



**Knowledge Representation &  
Reasoning  
&  
Introduction To Knowledge Graphs**

**Week 8 & 9 | Fall 2022  
Dr. Amna Basharat**



## **What Are Ontologies?**

- Definition
- Use
- Components
- Knowledge representation



„People can't share knowledge if  
they don't speak a common language“

*Thomas Davenport (1997)*



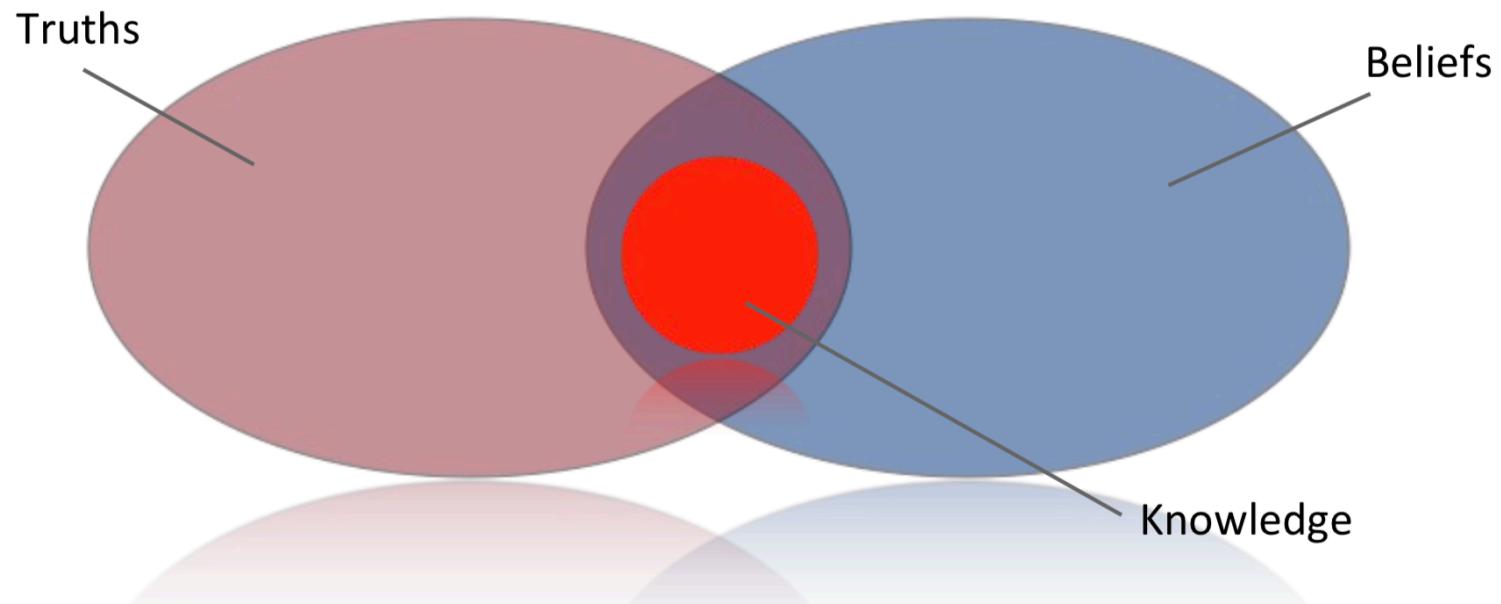


# ...To Speak a Common Language

- common symbols and concepts (**Syntax**)
- agreement about their meaning (**Semantics**)
- classification of concepts (**Taxonomy**)
- associations and relations of concepts (**Thesauri**)
- rules and knowledge about which relations are allowed and make sense (**Ontologies**)



# What Is Knowledge?



Traditional Definition: "Knowledge is a subset of all true beliefs"



To represent knowledge,  
we need a formal knowledge representation  
= ontologies





# Ontologies

**“Ontologies define 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, Fikes, Finin, Gruber, Senator, Swartout, 1991)**



# Definitions

- An ontology is an explicit specification of a conceptualization (Gruber)
- 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. (Swartout, Patil, Knight, Russ)
- An ontology provides the means for describing explicitly the conceptualization behind the knowledge represented in a knowledge base. (Bernaras, Lasergoiti, Correra)
- An ontology is a formal, explicit specification of a shared conceptualization (Studer, Benjamins, Fensel)



# Ontologies on the Semantic Web

- Symbolic models expressed in some formal (logical?) language to allow for automated reasoning





# Ontologies Used ...

- For communication between people and organizations
  - For enabling knowledge reuse and sharing
  - As basis for interoperability between systems
  - As repository of information
  - As query model for information sources
  - As vocabularies/schemas for Linked Data
- 
- **Key technology for the Semantic Web**



# In Philosophy...

Ontology is the philosophical study of the nature of being, existence, or reality, as well as the basic categories of being and their relations...



# Ontologies in Computer Science

"An ontology is an **explicit**, **formal** specification of a **shared conceptualization**. The term is borrowed from philosophy, where an Ontology is a systematic account of existence. For AI systems, what 'exists' is that which can be represented.“

*according to Thomas R. Gruber: A Translation Approach to Portable Ontology Specifications. Knowledge Acquisition, 5(2):199-220, 1993.*

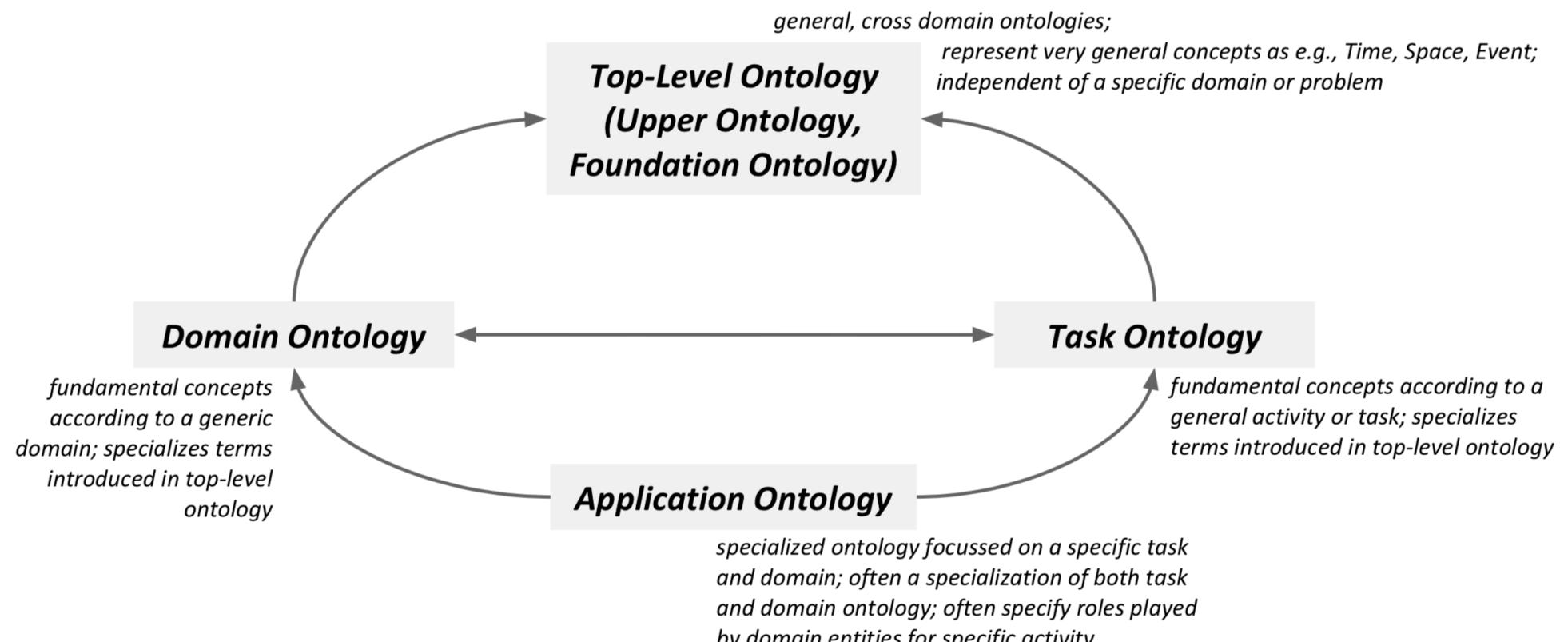
<b>conceptualization:</b>	abstract model (domain, identified relevant concepts, relations)
<b>explicit:</b>	meaning of all concepts must be defined
<b>formal:</b>	machine understandable
<b>shared:</b>	consensus about ontology



# **Types of Ontologies**



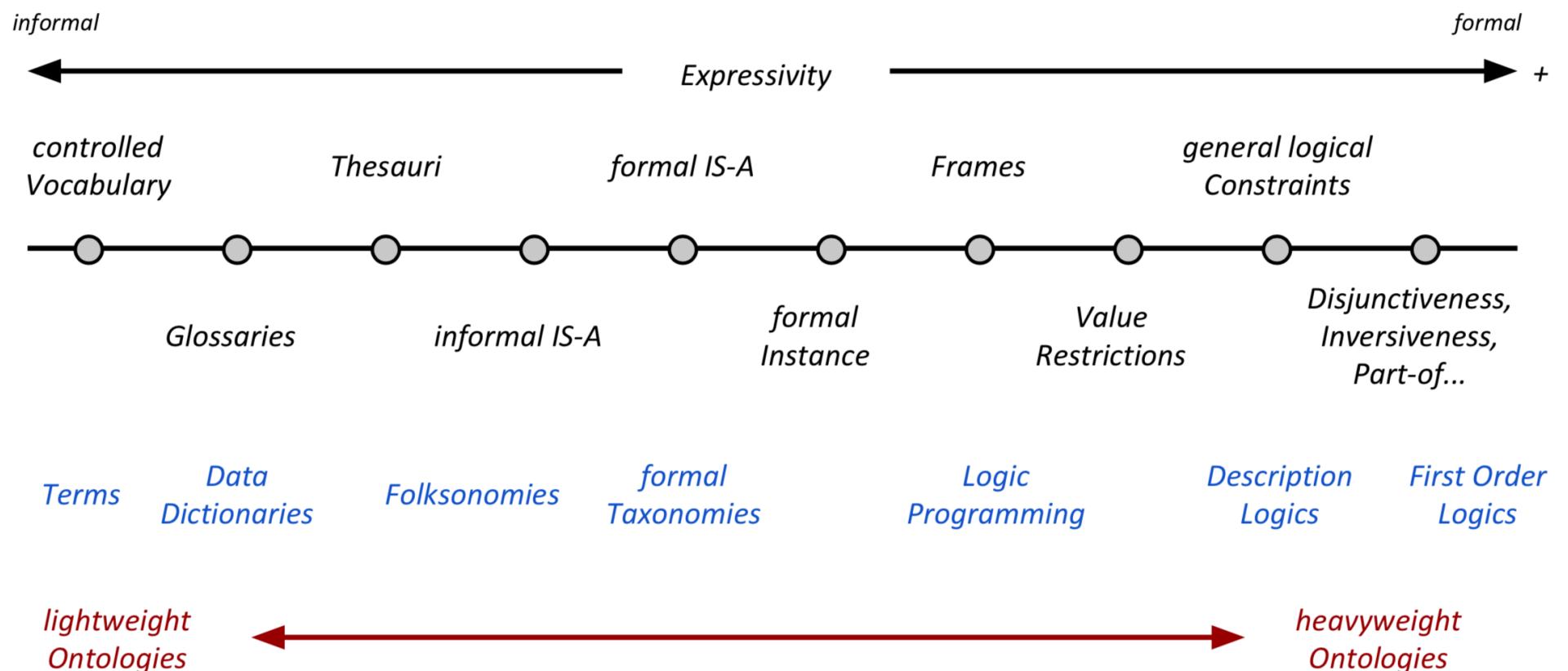
# Ontology Types and Categories (According to Their Level of Generality)



*(according to Guarino: Formal Ontology in Information Systems. 1998)*



# Ontology Types and Categories (According to Their Level of Semantic Expressivity)



(according to Lassila and McGuiness: The Role of Frame-Based Representation on the Semantic Web, 2001)

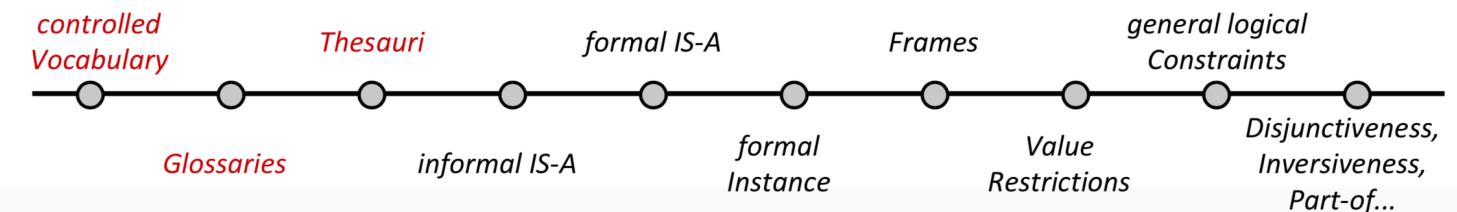


# Ontology Types and Categories (According to Their Level of Semantic Expressivity)

- **Controlled Vocabulary**: finite list of terms (e.g. catalogue)
- **Glossary**: finite list of terms including an informal definition in natural language
- **Thesauri**: [greek. "treasure, treasure house"]

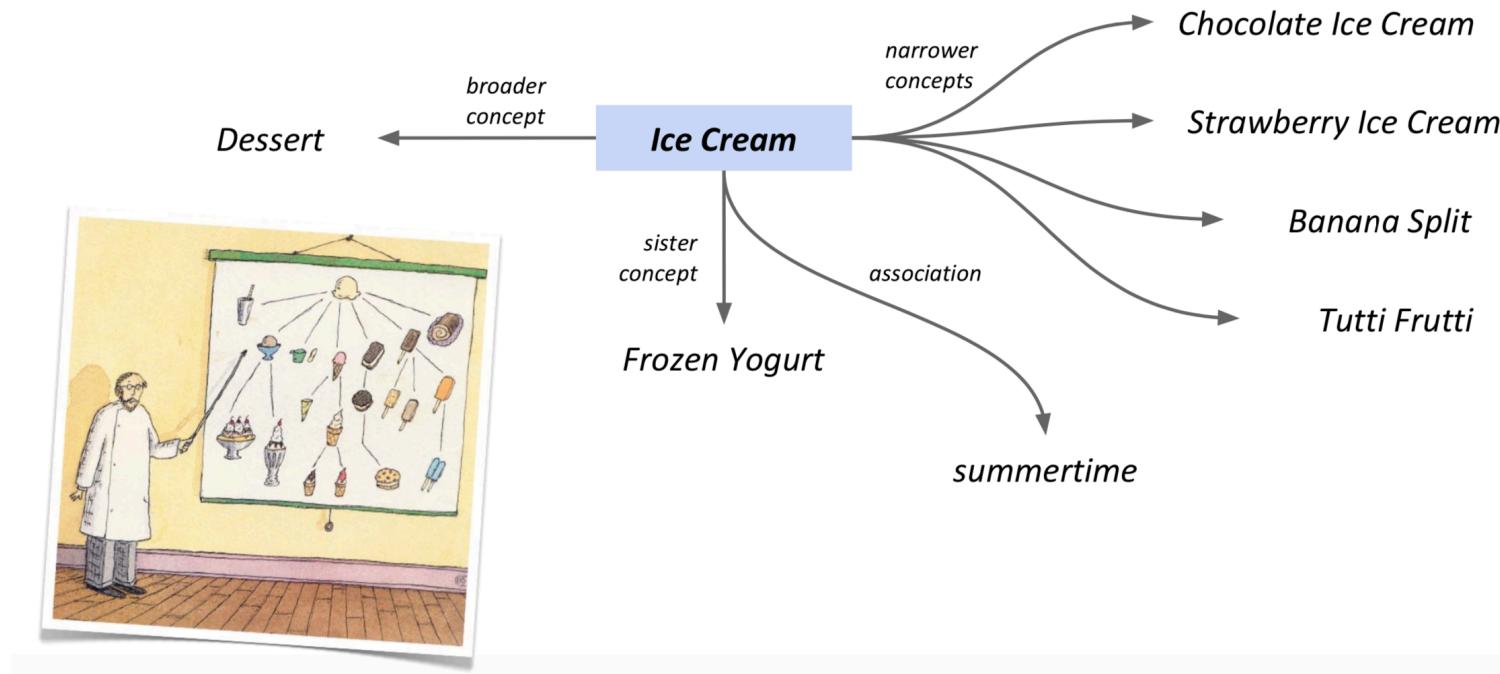
Controlled vocabulary, concepts are connected via relations.

- Equivalency (synonyms)
- Hierarchies (subclasses, superclasses)
- Homographs (Homonyms)
- Associations (similar concepts)





# Example of an Thesaurus Entry





# WordNet

WordNet Search - 3.1  
- [WordNet home page](#) - [Glossary](#) - [Help](#)

Word to search for: semantics

Display Options:

Key: "S:" = Show Synset (semantic) relations, "W:" = Show Word (lexical) relations

**Noun**

- S: (n) **semantics**
  - [direct hyponym / full hyponym](#)
    - S: (n) [deixis](#)
    - S: (n) [formal semantics](#)
    - S: (n) [lexical semantics](#)
    - S: (n) [cognitive semantics, conceptual semantics, semasiology](#)
    - [direct hypernym / inherited hypernym / sister term](#)
      - S: (n) [linguistics](#)
      - [derivationally related form](#)
  - S: (n) **semantics**
    - [direct hypernym / inherited hypernym / sister term](#)
      - S: (n) [meaning, substance](#)
        - S: (n) [idea, thought](#)
          - S: (n) [content, cognitive content, mental object](#)
          - S: (n) [cognition, knowledge, noesis](#)
          - S: (n) [psychological feature](#)
            - [abstraction, abstract entity](#)
            - S: (n) [entity](#)

## WordNet

- link-based electronic dictionary with semantic relations
- organized in 117587 „Synsets“, ordered by
  - Nouns (N)
  - Verbs (V)
  - Adjectives (Adj)
  - Adverbs (Av)

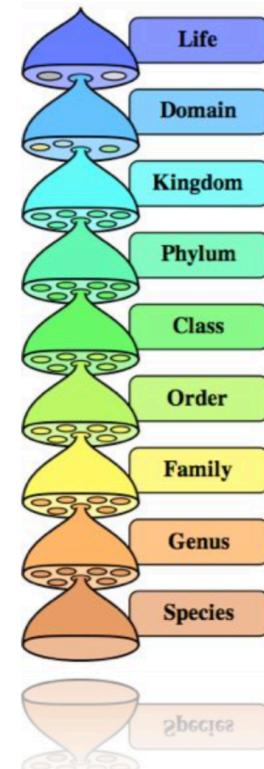
- <http://wordnetweb.princeton.edu/perl/webwn>



# Taxonomies

**Taxonomy:** Definition of a hierarchical system of groups  
(from [greek] *τάξις* (*taxis*) = order, arrangement and  
*νόμος* (*nomos*) = law, science) ...

- Also **classification schema**, nomenclature,...
- In science most times classification into (mono-) hierarchical sets (classes, subclasses, ...)
- (also) subject of **biology**:
  - The arrangement of organisms into a classification according to similarities.





# Taxonomies

- **Informal IS-A Hierarchy:**

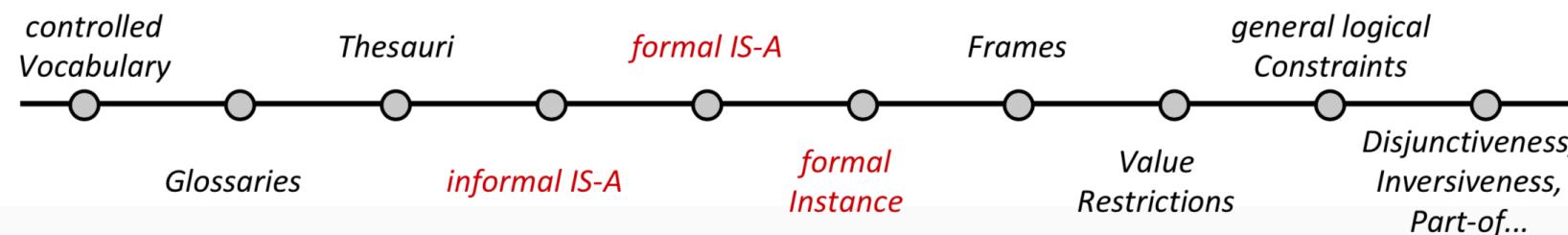
- Explicit hierarchy of classes, subclass relations are not strict (e.g. index of a library)

- **Formal IS-A Hierarchy:**

- Explicit Hierarchy of classes, subclass relations are strict

- **Formal instance:**

- Explicit Class hierarchy, besides strict subclass relations also instance-of relations are allowed.





# Different Kinds of "Ontologies"

- Controlled vocabularies, Concepts
- Taxonomies Concepts, is-a
- Thesauri  
Concepts, predefined relations
- Data models (e.g. EER, UML) Concepts, relations, axioms
- Logic-based ontologies Concepts, relations, axioms

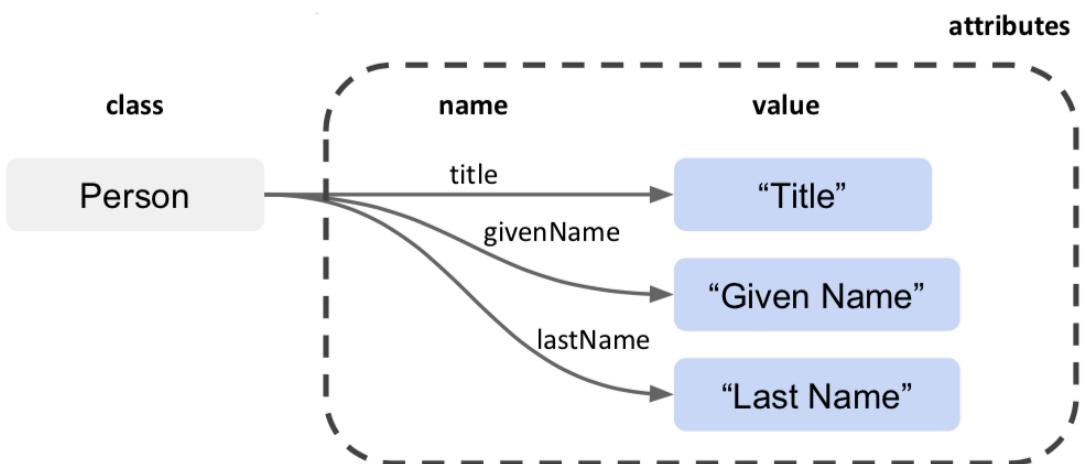


# **How To Represent Ontologies**



# How To Represent Ontologies

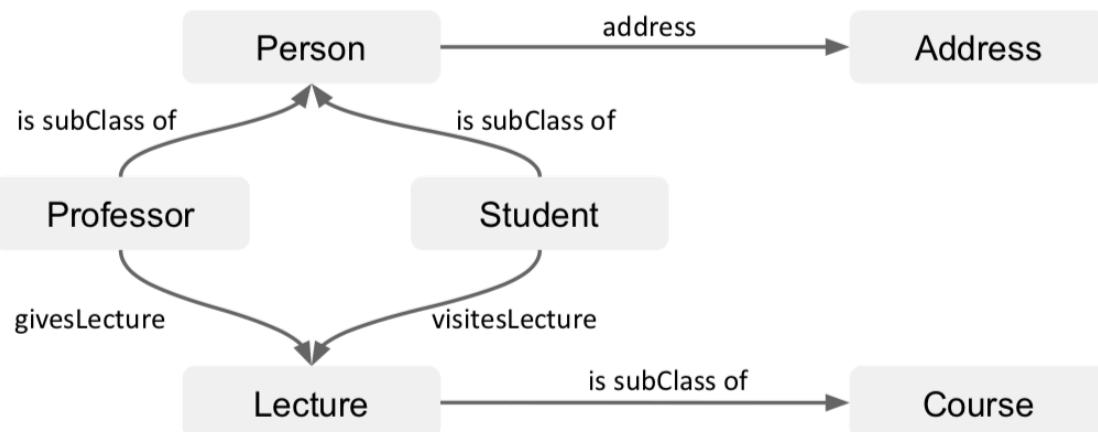
- Ontologies can be represented via Classes, Relations and Instances
- Classes are abstract groups, sets, or collections of objects and represent ontology concepts
- Classes are characterised via attributes
- Attributes are name-value pairs





# How To Represent Ontologies

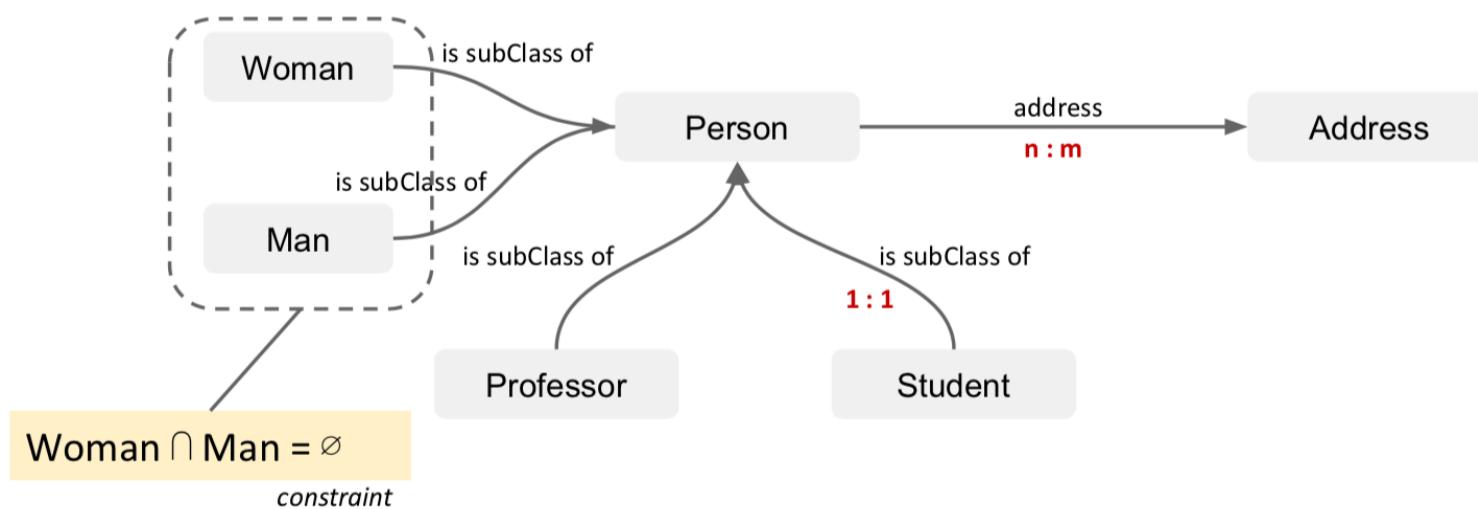
- Classes can be related to other classes  
Relations are special attributes, whose values are objects of (other) classes





# How To Represent Ontologies

- For Relations and Attributes Rules (Constraints) can be defined that determine allowed/valid values





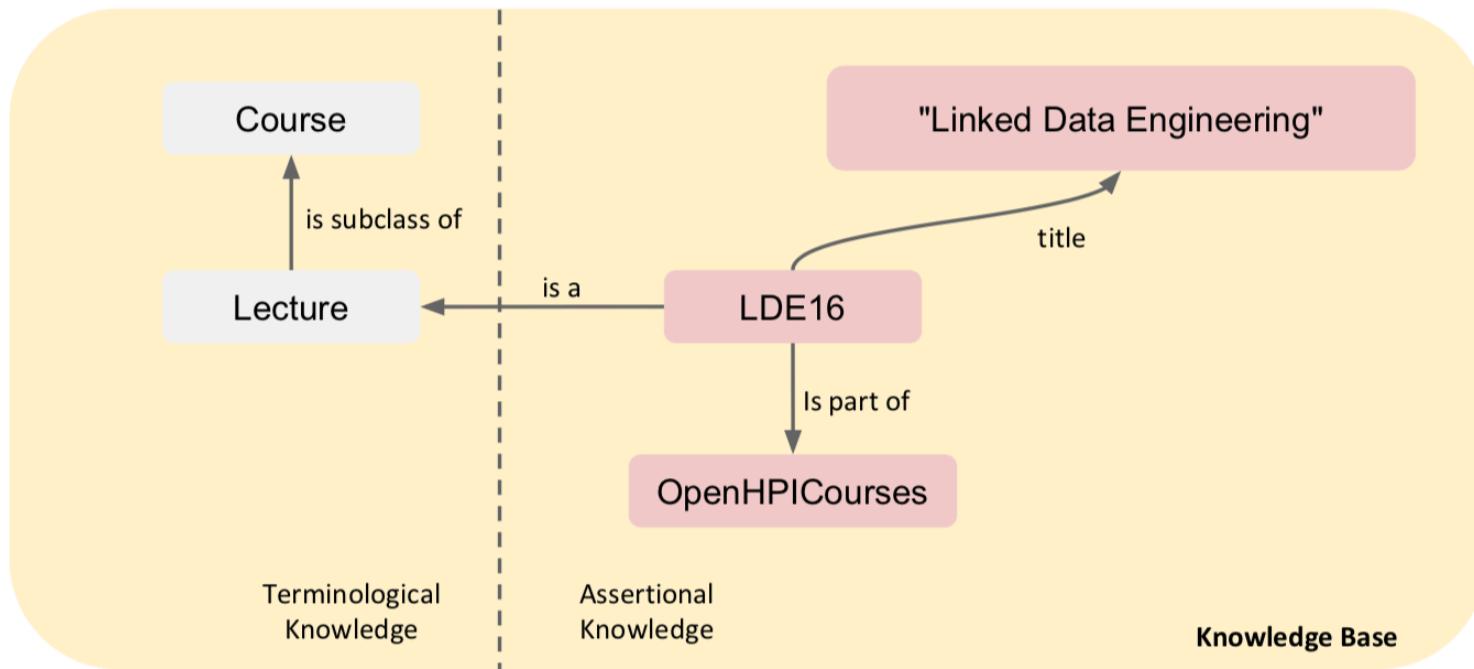
# How To Represent Ontologies

- Classes, relations, and constraints can be combined to form (complex) Statements / Assertions
- Special Case: formal Axioms
- Example:  
„it is not possible to attend two courses at the same time“
- Axioms describe knowledge that cannot be expressed simply with the help of other existing components.



# How To Represent Ontologies

- Instances describe individuals of an ontology





# **Understanding Vocabularies**



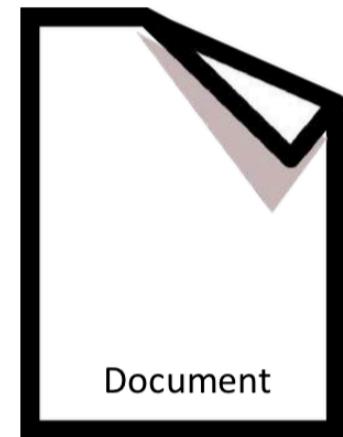
# Vocabularies

- A person's vocabulary is the set of words within a language that are familiar to that person. (Wikipedia)
- = "all the words known and used by a particular person" (Cambridge Advanced Learners Dictionary)
- On the Semantic Web, vocabularies define the concepts and relationships used to describe and represent an area of concern. (W3C)
- Vocabularies are used to
  - classify the terms that can be used in a particular application,
  - characterize possible relationships, and
  - define possible constraints on using those terms.



# Example

- The Dublin Core Vocabulary (Dublin Core Metadata Element Set)



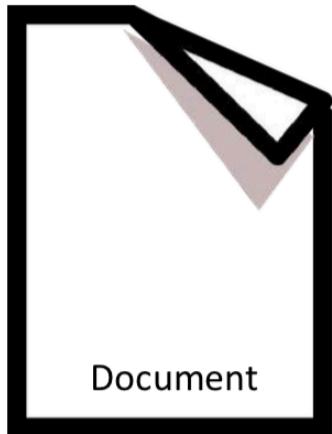
- Title
- Creator
- Subject
- Description
- Publisher
- Contributor
- Date
- Type
- Format
- Identifier
- Source
- Language
- Relation
- Coverage
- Rights





# Example

- The Dublin Core Vocabulary (Dublin Core Metadata Element Set)



- Title
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- Publisher
- Contributor
- Date
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- Format
- Identifier
- Source
- Language
- Relation
- Coverage
- Rights

PREFIX dct: <<http://purl.org/dc/terms/>> .

<[http://example.org/document\\_xyz](http://example.org/document_xyz)> dct:title "This is the title..."@en .



# Example

- Defining personal data for a user/person
  - e.g. given name, last name, address data, web page, email address, etc.
- There are several possibilities:
  - Define a new vocabulary according to your needs
  - Use existing vocabularies and (possibly) adapt your application accordingly
  - Use existing vocabularies and extend vocabularies according to your needs

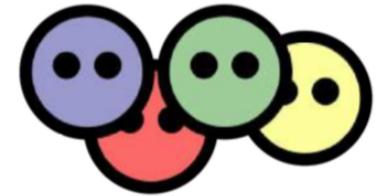


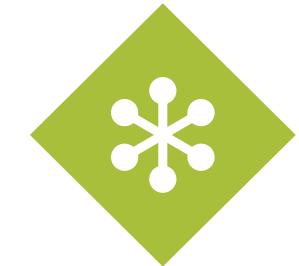
# Example of Linked Data Vocabularies

- FOAF - Friend of a Friend
  - describes persons, their activities and their relations to other people and objects

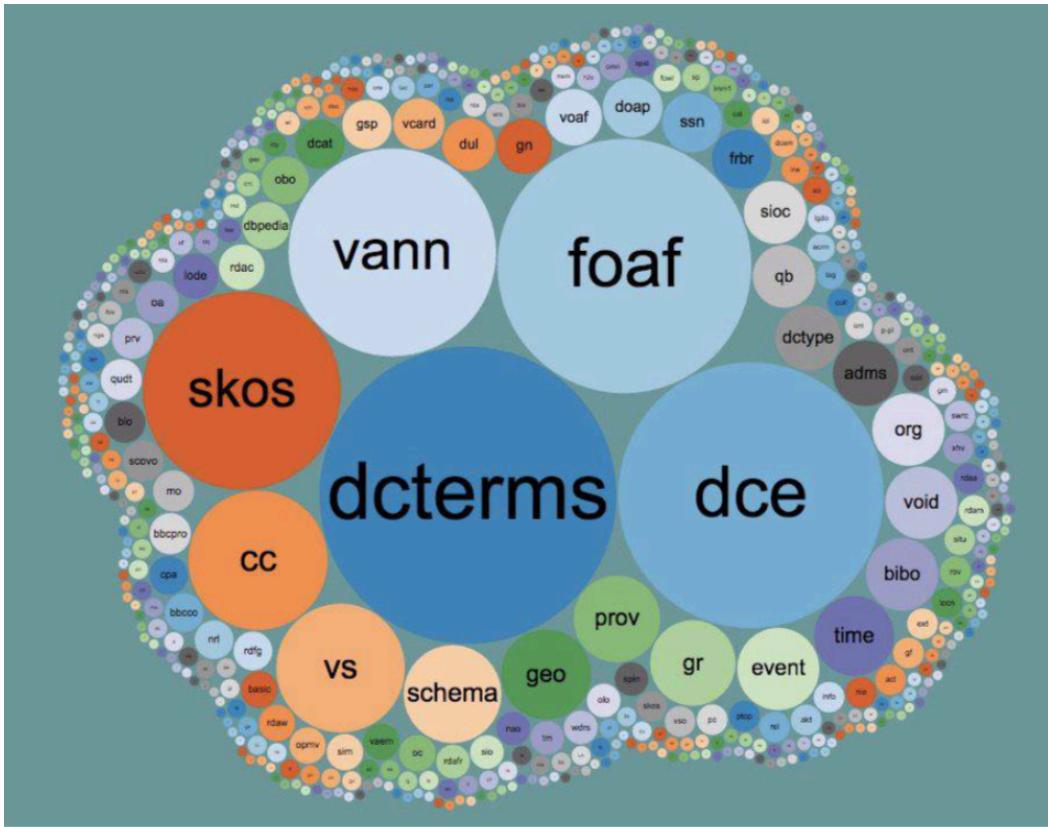
```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .  
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .  
@prefix foaf: <http://xmlns.com/foaf/0.1/> .  
  
<#me>  
    a foaf:Person ;  
    foaf:name "Harald Sack" ;  
    foaf:mbox <mailto:harald.sack@hpi.de> ;  
    foaf:homepage <https://hpi.de/meinel/lehrstuhl/team-fotos/senior-researcher/sack.html> ;  
    foaf:depiction <https://hpi.de/fileadmin/_migrated/pics/harald_min.jpg> ;  
    foaf:interest <http://linkeddata.org> ;  
    foaf:knows [  
        a foaf:Person ;  
        foaf:name "Magnus Knuth"  
    ] .
```

<http://www.foaf-project.org>





# Where To Find Linked Data Vocabularies



- <https://lov.linkeddata.es/dataset/lov/>