do not include Axioms and constraints.**

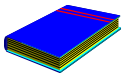
Heavyweight Ontologies :

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


Travel Protégé 3.1 beta (file:/Users/natasha/Library/Mail%20Downloads/Travel.pprj, Protégé Files (.pont and .pins))
protégé
Classes
Slots
Forms
Instances
Queries
CLASS BROWSER
For Project: Travel
Class Hierarchy
:THING
:SYSTEM-CLASS
Travel
Flight
American Airways Flight
AA7462
AA2010
AA0488
British Airways Flight
Iberia Flight
Ship
Train Travel
Location
European Location
African Location
Superclasses
:THING
CLASS EDITOR
For Class: Travel (instance of :STANDARD-CLASS)
Name
Travel
Documentation
A journey from place to place
Constraints
No Train from USA to Europe
Role
Concrete
Template Slots
Name
Cardinality
Type
Other Facets
arrival Date
required single
Instance of Date
arrival Place
required single
Instance of Location
company Name
multiple
String
departure Date
required single
Instance of Date
departure Place
required single
Instance of Location
single Fare
single
Float
:NAME
required single
String

Types of Ontologies
Lassila and McGuiness Classification



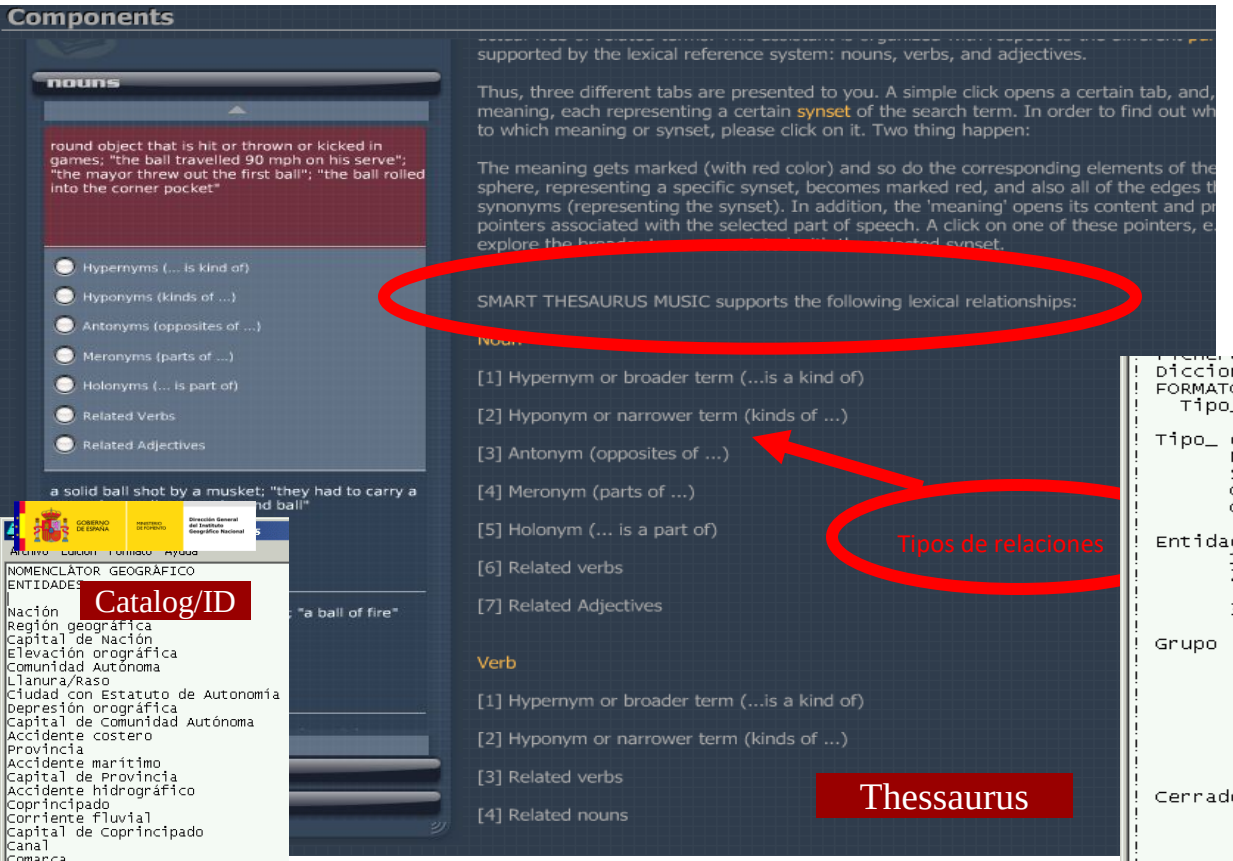


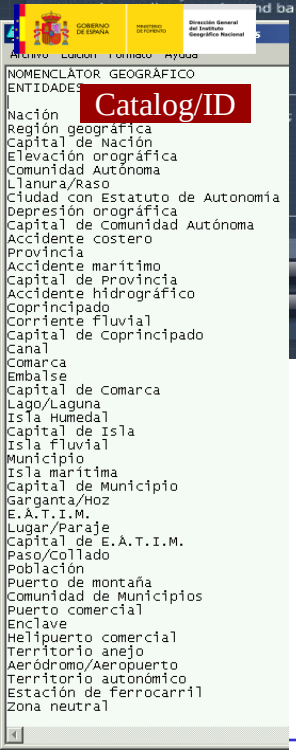
Lassila O, McGuiness D. The Role of Frame-Based Representation on the Semantic Web. Technical Report. Knowledge Systems Laboratory. Stanford University. KSL-01-02. 2001.

Catalog/ID Glossary Thessaurus Informal is-a

Informal is-a

Id	Category Name	Parent
20000	Water area	1
21000	Environmental area	20000
22000	Fishing Statistical area	20000
24020	Jurisdiction area	20000
21001	Inland/marine	21000
21002	Ocean	21000
21003	North/South/Equatorial	21000
21004	Sub Ocean	21000
21005	Large Marine ecosystem	21000



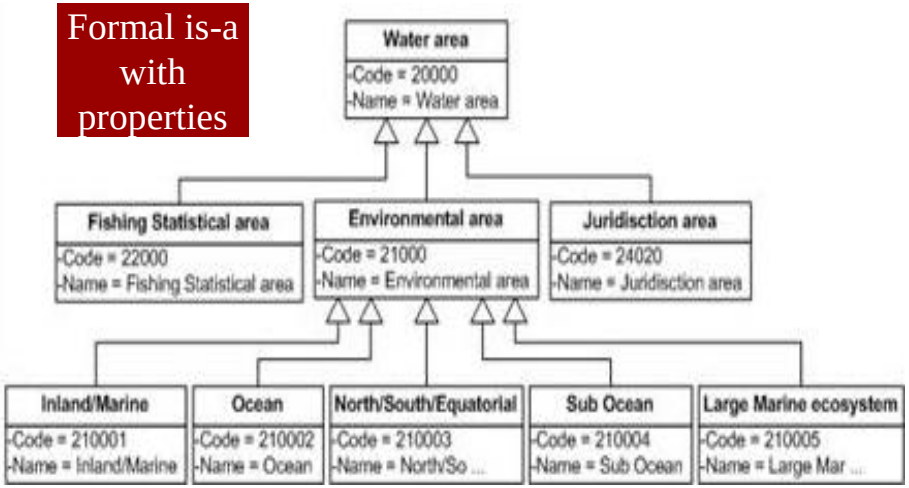



```
! Diccionario de conversión DGN -> EDM.
! FORMATO:
!   Tipo_dgn Entidad Tipo_istram Grupo Código_bcn Cerrado Trato
!
! Tipo_ dgn...NNSCCCGG                          Codigo_bcn...TTGGSS
!       NN   : Nivel elemento                          TT : Tema
!       S    : Estilo linea dgn                        GG : Grupo
!       CCC  : Color  linea dgn                        SS : Subgrupo
!       GG   : Grosor linea dgn
!
! Entidad                                       Tipo_istram....???
!       104 : polilinea
!       203 : célula se convierte a símbolo
!        -1 : célula se explota en sus componentes
!       304 : rótulo
!
! Grupo
!         0 : sin determinar
!         1 : carreteras
!         2 : hidrografía
!         3 : conducciones
!         4 : administrativo
!
!         En textos el grupo corresponde a la fuente Microstatic
!
! Cerrado
!        en lineas                                      en textos
!                1 : perimetral                                 n : altu
!                0 : entidad lineal abierta
!               -1 : cultivo perimetral
!               -2 : cultivo linea abierta
!
! Trato
!   I: Intocable  A: Altimetría  N: No tratar  T: Textos Asociad
!   S: Textos Sueltos  C: Cultivo  F: Solo salida !: Tratar norm
!                                  TTGGSS
02000900    104      1    0    090101    1    !I   Marco de hoja
02300902    104      2    0    100200    0    !    Base Geodésica de M
06003900    104      3    0    025102    0    !    Acantilado
06006900    104      4    0    025302    0    !    Costa rocosa no aca
06009900    104      5    2    037402    1    !    Playa fluvial de gu
06012900    104      6    0    025501    1    !    Lavas. Contorno
06015900    104      7    0    058303    0    !I   Dique de hormigón >
06018900    104      8    0    058304    0    !I   Dique de hormigón <
07013400    104      9    0    058302    0    !I   Dique de tierra
07016400    104     10    0    055401    1    !    Vertedero. Contorno
11003003    104     11    1    062202    0    !    Autopista. Enlace
11012000    104     12    0    056091    1    !I   Patio. Contorno
13003300    104     13    1    060101    0    !    Autopista. Eje
13303300    104     14    1    060131    0    !    Autopista en Contru
14002401    104     15    1    066901    1    !I   Puesto de S.O.S.
14003301    104     16    1    067901    1    !I   Peaje
15003003    104     17    1    062204    0    !    Autovía. Enlace
15003004    104     18    1    060701    0    !    Autovía
```

Informal is-a

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

Formal is-a with properties




```
(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 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-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

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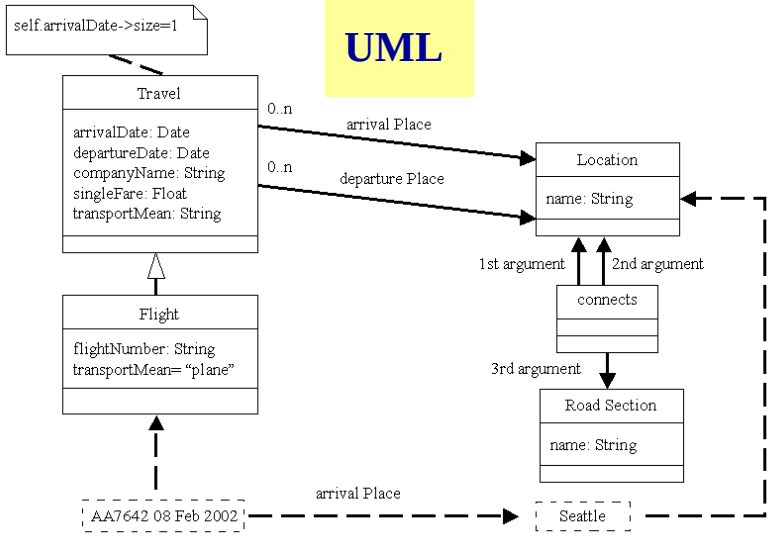
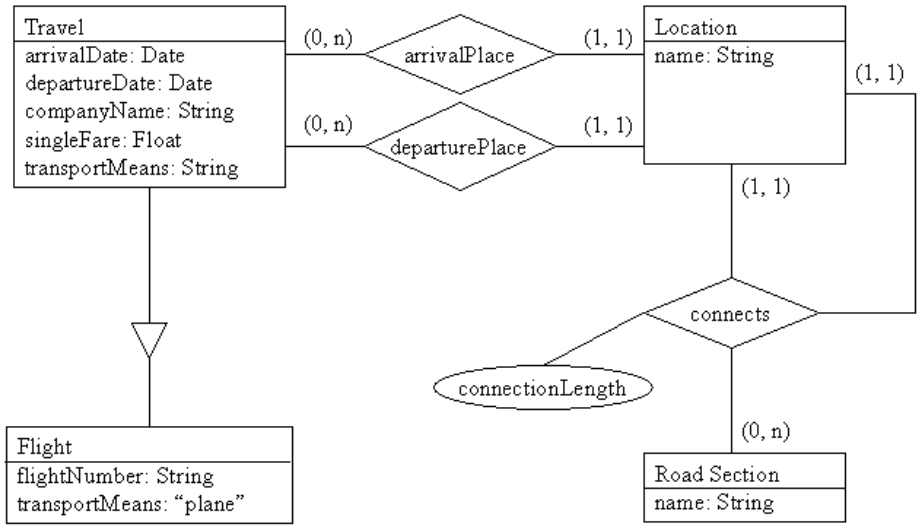
Ontologies

Approaches for building ontologies

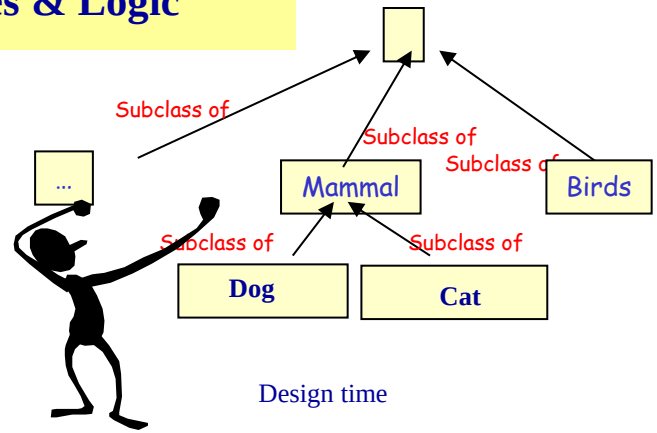
UML



E/R Model

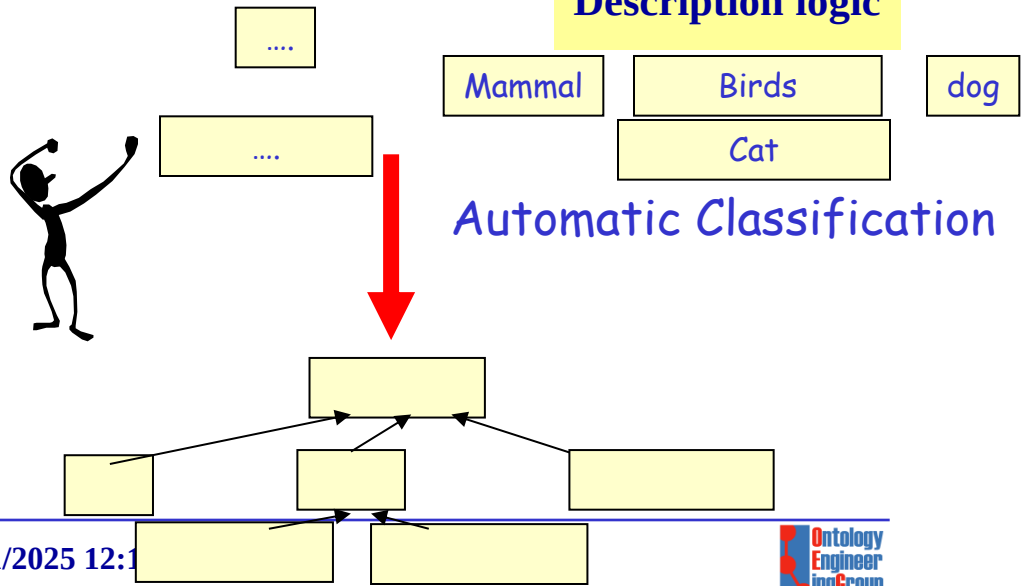


Frames & Logic



Design time

Description logic



Components of an Ontology

Concepts are organized in **taxonomies**

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

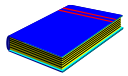
> **Subclass-of: Concept 1 x Concept2**
> **Connected to: Component1 x Component2**

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

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

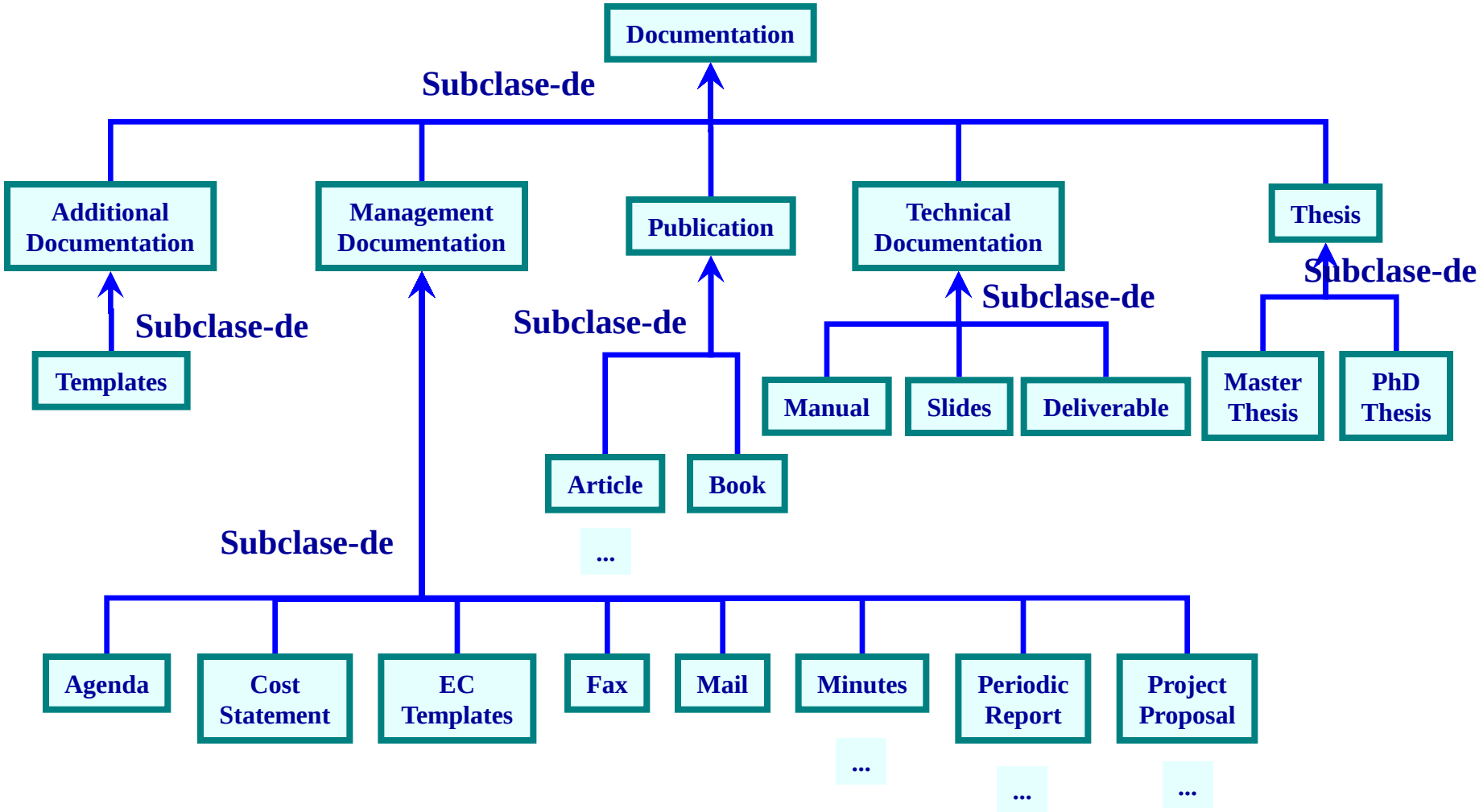
Instances Elements

Axioms Sentences which are always true



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

Documentation Taxonomy



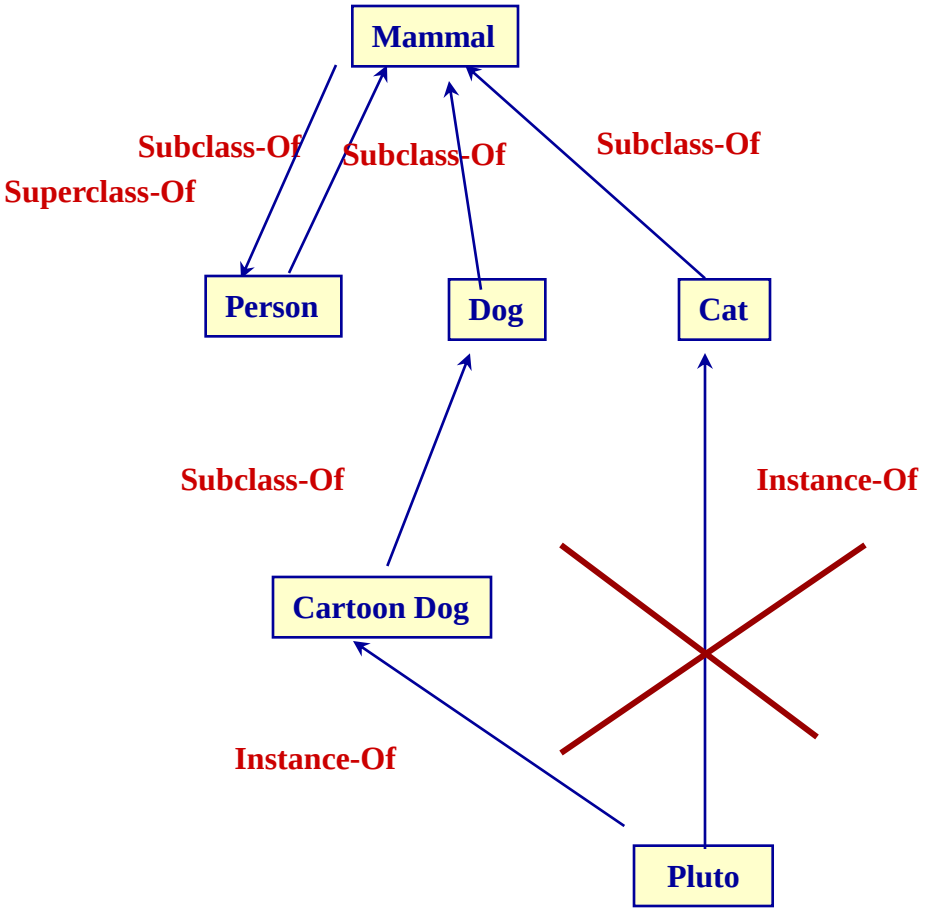
Modelling disjoint knowledge

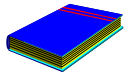
class-Partition: a set of disjoint classes

Disjoint: Defines the set of classes in the partition as subclasses of the parent class.
This classification does not necessarily to be complete.

Exhaustive-Disjoint: Defines the set of classes in the partition as subclasses of the parent class.
This classification is complete.

Why disjoint knowledge is important (I)



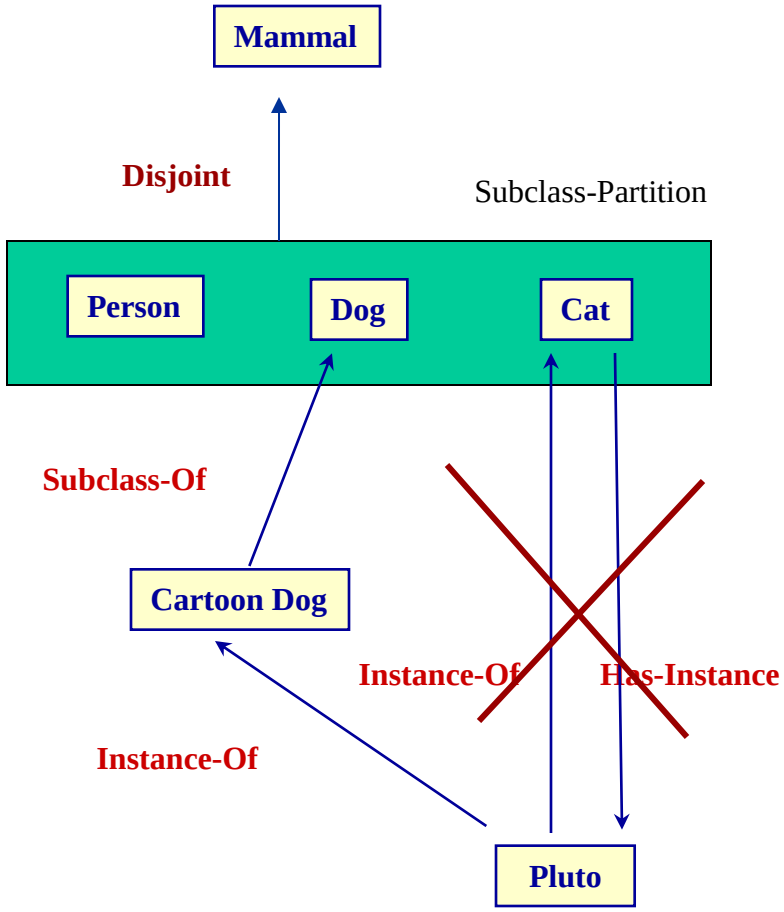


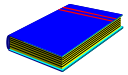
A. Gómez-Pérez. *Evaluation of Ontologies.*
International Journal of Intelligent Systems.
Vol. 16, Nº3. March 2001. PP391-410

Pluto could be an instance of cat and dog

Semantic Error

Why disjoint knowledge is important (II)

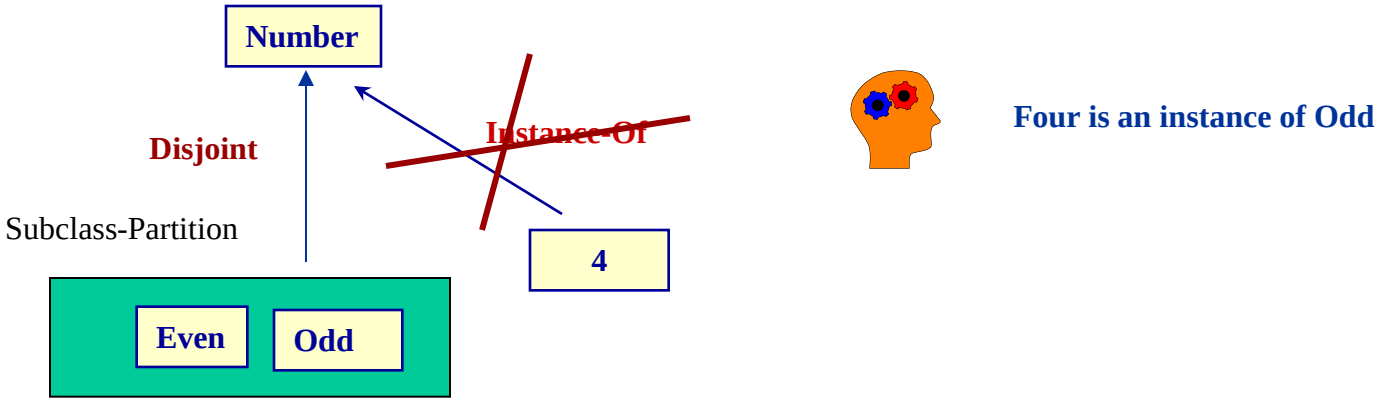


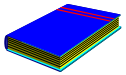


A. Gómez-Pérez. *Evaluation of Ontologies.*
International Journal of Intelligent Systems.
Vol. 16, Nº3. March 2001. PP391-410

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

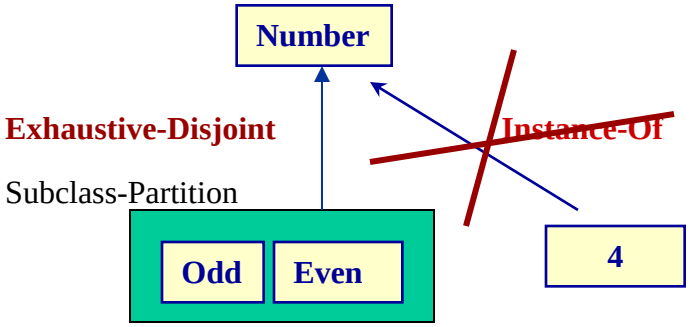
Why disjoint knowledge is important (III)





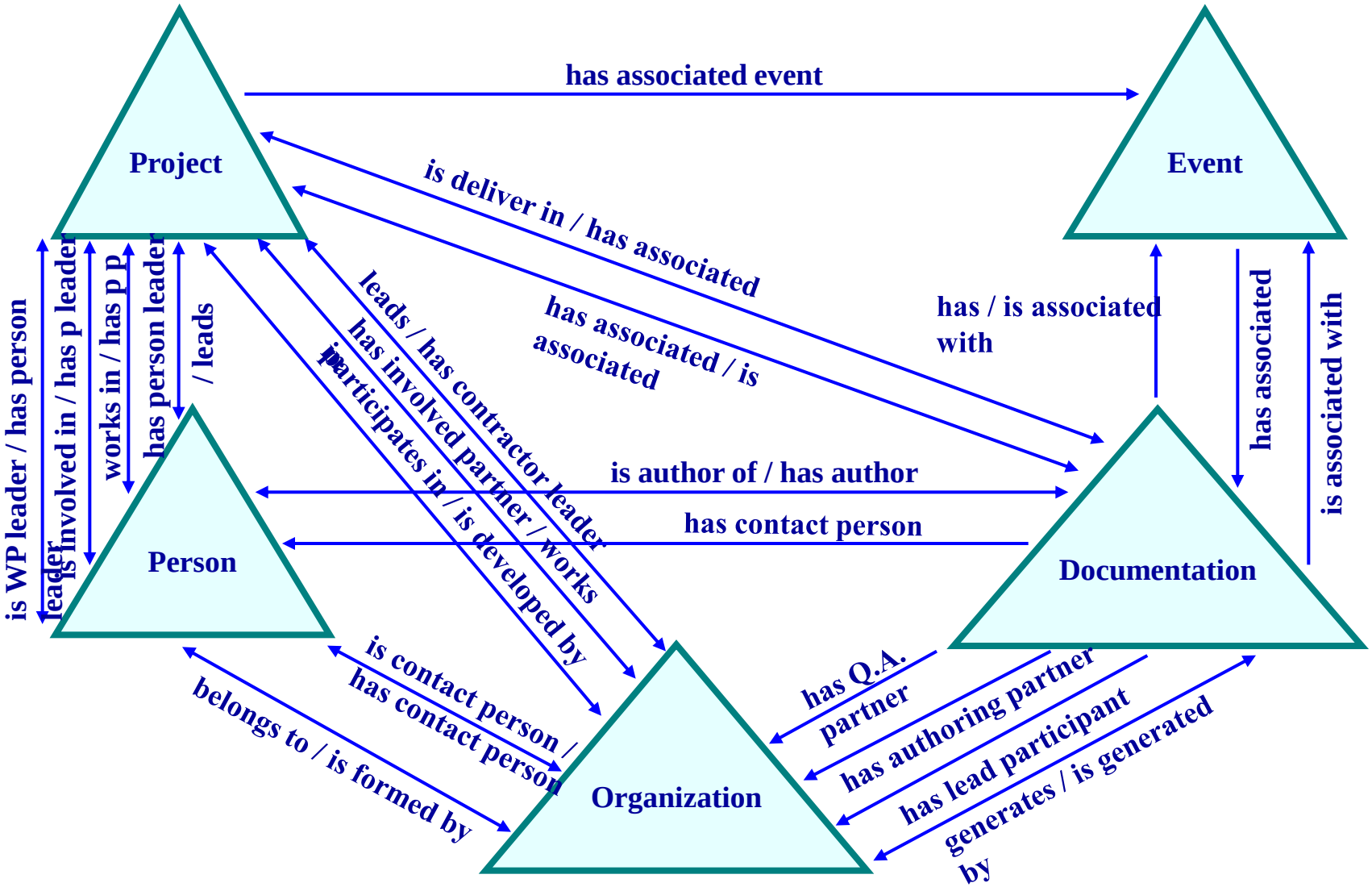
A. Gómez-Pérez. *Evaluation of Ontologies.* **International Journal of Intelligent Systems.** Vol. 16, Nº3. March 2001. PP391-410

Why disjoint knowledge is important (IV)

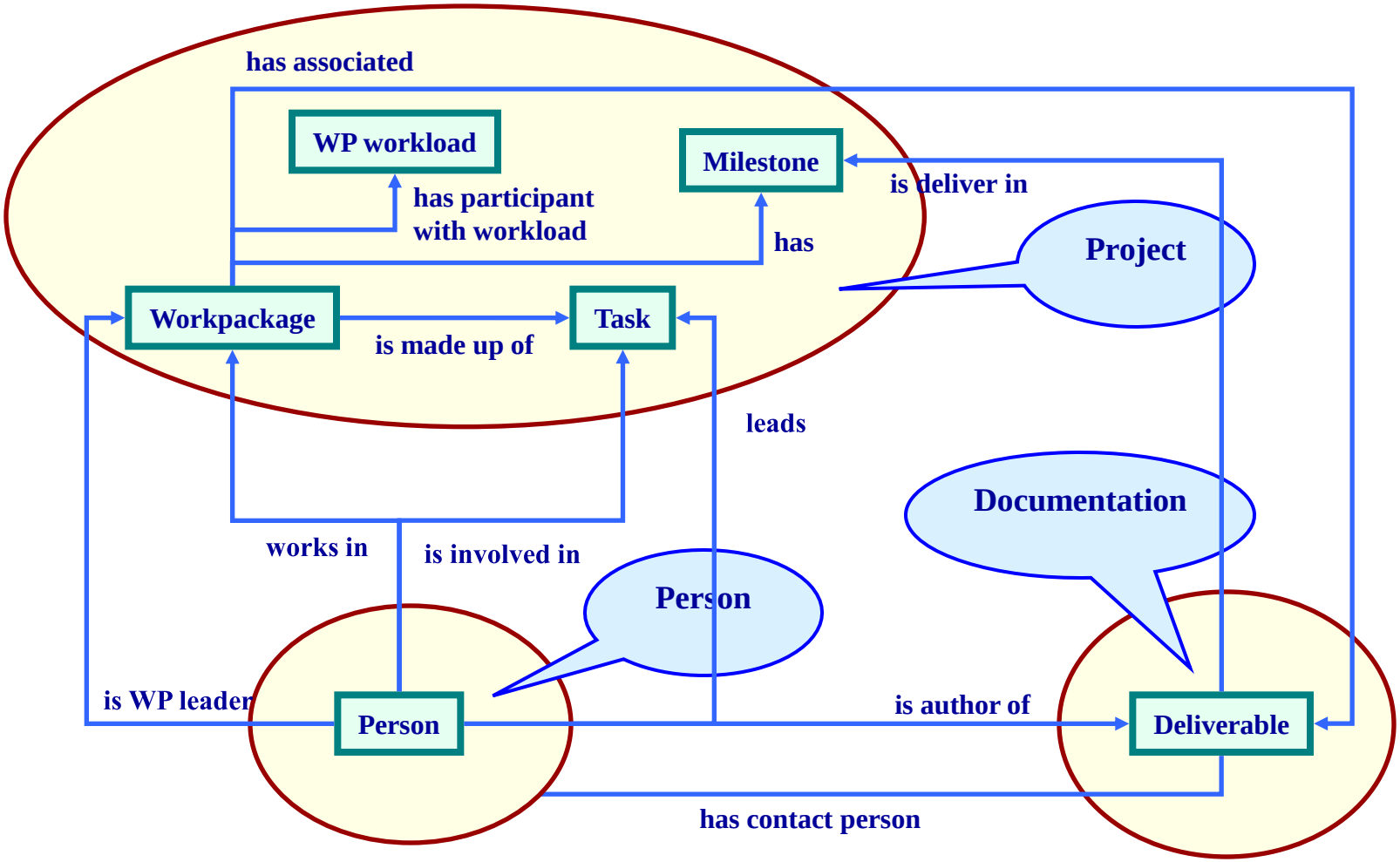


Four is an instance of something in the partition

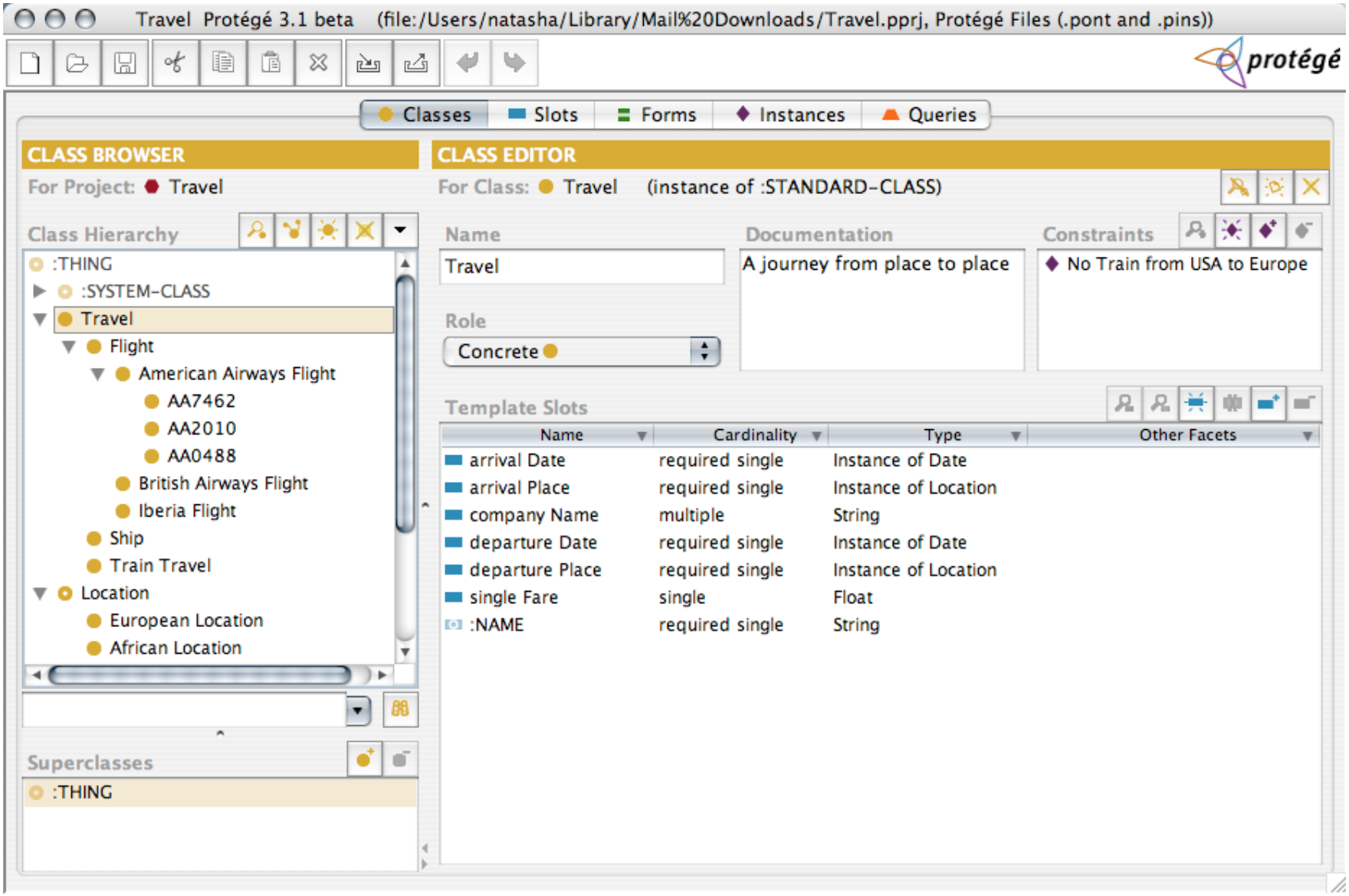
Relations between concepts



Relationships between Person, Project and Documentation



Properties


Travel Protégé 3.1 beta (file:/Users/natasha/Library/Mail%20Downloads/Travel.pprj, Protégé Files (.pont and .pins))
protégé
Classes
Slots
Forms
Instances
Queries
CLASS BROWSER
For Project: Travel
Class Hierarchy
:THING
:SYSTEM-CLASS
Travel
Flight
American Airways Flight
AA7462
AA2010
AA0488
British Airways Flight
Iberia Flight
Ship
Train Travel
Location
European Location
African Location
Superclasses
:THING
CLASS EDITOR
For Class: Travel (instance of :STANDARD-CLASS)
Name
Travel
Documentation
A journey from place to place
Constraints
No Train from USA to Europe
Role
Concrete
Template Slots
Name
Cardinality
Type
Other Facets
arrival Date
required single
Instance of Date
arrival Place
required single
Instance of Location
company Name
multiple
String
departure Date
required single
Instance of Date
departure Place
required single
Instance of Location
single Fare
single
Float
:NAME
required single
String

Example of axioms

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


(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)))))))
```

Table of Content

Ontologies

Types of Ontologies

Content Ontologies

Domain O.

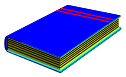
Scalpel, scanner
anesthetize, give birth

Task O.

goal, schedule
to assign, to classify

General/Common O.

Things, Events, Time, Space
Causality, Behavior, Function



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.

Issue of the Conceptualization

Representation O.

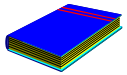
- Conceptualization of KR formalisms

Generic O.

- Reusable across D.

Domain O.

- Reusable



Application O.

- Non reusable
- Usable

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)

- **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)

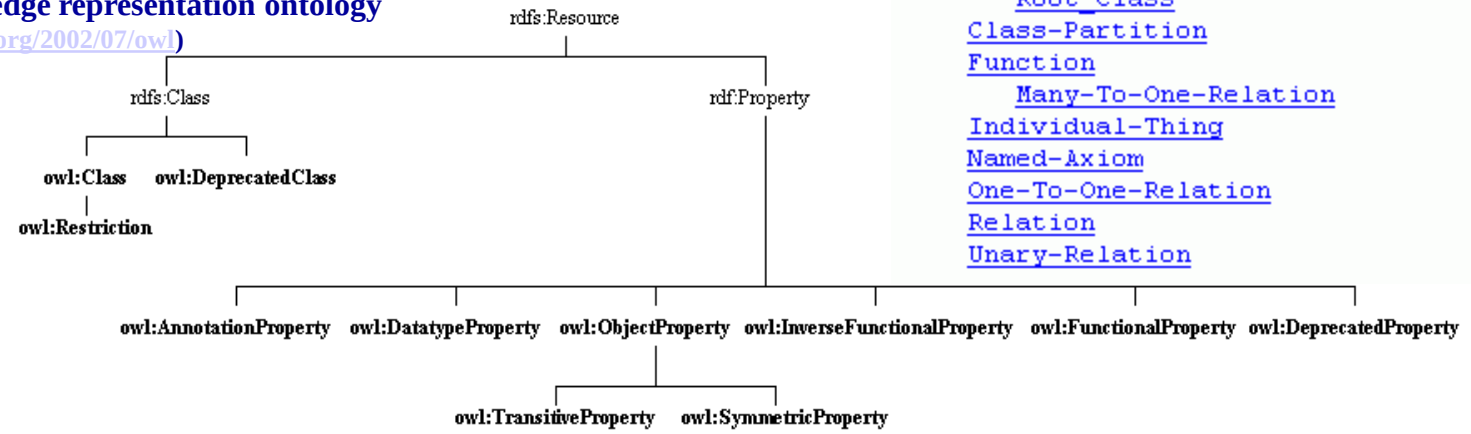
- **OIL knowledge representation ontology**
  (http://www.ontoknowledge.org/oil/rdf-schema/2000/11/10-oil-standard)

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

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

Class hierarchy (23 classes defined):

```
Binary-Relation
   Antisymmetric-Relation
      Asymmetric-Relation
      Partial-Order-Relation
         Total-Order-Relation
   Irreflexive-Relation
      Asymmetric-Relation
   Many-To-Many-Relation
   Many-To-One-Relation
   One-To-Many-Relation
   Reflexive-Relation
      Equivalence-Relation
      Partial-Order-Relation ...
   Symmetric-Relation
      Equivalence-Relation
   Transitive-Relation
      Equivalence-Relation
      Partial-Order-Relation ...
   Weak-Transitive-Relation
Class
   Root_Class
Class-Partition
Function
   Many-To-One-Relation
Individual-Thing
Named-Axiom
One-To-One-Relation
Relation
Unary-Relation
```



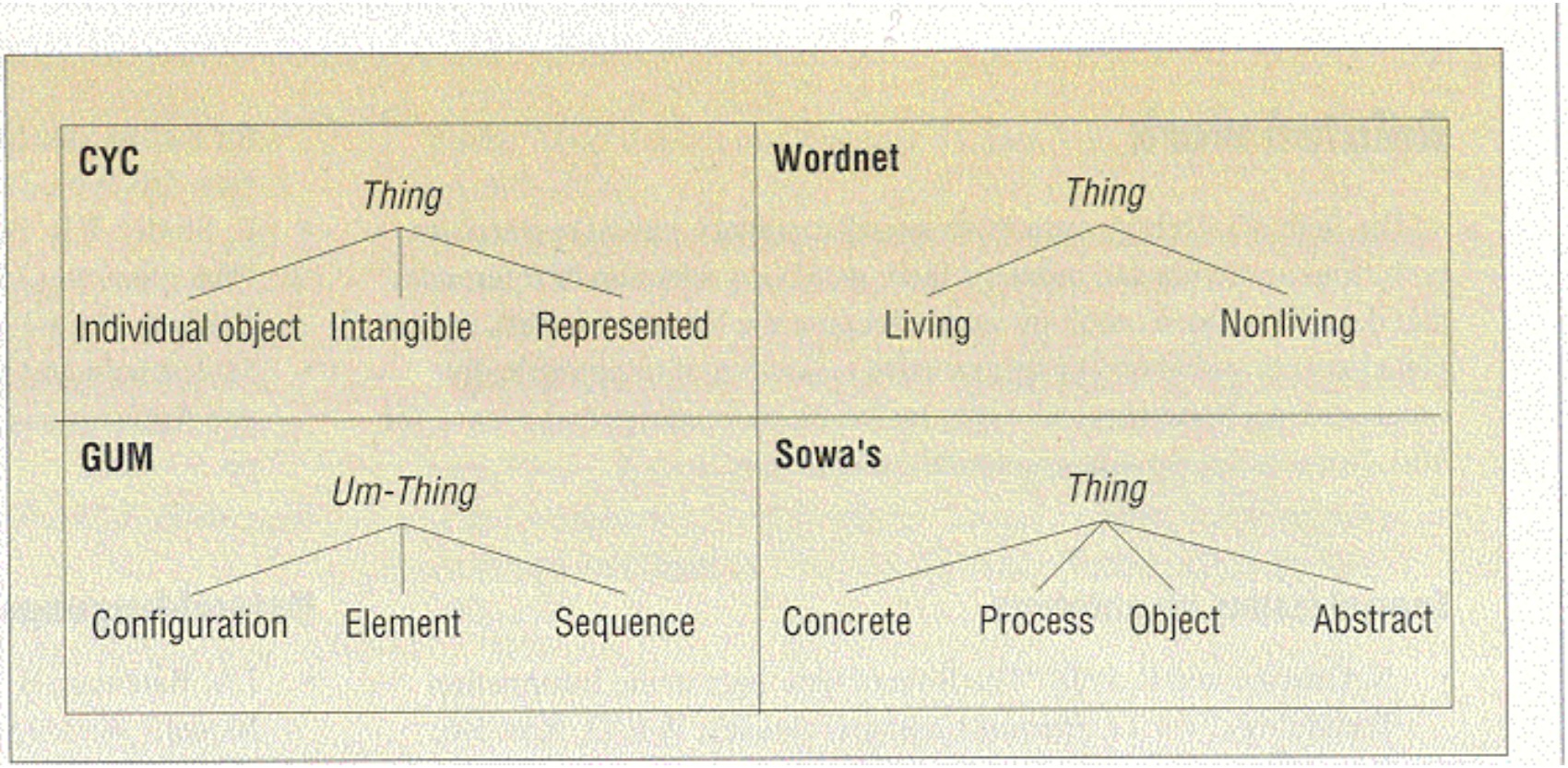
Definition of the relation SUBCLASS-OF in the Frame Ontology

```
(define-relation Subclass-Of (?child-class ?parent-class)

"Class C is a subclass of parent class P if and only if every instance of C is also an instance of P.  A class may have multiple superclasses and subclasses. Subclass-of is transitive: if (subclass-of C1 C2) and (subclass-of C2 C3) then (subclass-of C1 C3). Object-centered systems sometimes distinguish between a subclass-of relationship that is asserted and one that is inferred. For example, (subclass-of C1 C3) might be inferred from asserting (subclass-of C1 C2) and (subclass-of C2 C3)..."

:iff-def
  (and (Class ?parent-class)
       (Class ?child-class)
       (forall (?instance)
         (=> (Instance-Of ?instance ?child-class)
             (Instance-Of ?instance ?parent-class))))

:axiom-constraints
  (Transitive-Relation Subclass-Of)
:issues
  ((:see-also direct-subclass-of)
   (:see-also "In CycL, subclass-of is called #%allGenls because it is a slot from a collection to all of its generalizations  (superclasses)."
              "In the KL-ONE literature, subclass relationships are also called subsumption relationships and ISA is sometimes used for subclass-of.")
   ("Why is it called Subclass-of instead of subclass or superclass?"
    "Because the latter are ambiguous about the order of their arguments. We are following the naming convention that a binary relationship is read as an English sentence `Domain-element Relation-name Range-value'. Thus, `person subclass-of animal' rather than `person superclass animal'.")))
```

http://www-ksl.stanford.edu

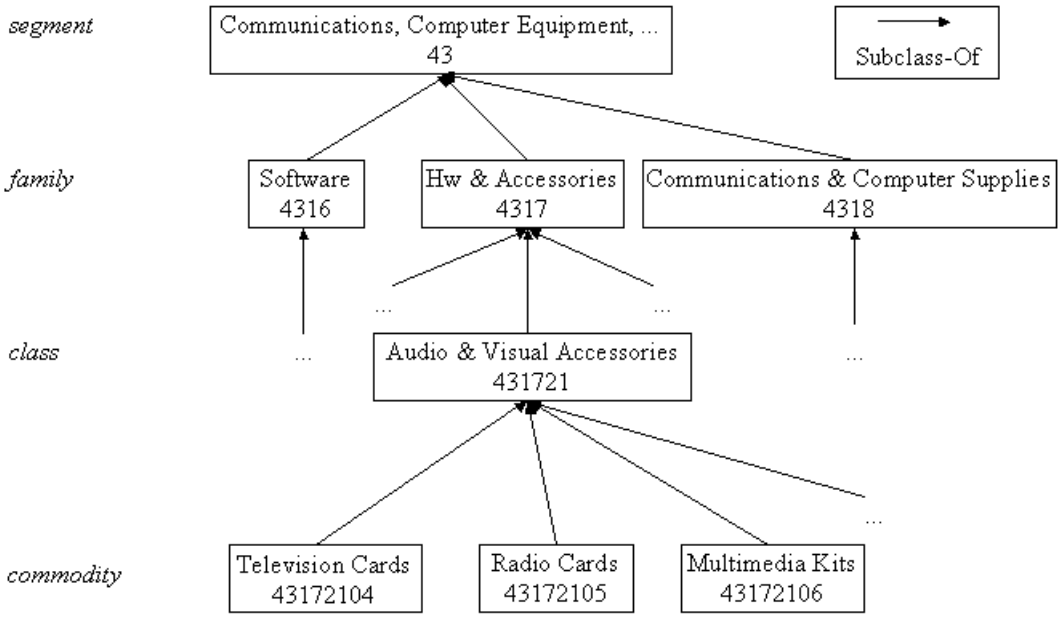
One Unique Top-Level Ontology?

Various proposals



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

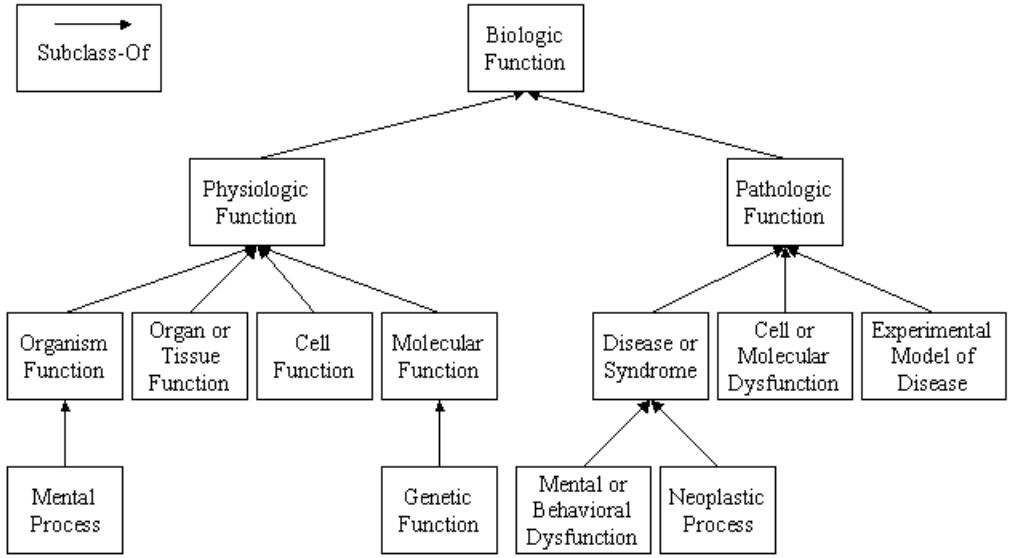
•**GALEN** (http://www.opengalen.org/)

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

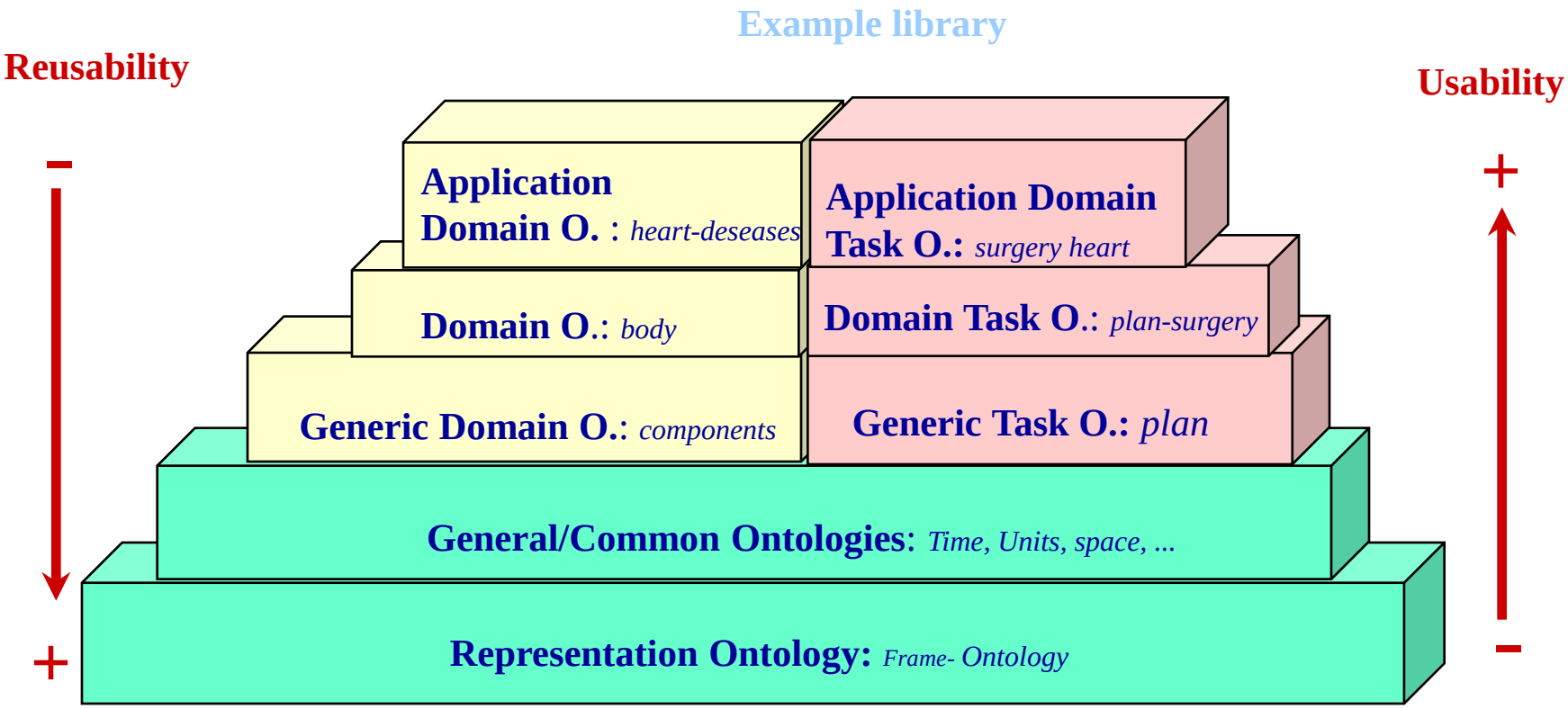
•**UMLS (Unified Medical Language System)**
(http://www.nih.gov/research/umls/)

•**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



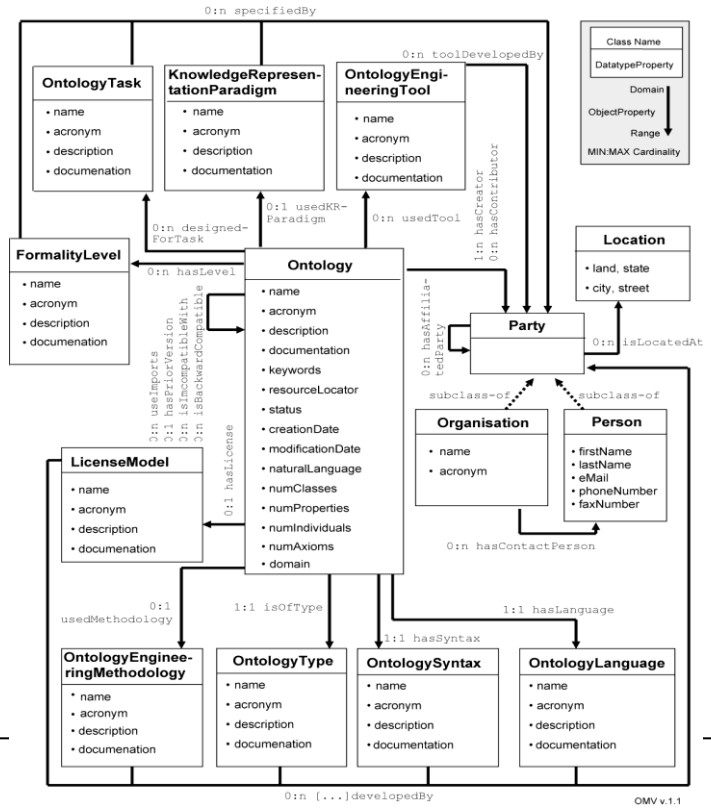
Libraries of Ontologies



http://delicias.dia.fi.upm.es/mirror-server/ont-serv.html

Searching Ontologies

- OMV: Ontology Metadata Vocabulary



- Ontology registries

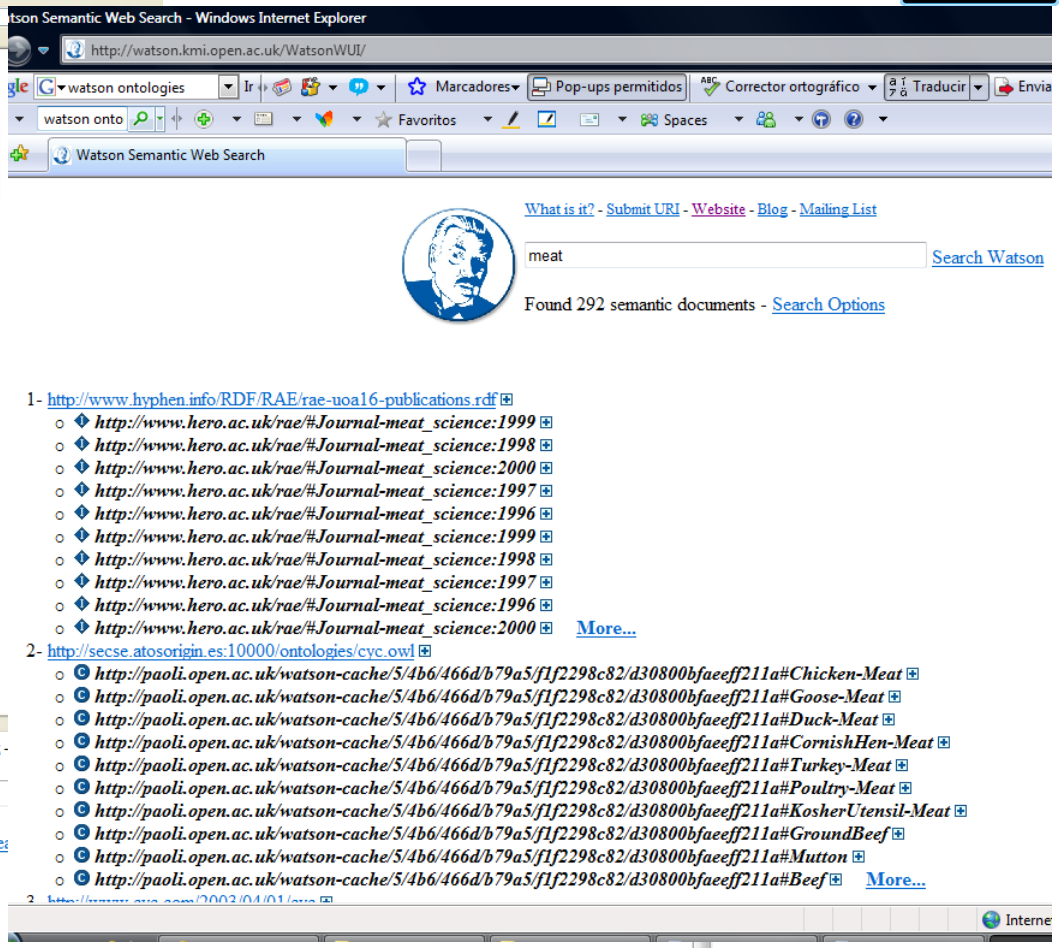
CYSTER

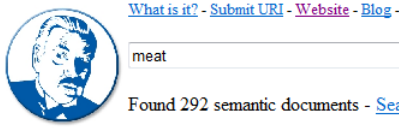
Onthology.org

knowledge zone one stop shop for ontologies

Swoogle semantic web search 2006

watson exploring the semantic web





11- http://neuroscientific.net/bio-zen.owl
- http://www.loa-cnr.it/ontologies/DOLCE-Lite#amount-of-matter

12- http://www.hyphen.info/RDF/RAE/rae-uoa44-publications.rdf
- http://www.hero.ac.uk/rae/#H-0153:UoA-44:Id-219109:PubNum-4

13- http://ontologyportal.org/translations/SUMO.owl.txt
- http://kmi-web05.open.ac.uk:81/cache/0/339/c2ff/21d76/1013cd189c/557c6d296bdc6957c#Meat
- http://kmi-web05.open.ac.uk:81/cache/0/339/c2ff/21d76/1013cd189c/557c6d296bdc6957c#Beverage

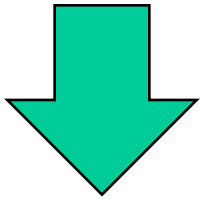
14- http://reliant.teknowledge.com/DAML/SUMO.daml
- http://kmi-web05.open.ac.uk:81/cache/1/f5d/857a/f0cae/8b96c6b3ac/1e19b0c5cf7f2a849#Meat
- http://kmi-web05.open.ac.uk:81/cache/1/f5d/857a/f0cae/8b96c6b3ac/1e19b0c5cf7f2a849#Beverage

15- http://reliant.teknowledge.com/DAML/SUMO.owl
- http://kmi-web05.open.ac.uk:81/cache/c/7a4/11d2/d58c5/c6f902b40b/2bdd54d158be86601#Meat
- http://kmi-web05.open.ac.uk:81/cache/c/7a4/11d2/d58c5/c6f902b40b/2bdd54d158be86601#Beverage

16- http://www.ling.helsinki.fi/kit/2004k/ctl310semw/OWL/wine.daml.rdf
- http://potato.cs.man.ac.uk/ontologies/booze#MEAT
- http://potato.cs.man.ac.uk/ontologies/booze#RED-MEAT
  - *Label:* RED-MEAT
  - *Comment:*
- http://potato.cs.man.ac.uk/ontologies/booze#LIGHT-MEAT-FOWL

What is an Ontology?

Shared understanding of a domain



Repository of vocabulary

- Formal definitions
- Informal definitions