Artificial Intelligence

Introduction to Ontology

Dr. Mustafa Jarrar

Sina Institute, University of Birzeit

mjarrar@birzeit.edu

www.jarrar.info

Watch this lecture and download the slides from

http://jarrar-courses.blogspot.com/2011/11/artificial-intelligence-fall-2011.html

Reading Material

0) Everything in these slides + everything I say

1) Thomas R. Gruber: Toward Principles for the Design of Ontologies Used for Knowledge Sharing
http://tomgruber.org/writing/onto-design.pdf

2) Nicola Guarino: Formal Ontology and Information Systems
http://www.loa-cnr.it/Papers/FOIS98.pdf

3) Ogden, C. K. & Richards, I. A. 1923. "The Meaning of Meaning." 8th Ed. New York, Harcourt, Brace & World, Inc.

4) A Gangemi: Lecture Notes on Artificial Intelligence:
http://ceur-ws.org/Vol-118/slides4.pdf

This lecture

Part I: Why Ontology (The need for Shared Semantics)

- What is an Ontology?

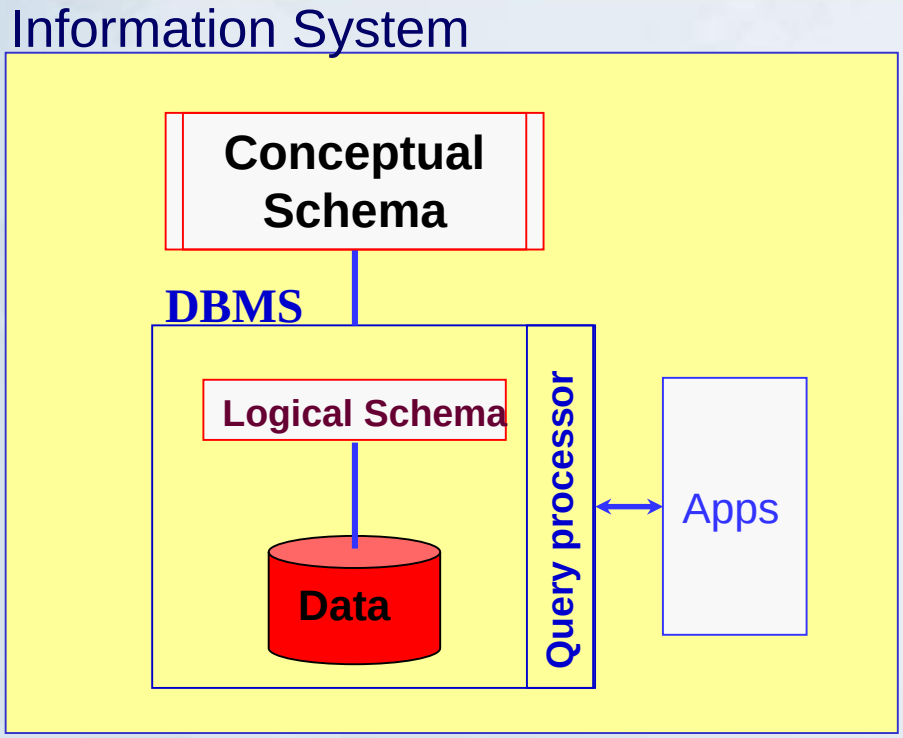
Lecture Keywords:

Ontology, What is an ontology, Conceptualization, Epistemology, Meaning triangle, Lexical Semantics, Knowledge Levels, Ontology-based Applications, Open Information Systems, Data Integration, Interoperability, eGovernment, Semantic Web, XML semantics, XML vs Ontology, Standard Vocabularies vs Ontology, Ontology vs Conceptual data Schema,

الانطولوجيا، ما هي الانطولوجيا، التصور، الابستمولجيا ، مثلث المعنى، الدلالة اللغوية، نظرية المعرفة، تطبيقات الانطولوجيا، انظمة المعلومات مفتوحة المصادر، توحيد البيانات، التوافق البيني، التبادل البيني، الحكومة الالكترونية، اللوب الدلاللي

Ontology-based Applications

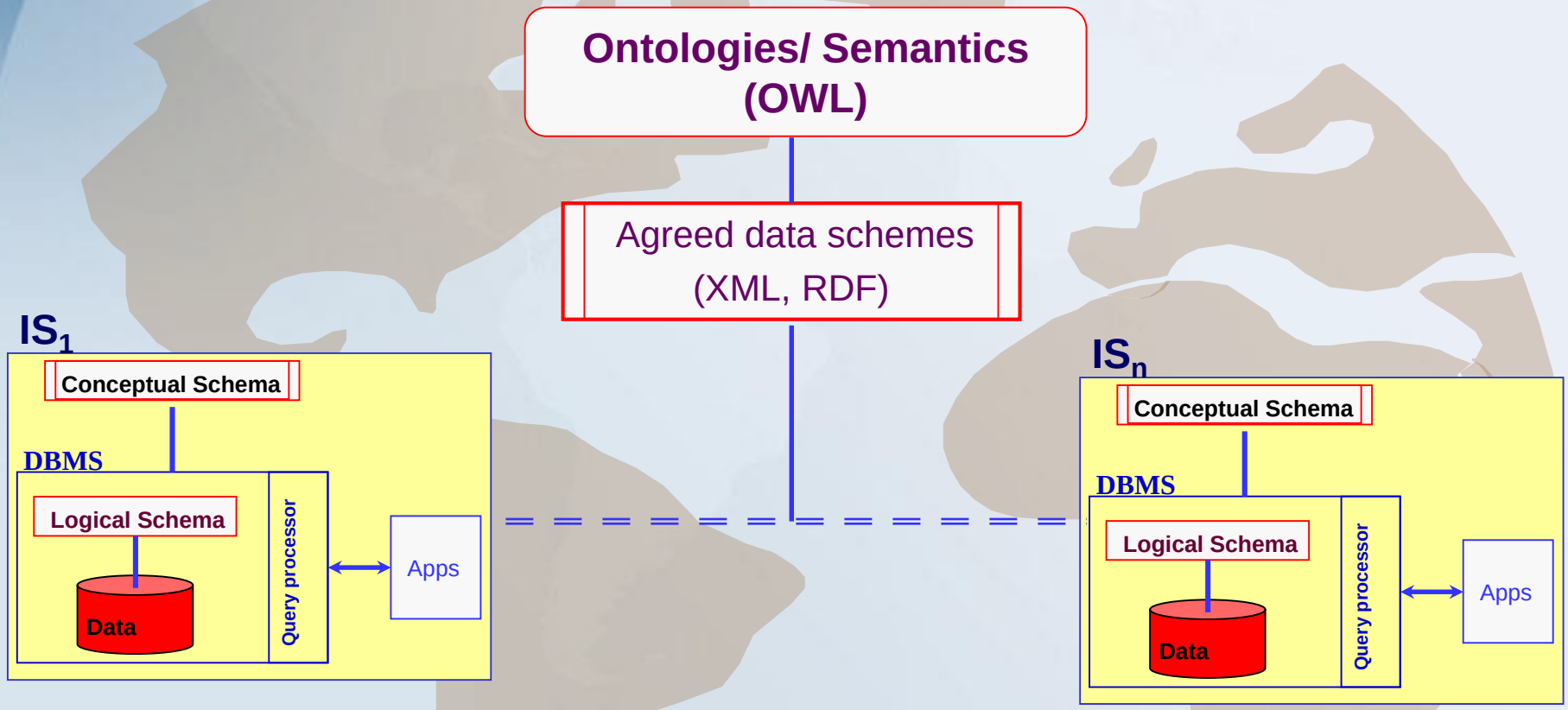
(i) Open Information Systems (Data Integration and Interoperability)



- Each Information System is made for one organization.
- Interoperation between Information Systems was important in the past.
- Why do we need conceptual schemes? for designing Information systems at the conceptual level.

Ontology-based Applications

(i) Open Information Systems (Data Integration and Interoperability)

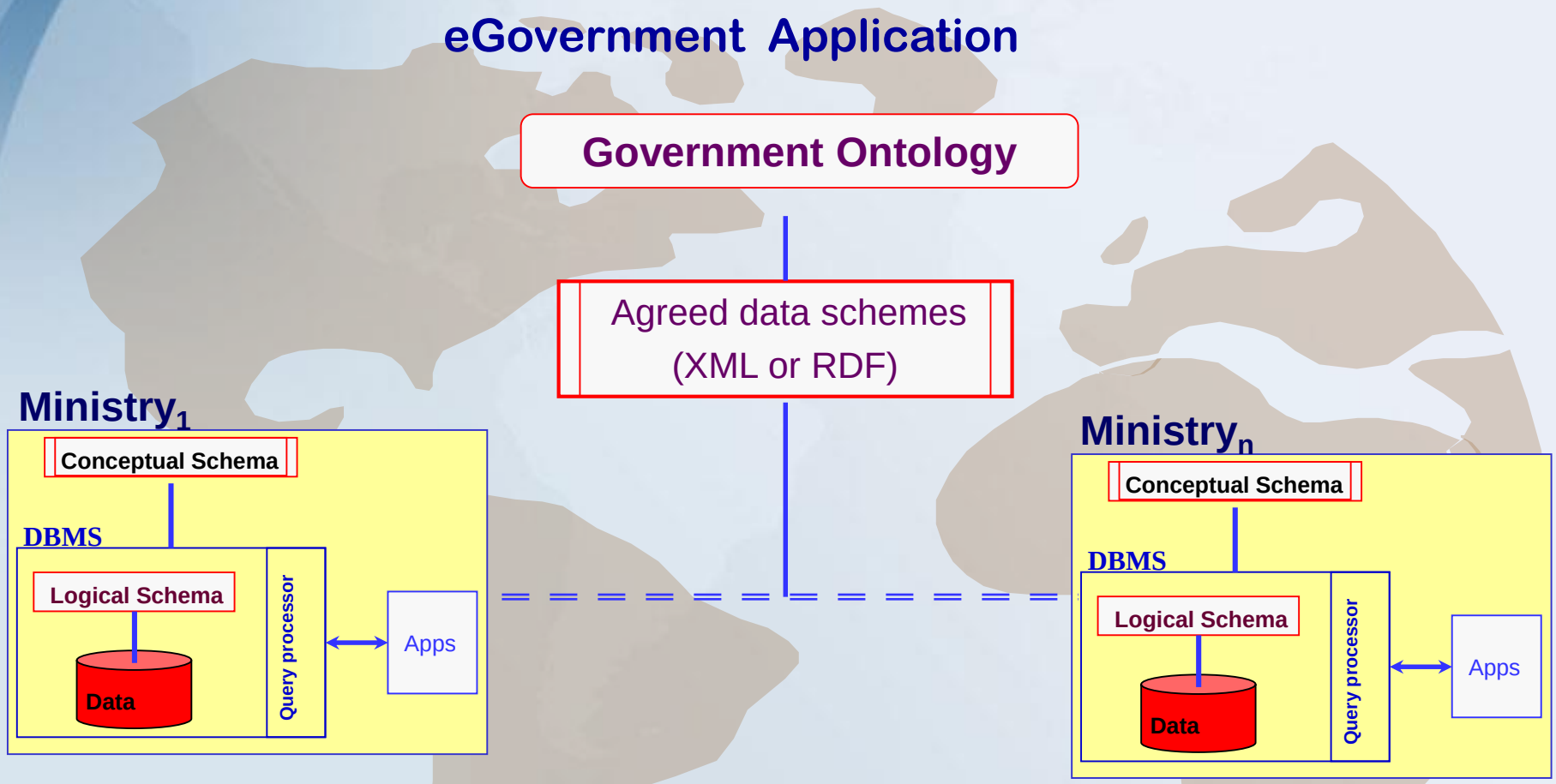


New needs:

Open data exchange, inter-organizational transactions, global queries…

Ontology-based Applications

(i) Open Information Systems (Data Integration and Interoperability)



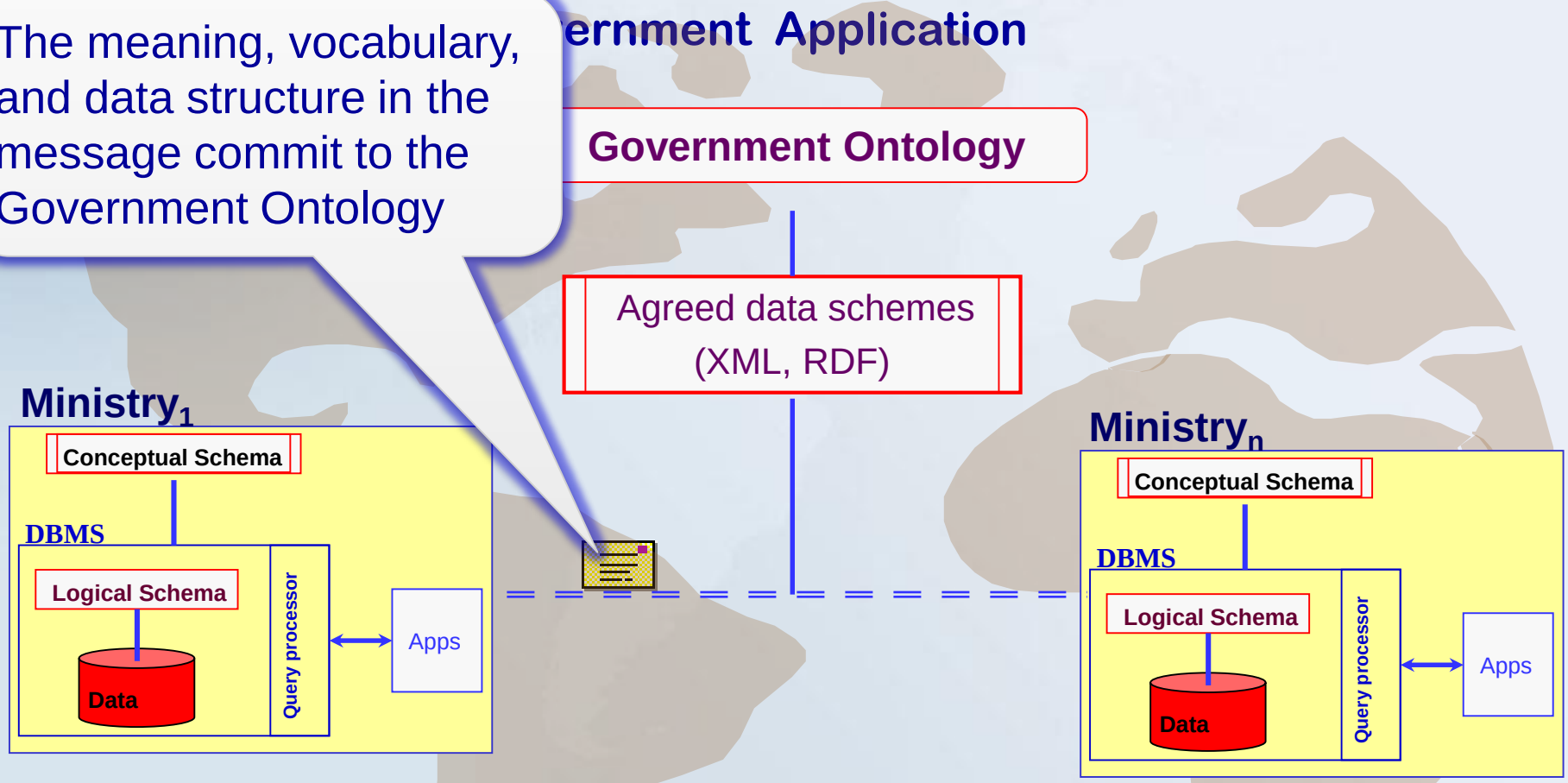
New needs:

Open data exchange, inter-ministry transactions, global queries…

Ontology-based Applications

(i) Open Information Systems (Data Integration and Interoperability)

The meaning, vocabulary, and data structure in the message commit to the Government Ontology



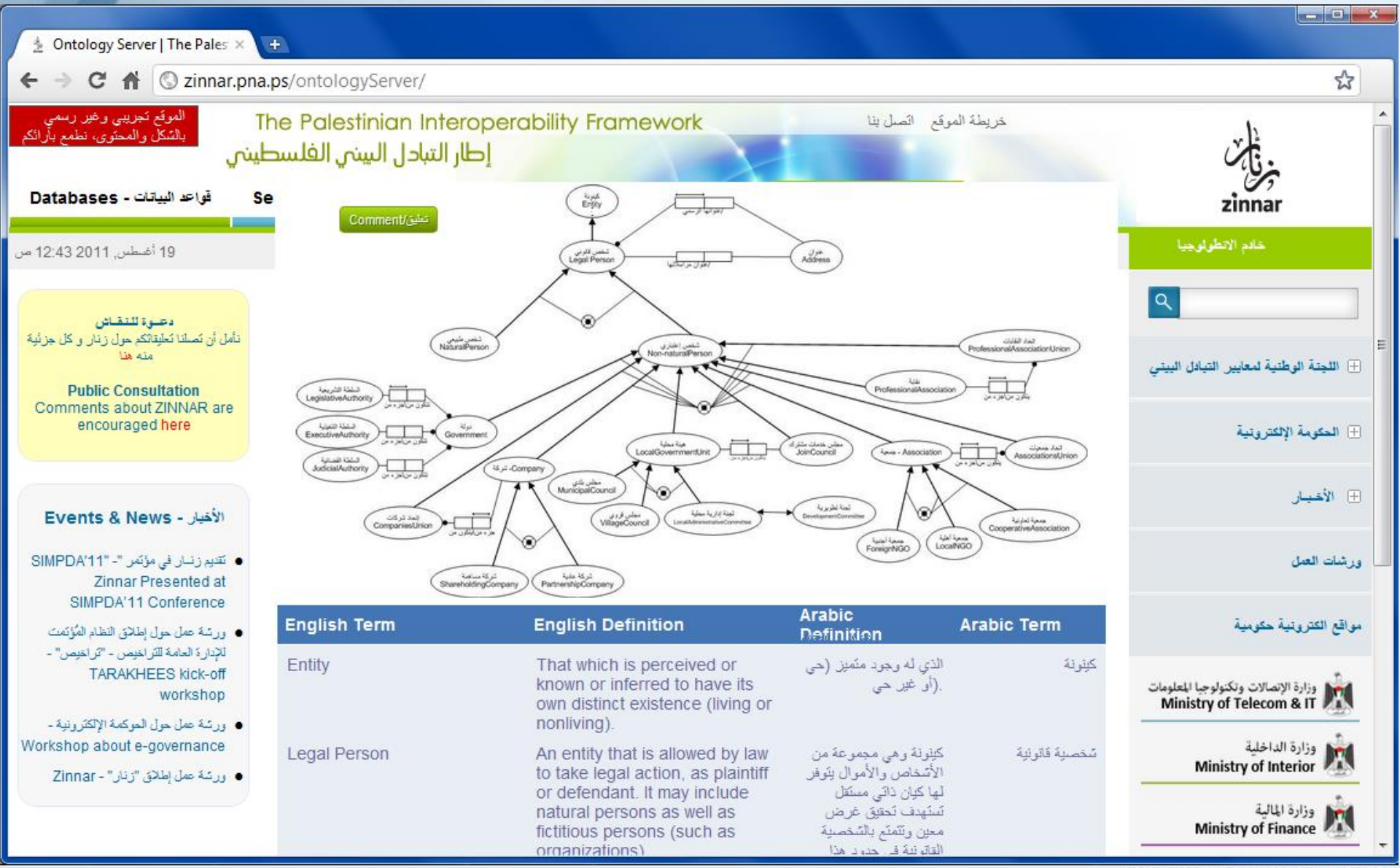
New needs:

Open data exchange, inter-ministry transactions, global queries…

Zinnar – Palestinian Government Ontology

Zinnar – Palestinian Government Ontology

Legal-Person Module

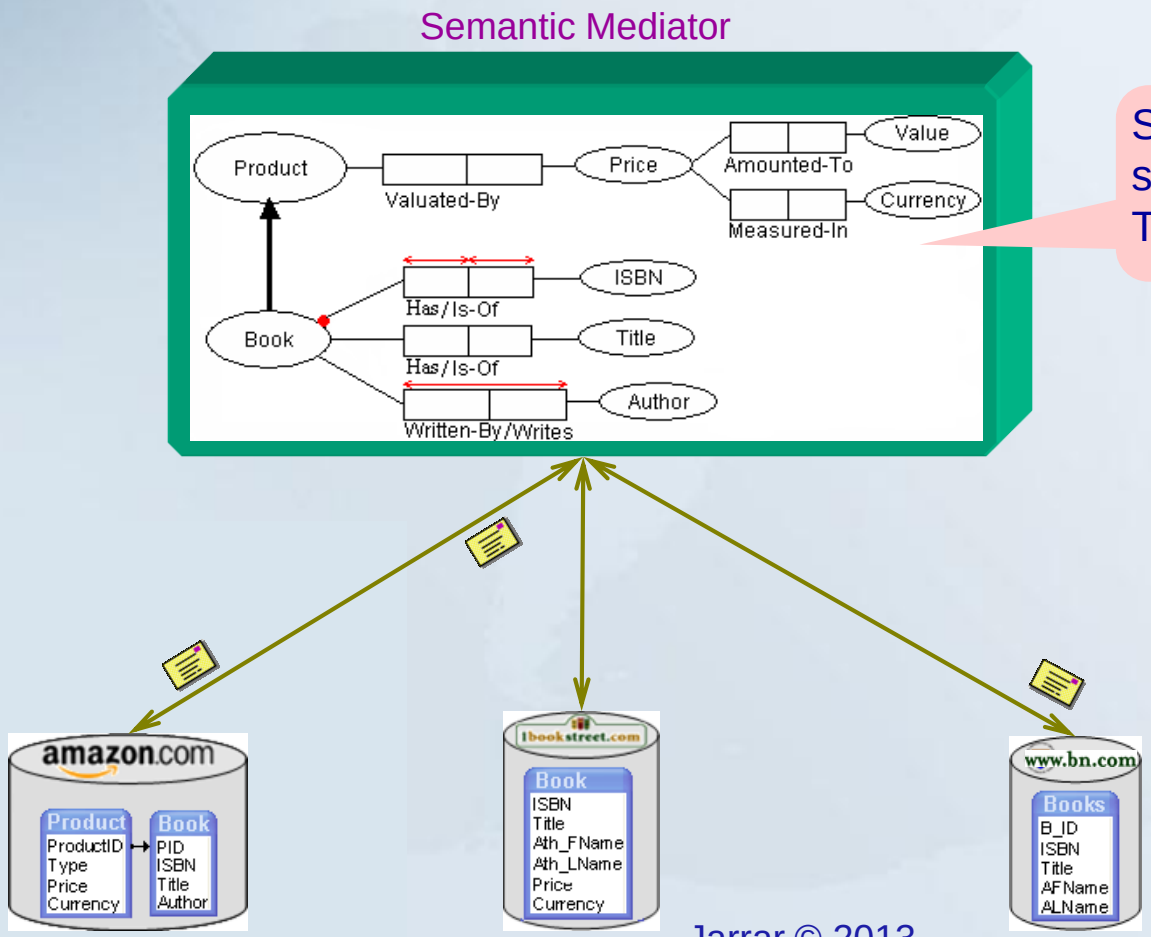


English Term	English Definition	Arabic Definition	Arabic Term
Entity	That which is perceived or known or inferred to have its own distinct existence (living or nonliving).	الذي له وجود متميز (حي أو غير حي).	كينونة
Legal Person	An entity that is allowed by law to take legal action, as plaintiff or defendant. It may include natural persons as well as fictitious persons (such as organizations)	كينونة وهي مجموعة من الأشخاص والأموال يتوفر لها كيان ذاتي مستقل تستهدف تحقيق غرض معين وتتمتع بالشخصية القانونية في حدود هذا	شخصية قانونية

Ontology-based Applications

(i) Open Information Systems (Data Integration and Interoperability)

E-Commerce Application

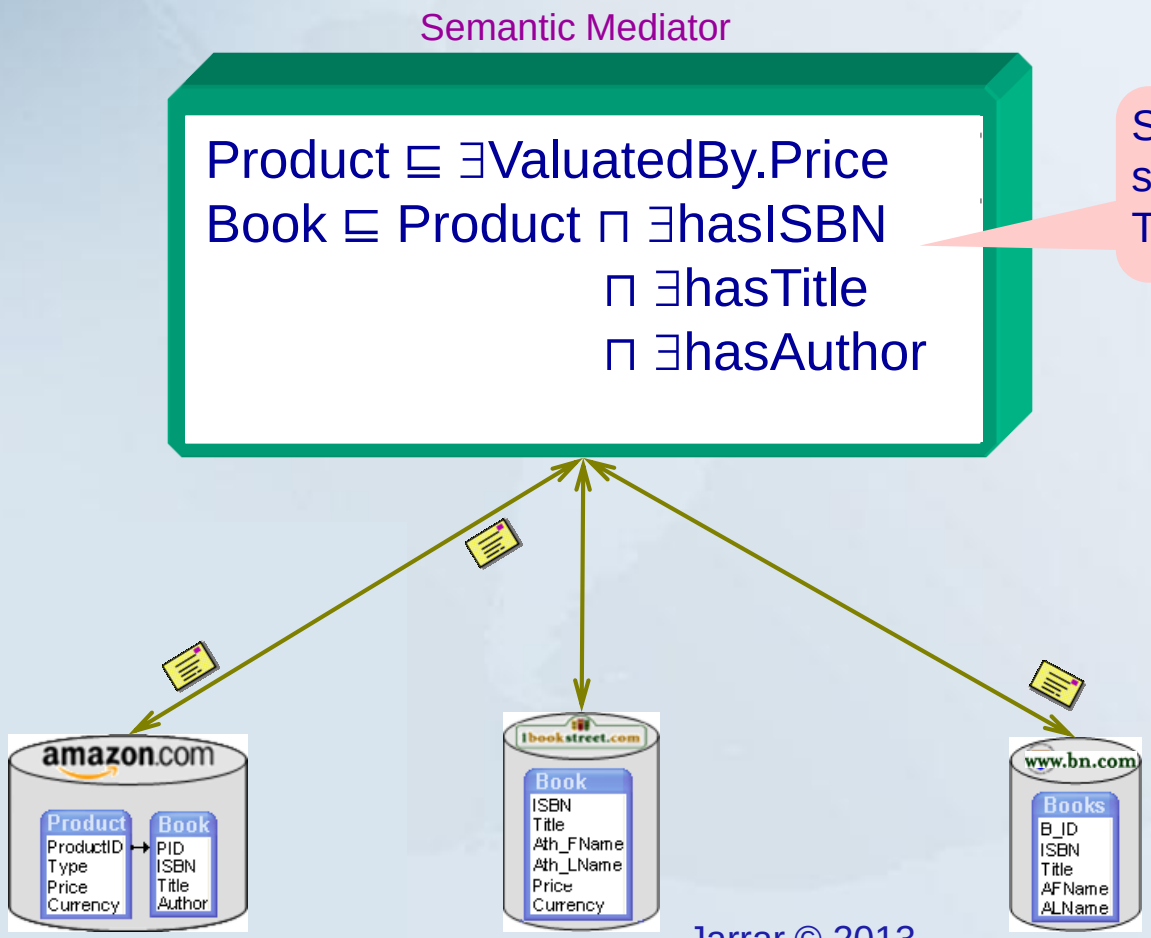


Shared meaning (i.e. formal semantics) of bibliographical Terminology

Ontology-based Applications

(i) Open Information Systems (Data Integration and Interoperability)

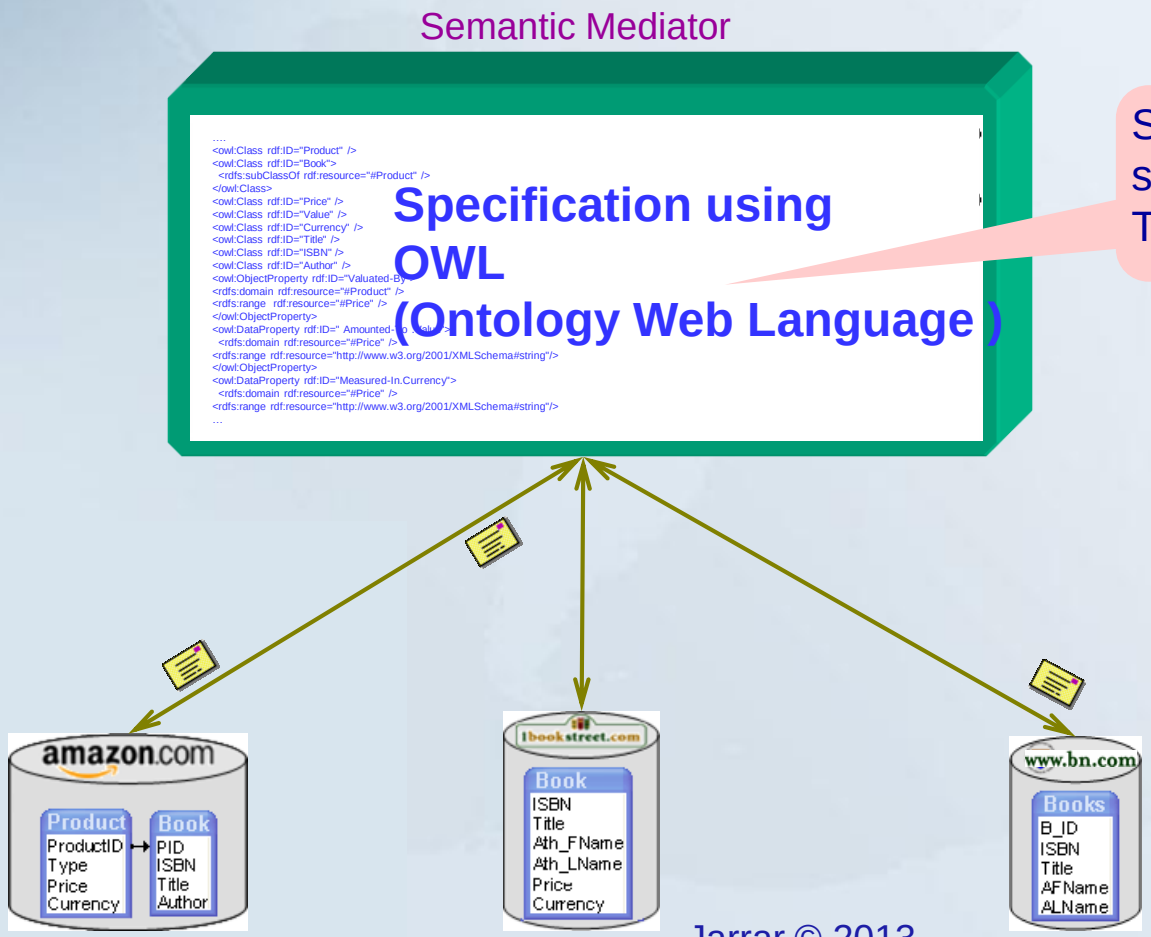
E-Commerce Application



Ontology-based Applications

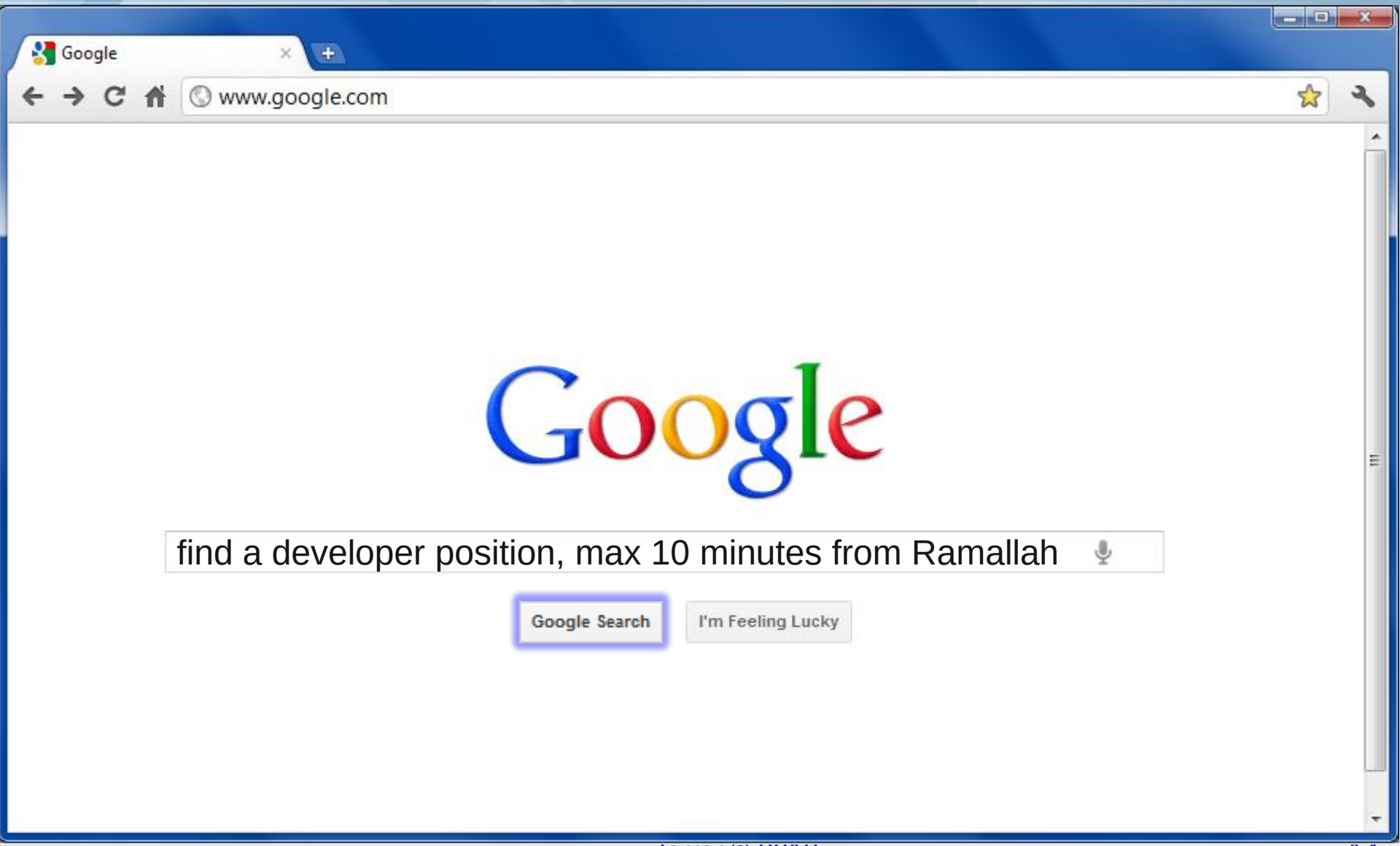
(i) Open Information Systems (Data Integration and Interoperability)

E-Commerce Application



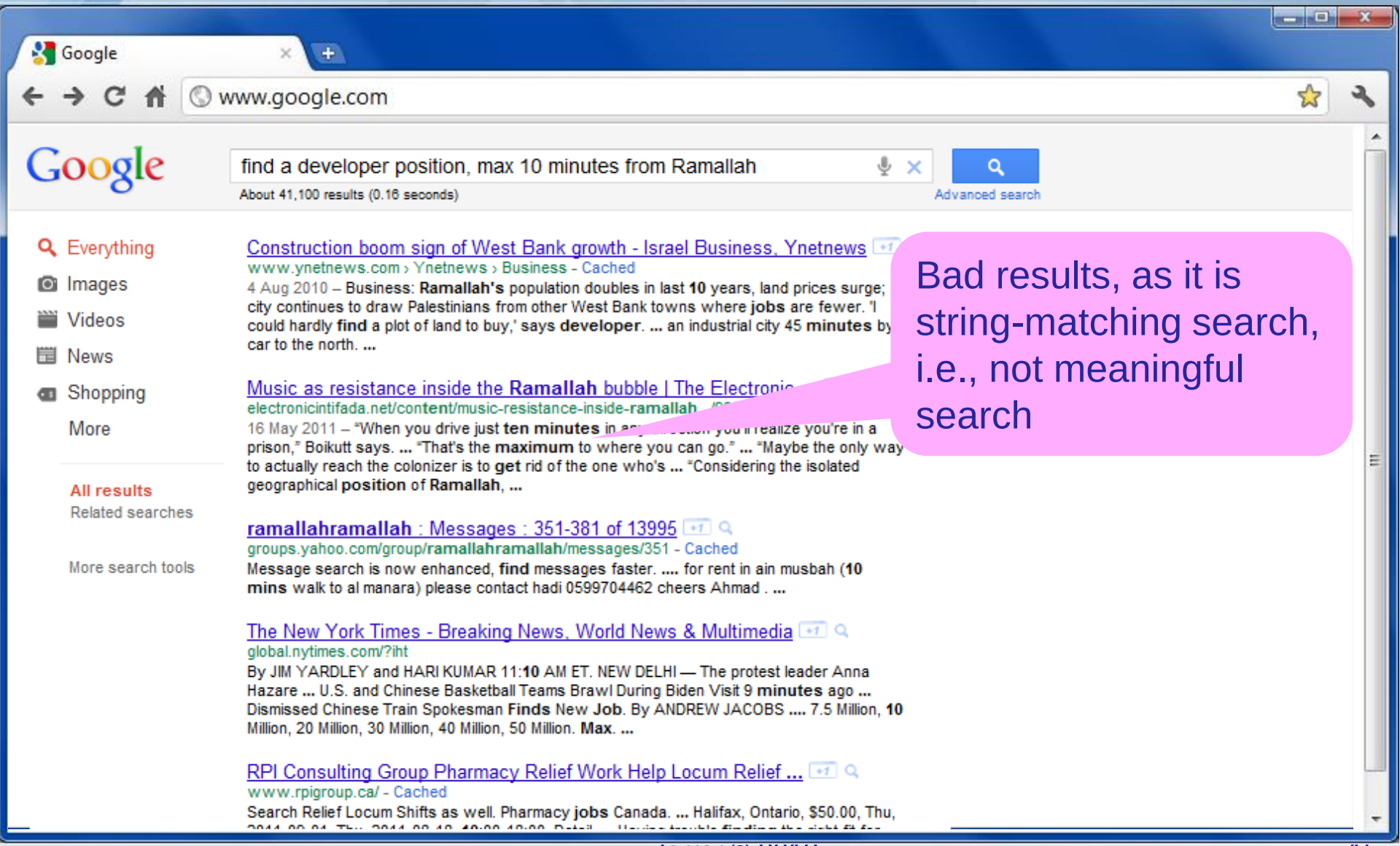
Ontology-based Applications

(ii)The Semantic Web scenario (RDFa)



Ontology-based Applications

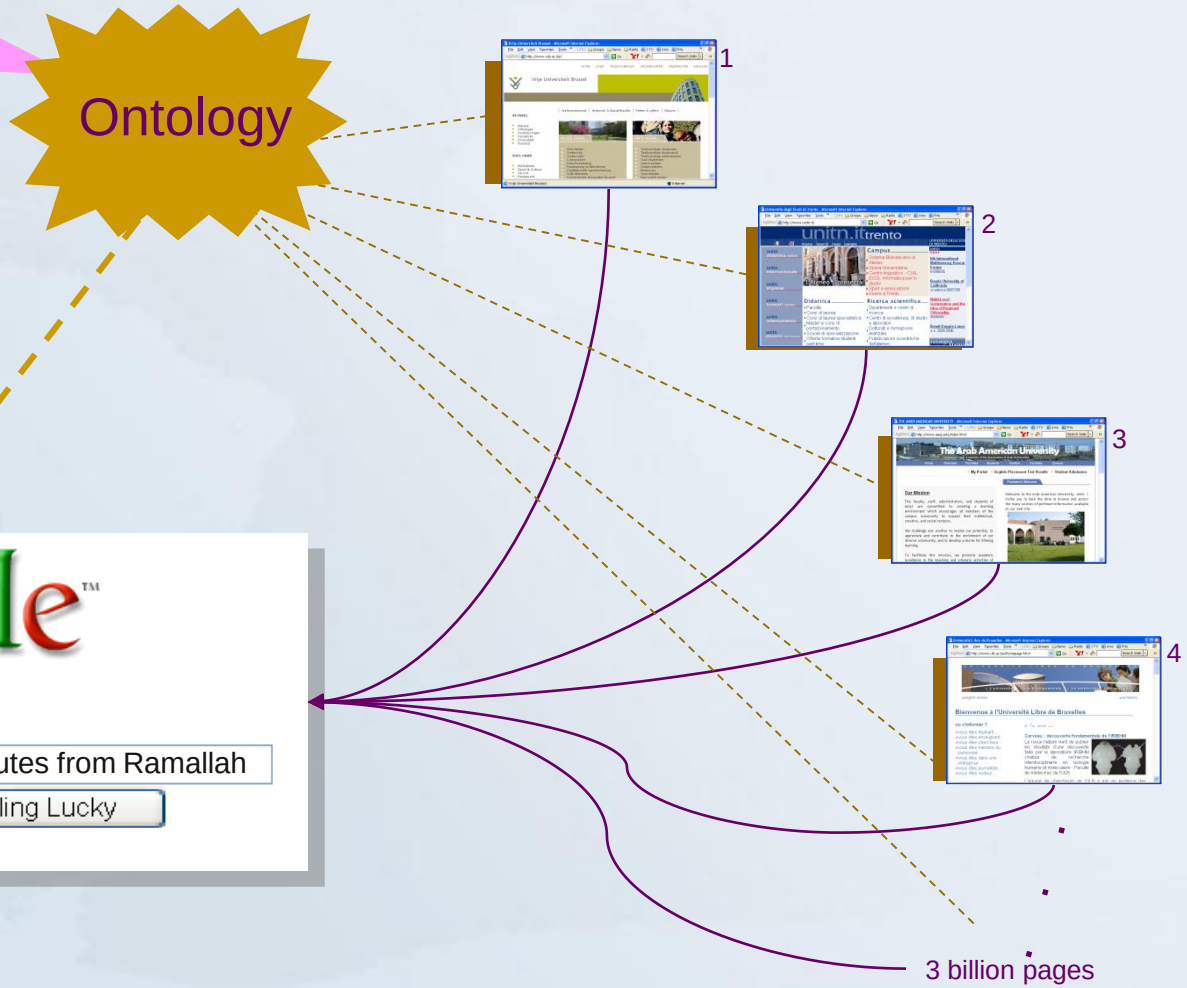
(ii)The Semantic Web scenario (RDFa)



Ontology-based Applications

(ii)The Semantic Web scenario (RDFa)

Shared meanings of things, This meaning is embedded inside web pages.

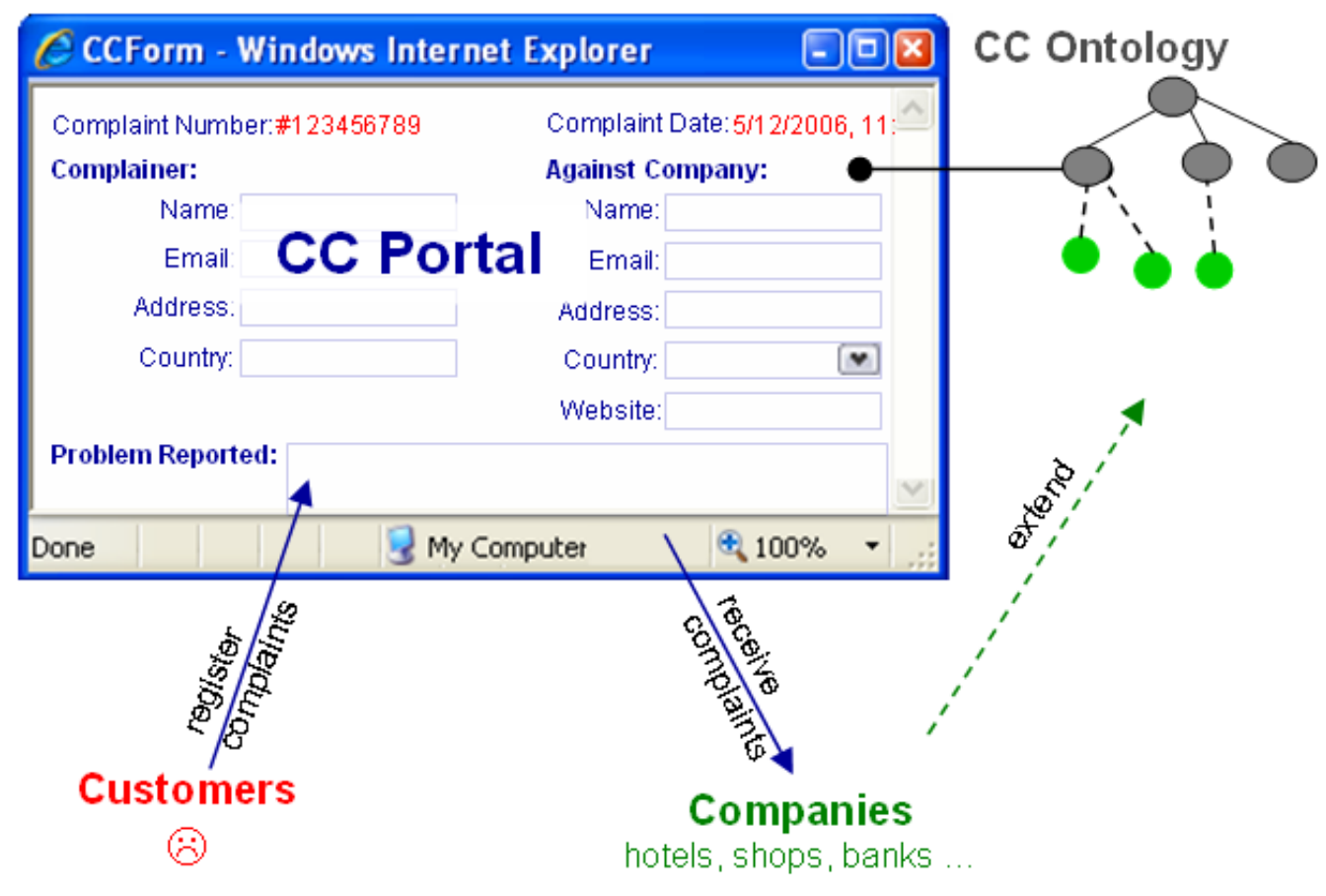


"The **semantic web**" mission: *syntax to semantic based search* → The next generation of the web.

Ontology-based Applications

(iii) Shared semantics in e-Commerce

Central customer complaining portal



See http://www.jarrar.info/publications/mjarrar-CCFORM-chapter.pdf.htm

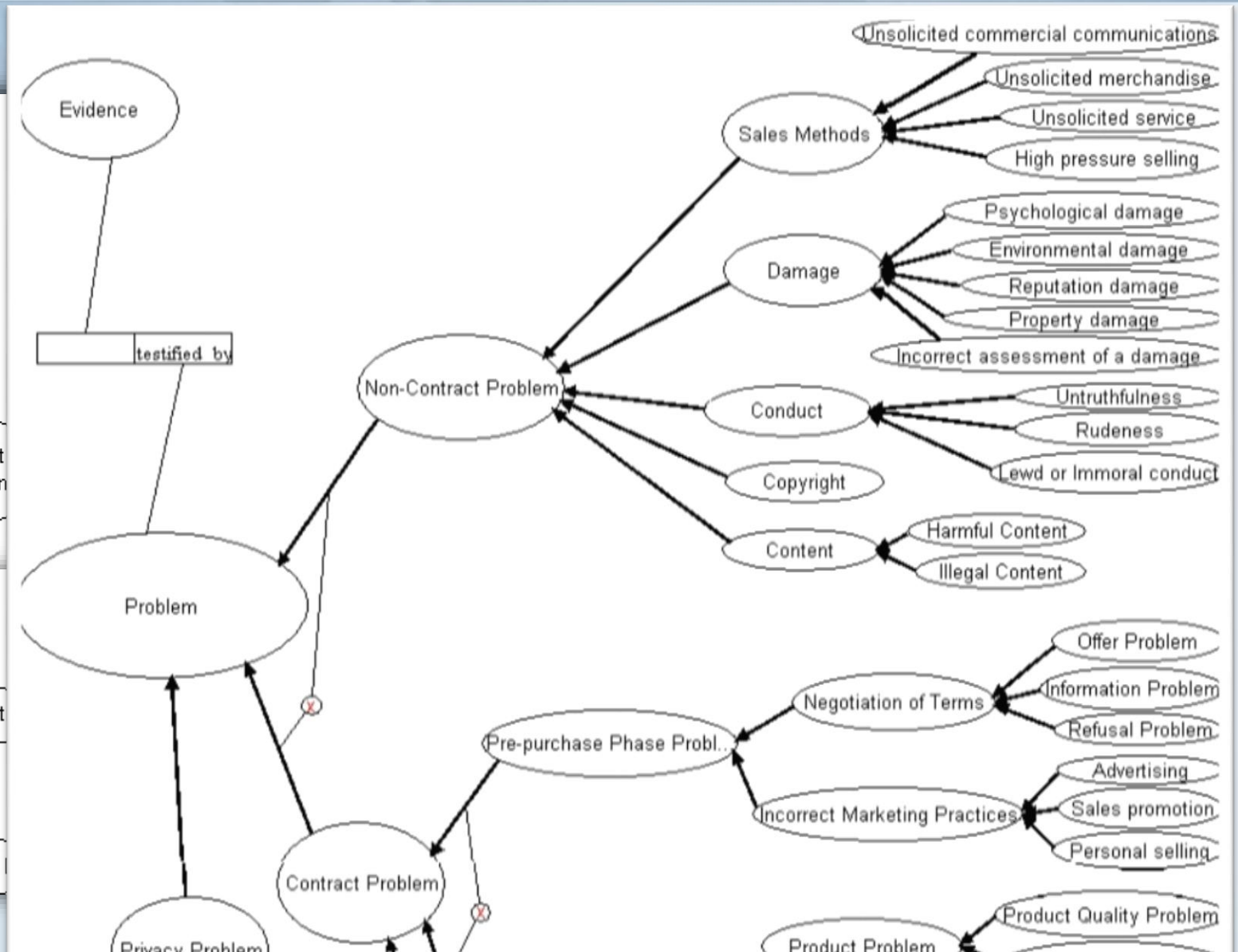
CCForm Project (EU FP5).

The idea of this project is to build a portal for treating customer complaints (CCPortal):

- Instead of developing a complaining system for each website offering products and services, these websites can provide a link to the CC Portal, so to allow customers to write their complaints.
- All types of complains (about anything) are collected centrally and product/service providers can respond and interact with customers in a transparent way through this CCPortal.
- A Customer Complaint Ontology (CCOntology) is built and used in the background; such that, the complaining vocabulary (all types of complaints, responses, etc.) become "standard" for all companies and customers.
- Nice idea, but not fully implemented yet.

Example (Customer Complaint Ontology)

See http://www.jarrar.info/publications/mjarrar-CCFORM-chapter.pdf.htm



The Need for a Shared Understanding

- The Internet and the open connectivity environments are creating a huge demand not only for sharing data but also its semantics.
- Not only humans but also computers needs to communicate meaningfully.
- However, due to different needs and background contexts, there can be widely varying viewpoints and assumptions regarding what is essentially the same subject matter; each may have differing, overlapping and/ or mis-matched concepts. [Martin Hepp]
- The consequent lack of a shared understanding leads to poor communication within and between people, organizations, and systems.

The Need for Meaning Mediation

"Lack of technologies and products to dynamically mediate discrepancies in business semantics will limit the adoption of advanced Web services for large public communities whose participants have disparate business processes"

Gartner Research, February 28, 2002

XML vs Ontology
Common Alphabet is not Enough…

One may ask:

Can we use XML instead of ontologies?

```
<aaa>
  <bbb> Orientalism </bbb>
  <ccc>Edward Said</ccc>
  <ddd>11</ddd>
</aaa>
```

```
<Book>
  <Title> Orientalism </Title>
  <Author>Edward Said</Author>
  <Price>11</Price>
</Book>
```

"XML is only the first step to ensuring that computers can communicate freely. XML is an alphabet for computers, and as everyone who travels in Europe knows, knowing the alphabet doesn't mean you can speak Italian or French" [Business Week, March 18, 2002]

- XML provides syntax, ontologies provide semantics\meaning.

Standard Vocabularies vs Ontology

Can we use business glossaries instead of ontologies?

Contract: A binding agreement between two or more legal persons that is enforceable by law; an invoice can be a contract.
Complaint: An expression of grievance or resentment issued by a complainant against a compliant-recipient, describing a problem(s) that needs to be resolved.
Legal Person: An entity with legal recognition in accordance with law. It has the legal capacity to represent its own interests in its own name, before a court of law, to obtain rights or obligations for ….

- Vocabulary definitions are often ambiguous or circular
- People don't implement such definitions correctly anyway

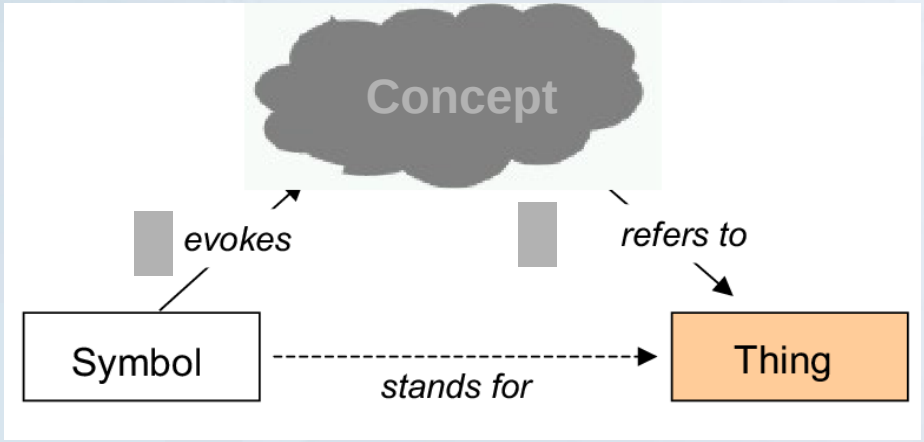
➢ Standard vocabularies don't provide precise and formal meanings, as ontologies

The meaning of Meaning (Semantics)

Based on [3]

- Humans require words (or at least symbols) to communicate efficiently. The mapping of words to things is indirect. We do it by creating concepts that refer to things.

- The relation between symbols and things has been described in the form of the meaning triangle:



"Jaguar"
البغور

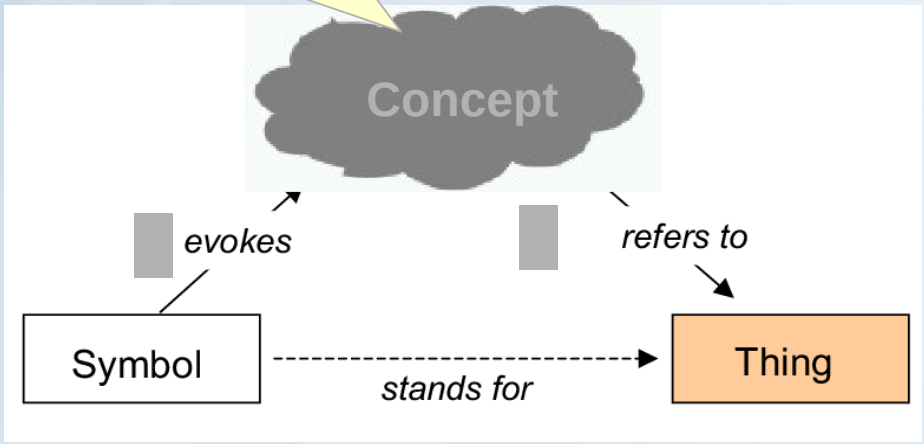
Ogden, C. K. & Richards, I. A. 1923. "The Meaning of Meaning." 8th Ed. New York, Harcourt, Brace & World, Inc

[Carole Goble, Nigel Shadbolt, Ontologies and the Grid Tutorial]

The meaning of Meaning (Semantics)

Concept: a set of rules we have in mind to distinguish similar things in reality.

An instance of a concept
الماصدق



"Jaguar"
البغور

The meaning of Meaning (Semantics)

- A **Term** (/symbol) may refer to different concepts (Animal: Jaguar, Car:Jaguar)
- **A Concept** might not be agreed on among all people (i.e., not exactly the same set of rules are agreed by all people)

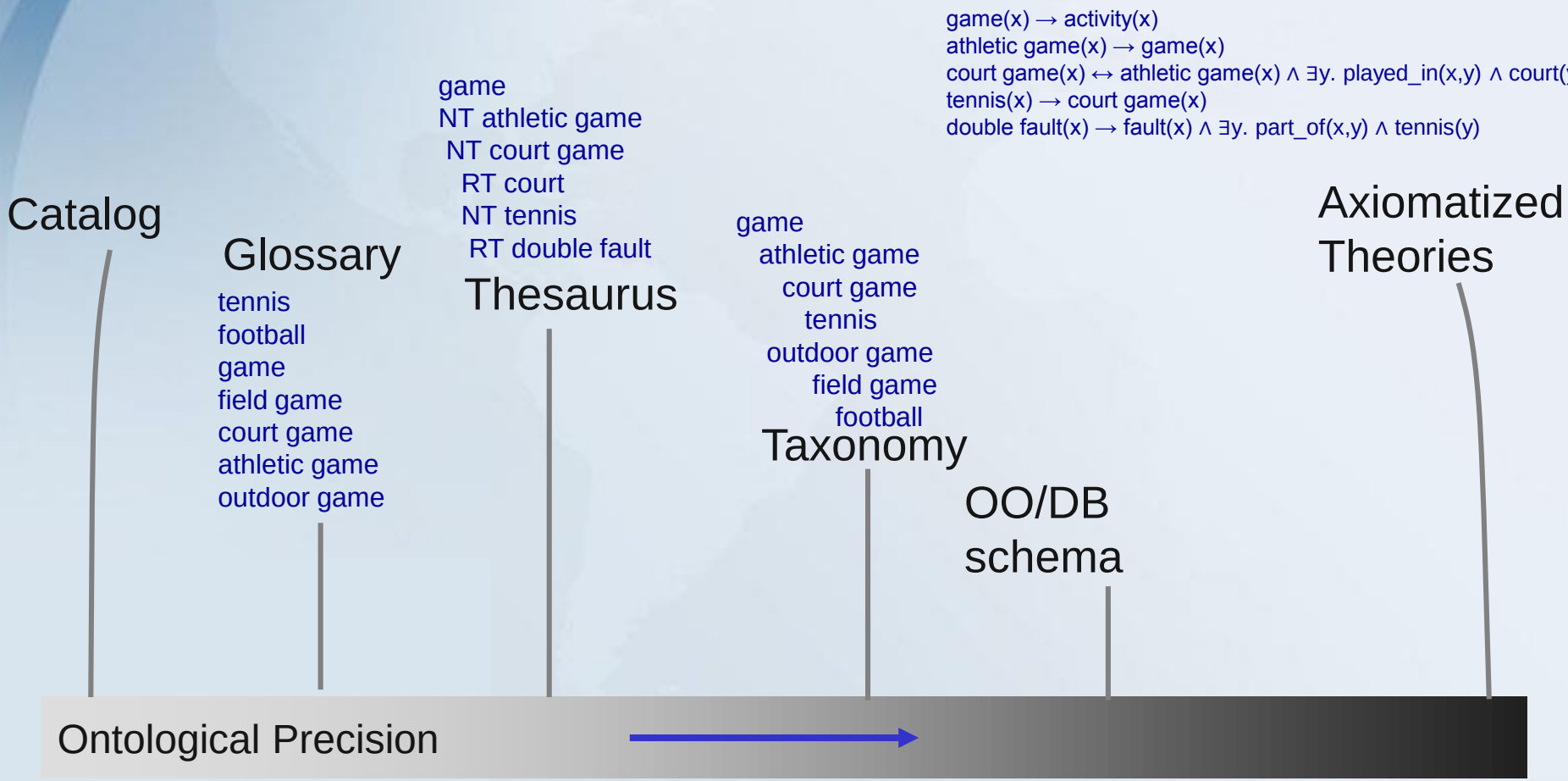
Dictionaries represent meanings approximately and informally, mixed with lexical aspects.

Ontologies specify the meaning formally and precisely.

➢ We will come to this topic (Lexical Semantics) in more details later

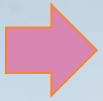
Levels of Ontological Precision

Based on [2]



Outline

- Why Ontology (The need for Shared Semantics)



What is Ontology

What is an Ontology?

In Philosophy

Ontology as such is usually contrasted with ***Epistemology***, which deals with the nature and sources of our knowledge [a.k.a. Theory of Knowledge]. Aristotle defined Ontology as the science of being as such: " unlike the special sciences, each of which investigates a class of beings and their determinations, Ontology regards all the species of being *qua* being (كينونات) and the attributes (صفات) which belong to it *qua* being" (Aristotle, *Metaphysics*, IV, 1).

- It is the science of what is (in the universe) .
- Ontos (that which exists) + logos (knowledge of)
- Dates back to Artistotle
- Quine, 1969: “To exist is to be the value of a quantified variable”

الانطولوجيا: علم الوجود بما هو موجود)(

➔ So, it is a science (branch of philosophy): Analytical Philosophy

What is an Ontology?

In computer science

- McCarthy (1980) calls "a list of things that exist" an ontology.
- Gruber (1995): "an explicit specification of a conceptualization".
- Welty (later): "Description of the kinds of entities there are and how they are related".
- Some people refer to as a domain model or a conceptual model.

- To simplify it:

  Once my grandmother asked me about my research, I said "ontology", she said what it this? I said: "**it is a dictionary that computers can understand**". She said, how? I said, the computer computes the meaning as it is represented in logic.

➢ Note that "ontology" here is not a new name for an old thing.

What is an Ontology?

- An ontology is ...
  - an *explicit specification of a conceptualization* [Gruber93]
  - a *shared understanding of some domain of interest* [Uschold,Gruninger96]

- Some aspects and parameters:
  - a formal specification (*reasoning* and "*execution*")
  - ... of a conceptualization of a domain (*community*)
  - ... of some part of world that is of interest (*application*)

- Provides:
  - A *common vocabulary* of terms
  - Some specification of the *meaning of the terms* (semantics)
  - A *shared "understanding"* for people and machines

What is an Ontology?

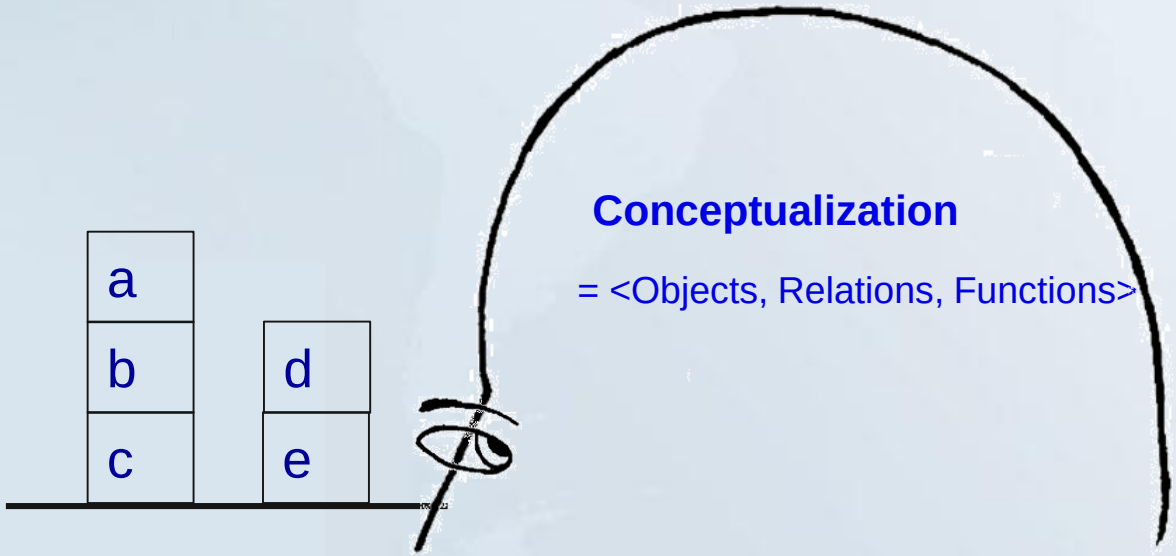
Optional Reading

In computer science

Gruber (1995): "**a explicit specification of a conceptualization**".

Written in logic, as a set of axioms i.e. a theory

the set of objects and relations in a domain. <Objects,Relations,Functions>



What is an Ontology?

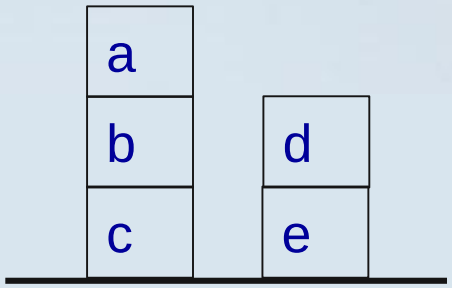
Optional Reading

In computer science

Gruber (1995): "**a explicit specification of a conceptualization**".

Written in logic, as a set of axioms i.e. a theory

the set of objects and relations in a domain. <Objects,Relations,Functions>



Conceptualization:

Block {a, b, c, d, e}

On {<a,b>,<b,c>,<d,e>}

Above {<a,b>,<b,c>,<d,e>}

Clear {<a>,<d>}

Table {<c>,<e>}

Hat {<b,a>,<c,b>,<e,d>}

The ontology is a set of axioms used to specify **this** conceptualization:

$\forall x \forall y \; On(x,y) \Rightarrow Above(x,y)$

…

Sharing these axioms (i.e., ontology) means sharing the same understanding

What is an Ontology?

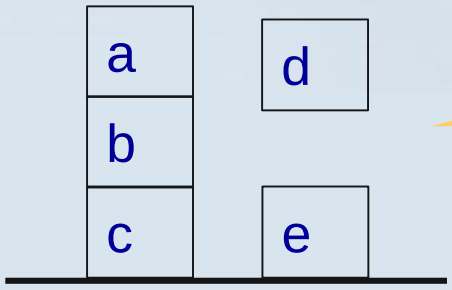
Optional Reading

In computer science

Gruber (1995): "**a explicit specification of a conceptualization**".

Written in logic, as a set of axioms i.e. a theory

the set of objects and relations in a domain. <Objects,Relations,Functions>



Conceptualization:

Block {a, b, c, d, e}

Above {<a,b>,<b,c>,<d,e>}

Clear {<a>,<d>}

Table {<c>,<e>}

Hat {<b,a>,<c,b>,<e,d>}

Guarino's:

➔ This change implies changing the conceptualization.

➔ Do we need to change our conceptualization each time there is some re-arrangements in the world?!

What is an Ontology?

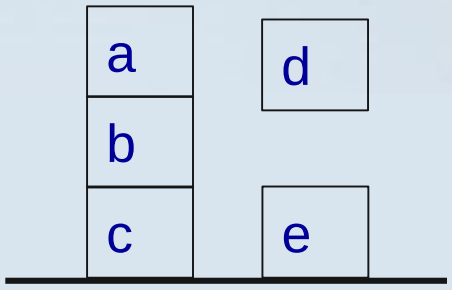
Optional Reading

In computer science

Gruber (1995): "**a explicit specification of a conceptualization**".

Written in logic, as a set of axioms i.e. a theory

the set of objects and relations in a domain. <Objects,Relations,Functions>



Conceptualization:

Block {a, b, c, d, e}

On {<a,b>,<b,c>,<d,e>}

Above {<a,b>,<b,c>,<d,e>}

Clear {<a>,<d>}

Table {<c>,<e>}

Hat {<b,a>,<c,b>,<e,d>}

Guarino's:

➔ this conceptualization is a state of affairs (= one situation a snapshot) of the domain.

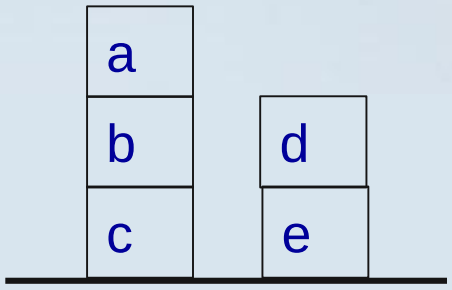
➔ This definition of conceptualization has a problem.

Guarino's definition of a conceptualization

Optional Reading

independent of any specific interpretation, model, or situation,

A conceptualization is an **intensional** semantic structure, which encodes the implicit rules constraining the structure of a piece of reality



Conceptualization:

$[[Block]]_D$	{a, b, c, d, e}
$[[On]]_D$	{<a,b>,<b,c>,<d,e>}
$[[Above]]_D$	{<a,b>,<b,c>,<d,e>}
$[[Clear]]_D$	{<a>,<d>}
$[[Table]]_D$	{<c>,<e>}
$[[Hat]]_D$	{<b,a>,<c,b>,<e,d>}

➔ These should not be ordinary ***relations***, but rather ***conceptual relations***.

➔ A relations has a **model.** *(extensional interpretation).*

➔ A conceptual relation has **intended models**. (Intensional interpretation).

Guarino's definition of a conceptualization

Optional Reading

independent of any specific interpretation, model, or situation,

A concetualization is an **intensional** semantic structure, which encodes the implicit rules constraining the structure of a piece of reality

Ordinary relations are defined on a *domain* D

Conceptual relations are defined on a *domain space* <D, W>

An Ontology is an **artifact** designed with the purpose of expressing the **intended meaning** of a (shared) **vocabulary.**

• A shared vocabulary plus a specification (**characterization)** of its intended meaning

How can we formally describe the meaning of a vocabulary?

Given the “Palestinian Government” domain.

How can we formally describe the meaning of the vocabulary (citizen, company, salary, tax, car, land, etc.) in this domain?

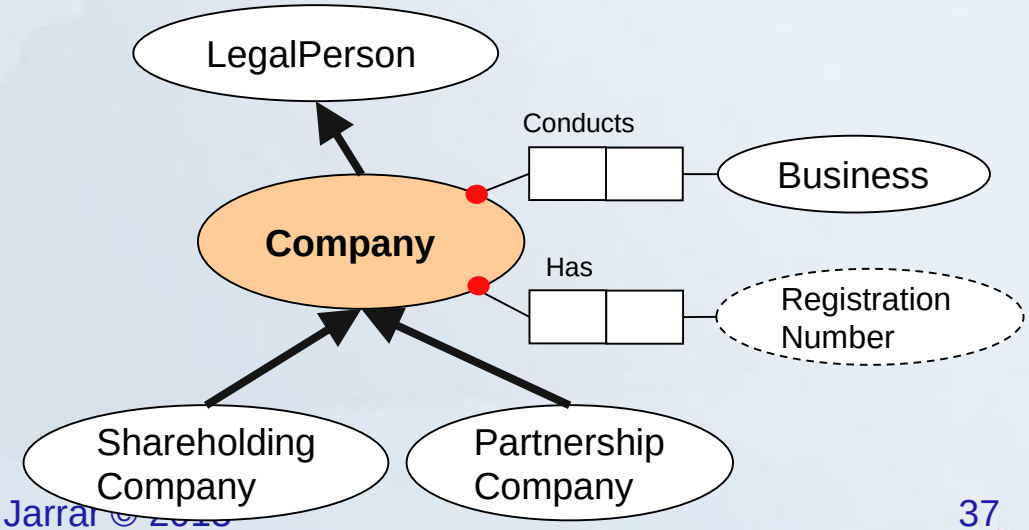
Example: *Company* = a type of legal person, registered to conduct business, and recognized by its registration number. There are two types of companies: Shareholding Company and Partnership Companies.

In logic:

$$\text{Company} \sqsubseteq \text{LegalPerson} \sqcap \text{Conduct.Business} \sqcap \exists \text{Has.RegestrationNumber}$$

$$\text{ShareholdingCompany} \sqsubseteq \text{Company}$$

$$\text{PartnershipCompany} \sqsubseteq \text{Company}$$



How can we formally describe the meaning of a vocabulary?

➔ Notice that meaning/semantics of “Company” can be determined from its **position** in the diagram, i.e., it is relations with other concepts, and constraints.

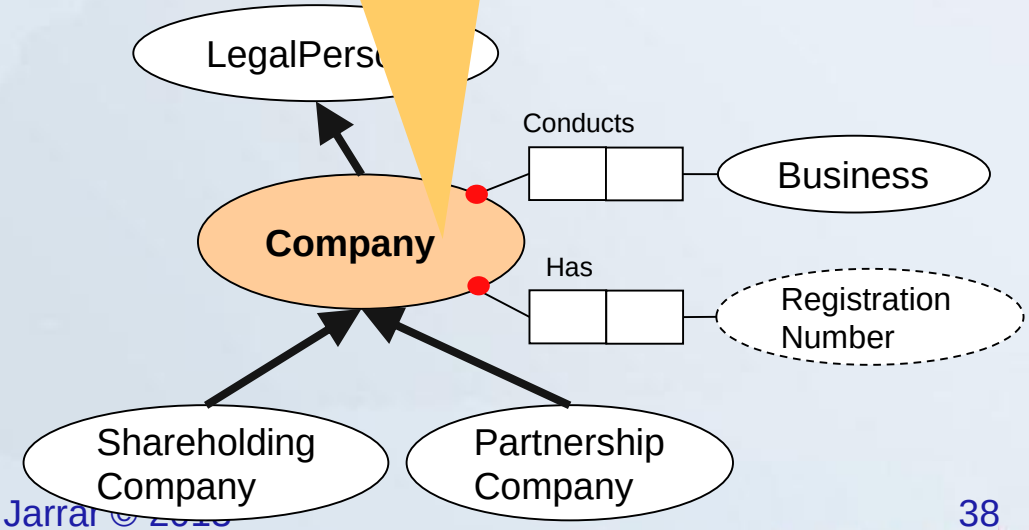
Example: *Company* = a type of legal person d to conduct business, and recognized by its registration n here are two types of companies: Shareholding Company and Partn Companies.

In logic:

$$\text{Company} \sqsubseteq \text{LegalPerson} \sqcap \text{Conduct.Business} \sqcap \exists \text{Has.RegestrationNumber}$$

$$\text{ShareholdingCompany} \sqsubseteq \text{Company}$$

$$\text{PartnershipCompany} \sqsubseteq \text{Company}$$



How can we formally describe the meaning of a vocabulary?

- Ministries need such precision and formal definitions to exchange data meaningfully.
- We may use ORM/ER/UML as a language to specify the meaning (i.e., semantics) of a domain, as a formal notations. OWL is the standard ontology language.

➢ Thus, an ontology consists of Concepts, Relations between these concepts, and some Rules.

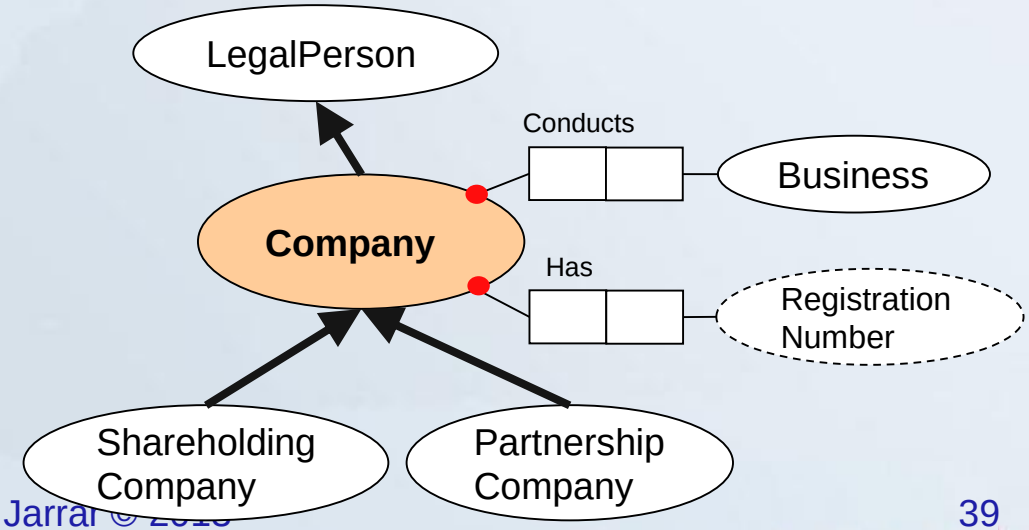
➢ The most important relation is the subtype relation.

In logic:

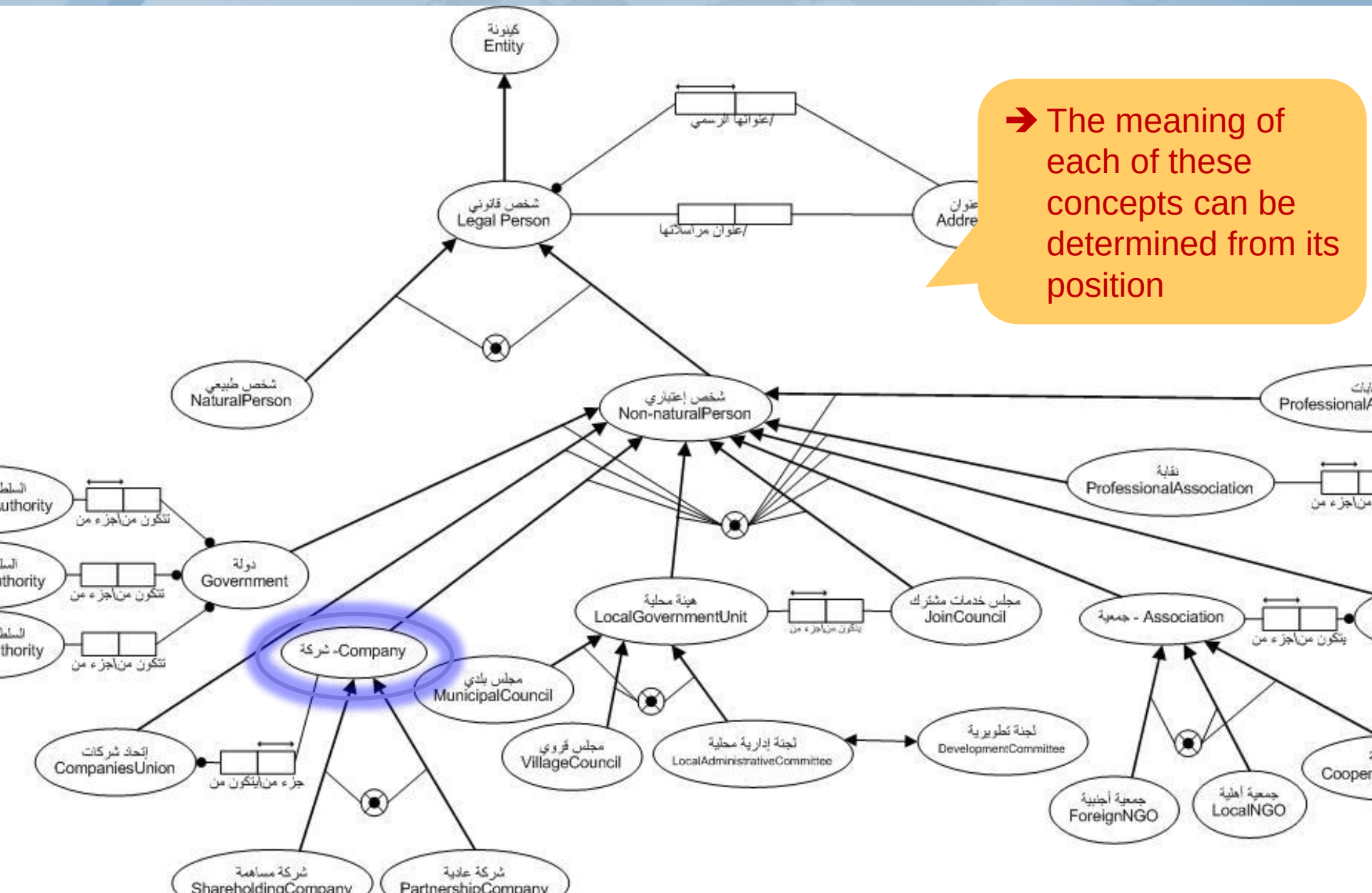
$$\text{Company} \sqsubseteq \text{LegalPerson} \sqcap \text{Conduct.Business} \sqcap \exists \text{Has.RegestrationNumber}$$

$$\text{ShareholdingCompany} \sqsubseteq \text{Company}$$

$$\text{PartnershipCompany} \sqsubseteq \text{Company}$$



Part of the LegalPerson Ontology, in Palestine



➔ The meaning of each of these concepts can be determined from its position

Ontology vs Conceptual data Schema

- But can we say that an ontology is a conceptual schema?

  i.e., is it true that the Palestinian government ontology is a conceptual database schema covering all data elements in all government databases?

➢The answer is No!

➢Then what is the difference between an ontology and a schema?

➢DB schema provides skeleton/structure to the data, not meaning.

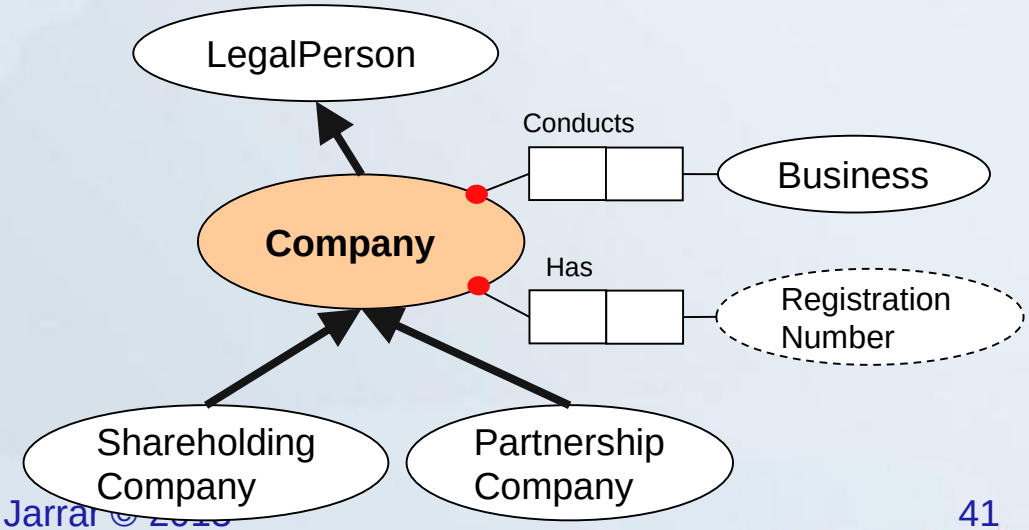
➢Although ontology provides structure to the data, but the meaning is the most important aspect.

In logic:

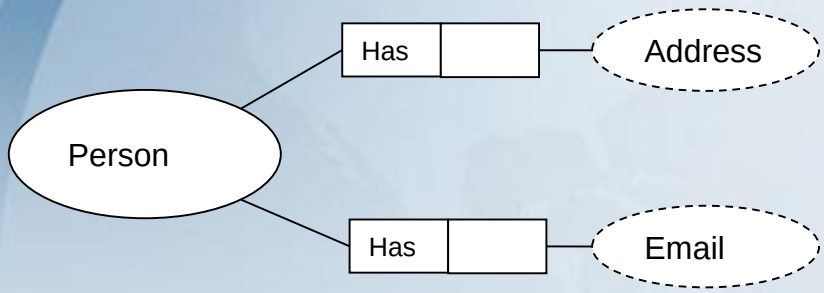
$$\text{Company} \sqsubseteq \text{LegalPerson} \sqcap \text{Conduct.Business} \sqcap \exists \text{Has.RegestrationNumber}$$

$$\text{ShareholdingCompany} \sqsubseteq \text{Company}$$

$$\text{PartnershipCompany} \sqsubseteq \text{Company}$$



Is this an Ontology or a Data Schema?



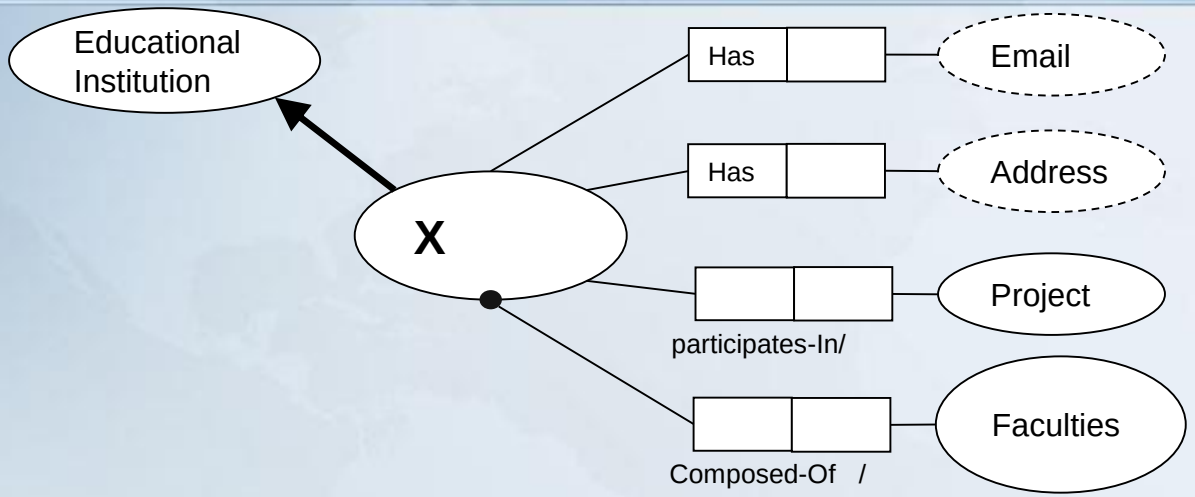
$$\text{Person} \sqsubseteq \text{HasAddress.String} \sqcap \text{hasEmail}$$

In OWL

```
<owl:Class rdf:ID="Person" />
<owl:Class rdf:ID="Address" />
<owl:Class rdf:ID="email" />
<owl:DataProperty rdf:ID="Has-Address">
  <rdfs:domain rdf:resource="#Person" />
  <rdfs:range rdf:resource="www.w3.org/2001/XMLSchema#string"/>
</owl:ObjectProperty>
<owl:DataProperty rdf:ID="Has-Email">
  <rdfs:domain rdf:resource="#Person" />
  <rdfs:range rdf:resource="www.w3.org/2001/XMLSchema#string"/>
</owl:ObjectProperty>
```

→ What makes and ontology an ontology, not a schema?

Where is the meaning (example: What is X?)

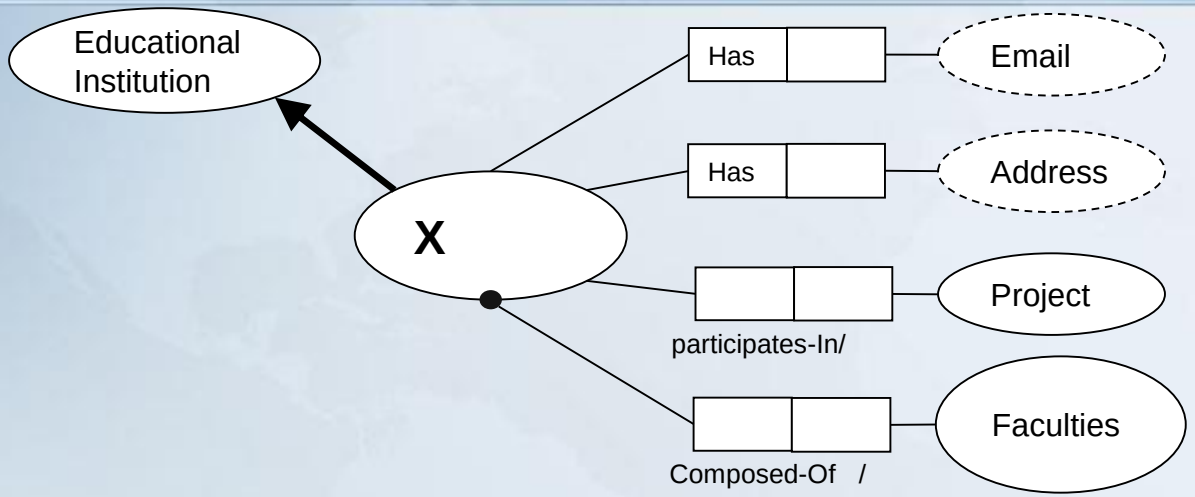


If you can be sure of what is X from its position, then its characteristics (i.e., relations with other concepts) are suitable for defining its meaning?

Which of these characteristics are more distinguishing?
(*Intrinsic* verse *extrinsic* characteristics)

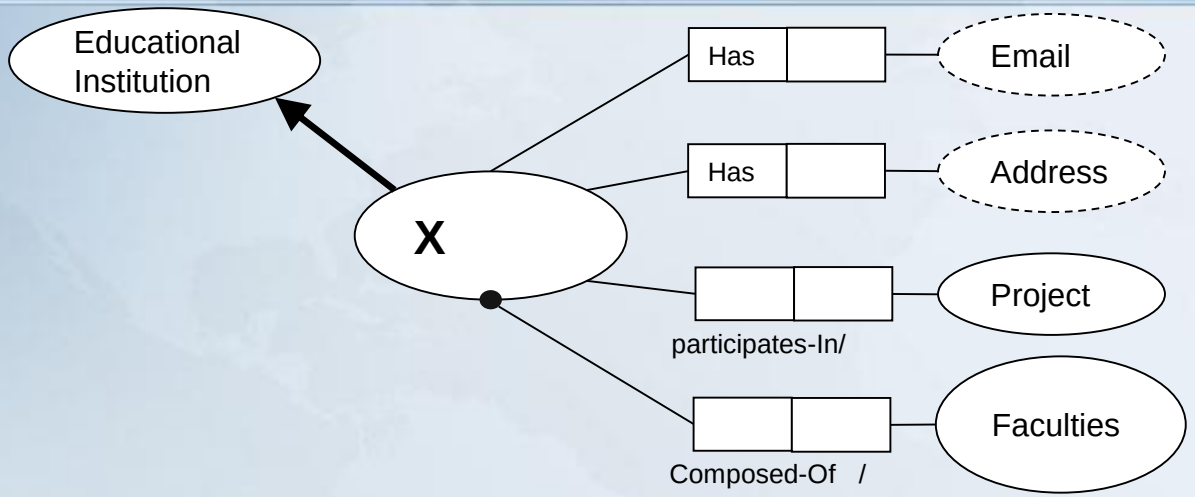
"An **intrinsic property (** الصفات الجوهرية **)** is typically something inherent to an individual, not dependent on other individuals, such as having a heart or having a fingerprint. **Extrinsic properties (** الصفات العرضية **)** are not inherent, and they have a relational nature, like "being a friend of John". Among these, there are some that are typically assigned by external agents or agencies, such as having a specific social security number, having a specific customer ID, or even having a specific name." [GW00]

Where is the meaning (example: What is X?)



- An ontology that doesn't hold intrinsic properties is not a good ontology, it becomes a schema, with poor or no meaning.
- Ideally, it should *"...catch all and only the intended meaning"* [Gangemi 04]
- Notice that having all and only the intrinsic properties is :
  (i) very difficult to represent ,e.g. how to represent "person has brain",
  (ii) such properties are not needed in IT applications, so why to have them.
- Thus, it is not necessary that the intrinsic properties be explicitly captured in the ontology, but these properties must govern the way we think and build the ontology.

Where is the meaning (example: What is X?)



- Hence, you (as a knowledge engineer) should be smart when making choices, so to achieve a general but applicable ontology, and not to end with a schema.
- The more a knowledge engineer is aware of ontology modeling challenges, the better his/her skills will be in building quality ontologies.

➔There are some methodologies to guide you building quality ontologies)

(Ontology Modeling Challenges and Methodologies will be discussed later)

The Ontological Level

Based on [3]

Level	*Primitives*	*Interpretation*	*Main feature*
Logical	Predicates, functions	Arbitrary	Formalization
Epistemological	Structuring relations	Arbitrary	Structure
Ontological	**Ontological relations**	**Constrained**	**Meaning**
Conceptual	Conceptual relations	Subjective	Conceptualization
Linguistic	Linguistic terms	Subjective	Language dependence