CS3025 Knowledge-Based Systems

Standard Languages for the Semantic Web

Jeff Z. Pan

History of Knowledge Representation

1. Natural language: long history
2. Semantic network
   - highlight **structured** information
   - no well-defined syntax and formal semantics
3. Frame
   - **class (concept), individual (object), property (relation)**
   - **subclass-of, instance-of**, property
   - defaults, procedures
4. First order logic
   - **formal**, (too) expressive
5. **KL-ONE/Description Logics/Ontology Language**
   - subset of FOL with good **implementability**
6. **Rules**
   - **intuitive**, with reasonable implementability

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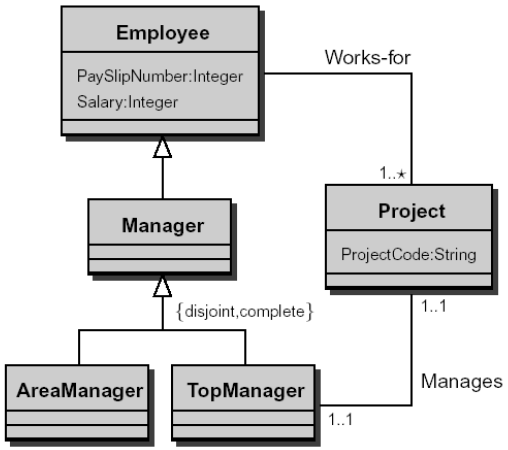
Set Theory



- A set is an unordered collection of objects
  - Basic relation: member-of
  - Other relations: subset, superset, equivalent
  - Basic operations: union, intersection, difference, complements
- An individual is a name for an object
- A class "*is*" a set of objects
  - Employee: {E1, E2, E3, E4}
  - Project: {P1, P2}
- A property "*is*" a set to pairs (tuples) of objects
  - Works-for: {<E1,P1>, <E2,P1>, <E2,P2>, <E3,P1>, <E3,P2>, <E4,P2>}

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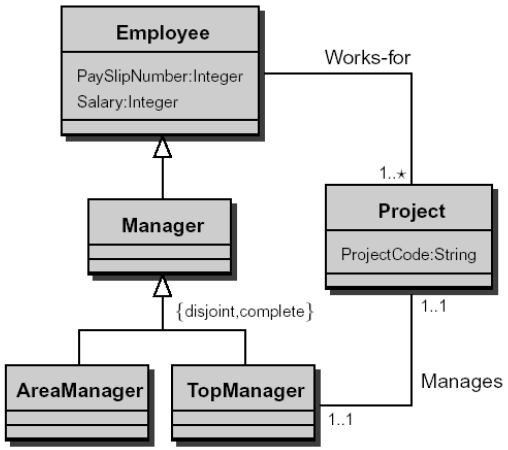
Set Theory and Interpretations



- Interpretations relate symbols with sets
- Interpretation is often written as $(\Delta^I, \bullet^I)$
  - Δ^I : interpretation domain
    - similar to universal set
    - e.g., Δ^I = {E1, E2, E3, E4, P1, P2}
  - $\bullet^I$: interpretation function
- Interpretations of individuals, classes and properties
  - all individuals are members of the domain: $o^I \in \Delta^I$
  - all classes are subsets of the domain $A^I \subseteq \Delta^I$
    - e.g., Employee^I= {E1, E2, E3, E4}
  - all properties are subsets $R^I \subseteq \Delta^I \times \Delta^I$

    e.g., Works-for^I= {<E1,P1>, <E2,P1>, <E2,P2>, <E3,P1>, <E3,P2>, <E4,P2>}

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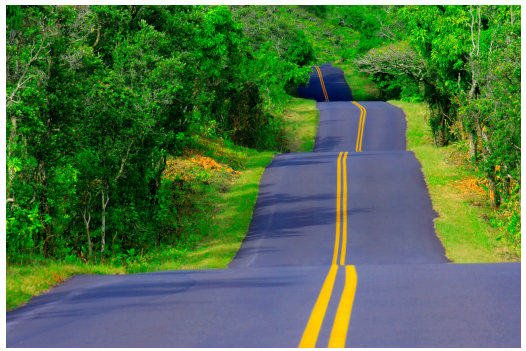
Roadmap



- Foundation
  - KR, ontology and rule; set theory
- Knowledge capture
- Knowledge representation
  - Ontology: Semantic Web standards RDF and OWL, Description Logics
  - Rule: Jess
- Knowledge reasoning
  - Ontology: formal semantics, tableaux algorithm
  - Rule: forward chaining, backward chaining
- Knowledge reuse and evaluation
- Meeting the real world
  - Jess and Java, Uncertainty, Invited talk

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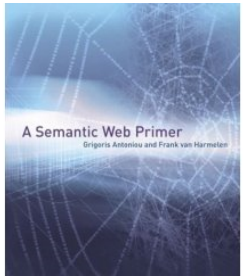
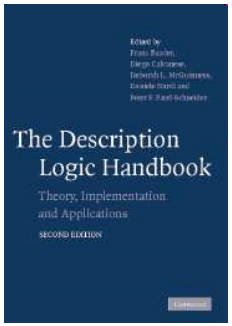
Lecture Outline

- Motivation
- Introduction to RDF and OWL
- Some More Details of RDF and OWL
- Practical



[Section 3.1 – 3.5, Section 4.1 - 4.3]



[Chapter 14]

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Motivations

- SW requires meaning of web resources understandable by programs
- Other Web standards do not provide means of talking about semantics of data
  - HTML mixes content with presentation
  - XML only provides the standard syntax to structure data

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What is the Problem?

- Consider a typical web page:

- HTML Markup consists of:
  - rendering information (e.g., font size and colour)
  - Hyper-links to related content
- Content is accessible to humans but not (easily) to computers…

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What Information Can We See…

WWW2002

The eleventh international world wide web conference

Sheraton waikiki hotel

Honolulu, hawaii, USA

7-11 may 2002

1 location 5 days learn interact

Registered participants coming from

australia, canada, chile denmark, france, germany, ghana, hong kong, india, ireland, italy, japan, malta, new zealand, the netherlands, norway, singapore, switzerland, the united kingdom, the united states, vietnam, zaire

Register now

On the 7th May Honolulu will provide the backdrop of the eleventh international world wide web conference. This prestigious event …

Speakers confirmed

Tim berners-lee

Tim is the well known inventor of the Web, …

Ian Foster

Ian is the pioneer of the Grid, the next generation internet …

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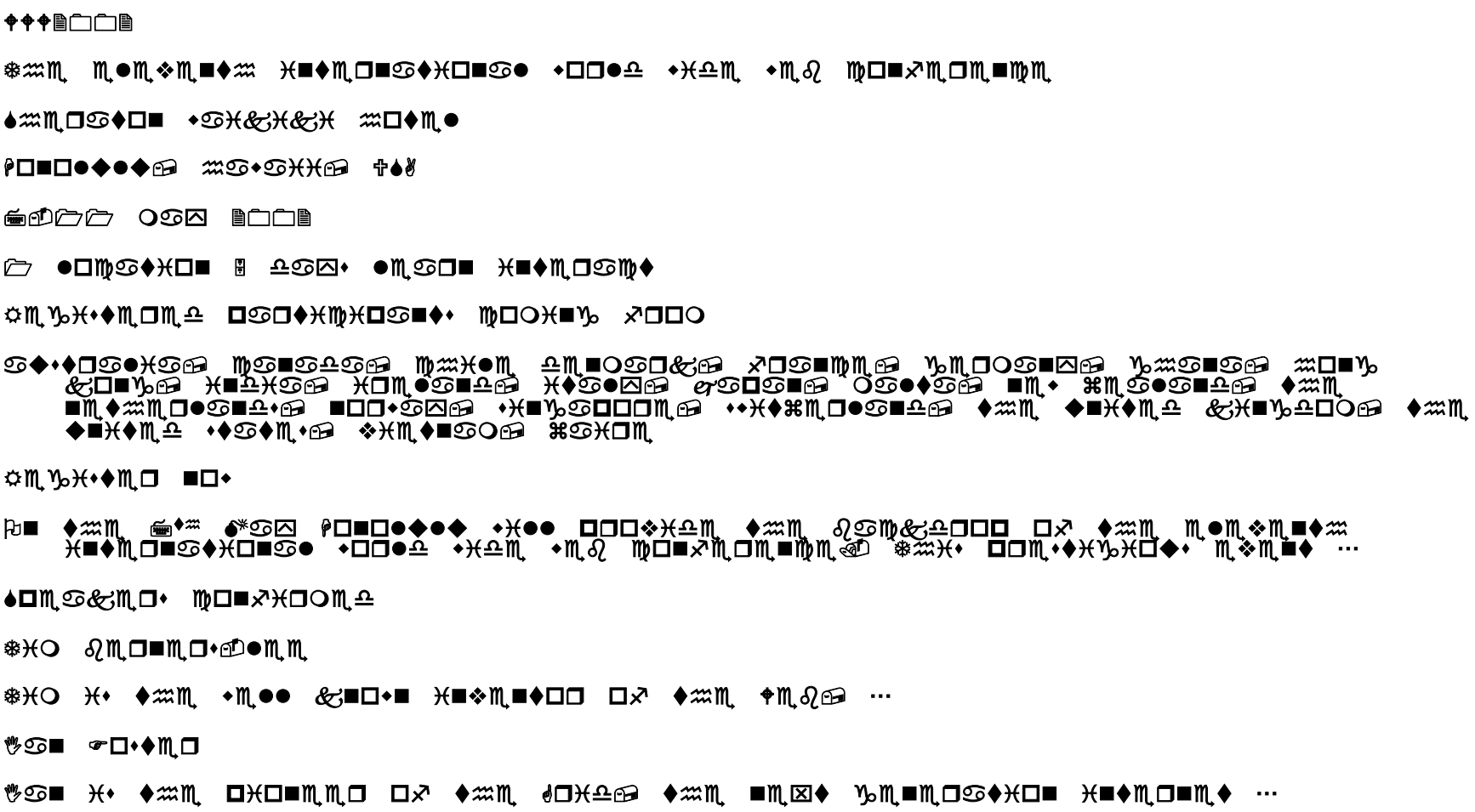
What Information Can a Program See…



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Solution: XML Markup with "Meaningful" Tags?

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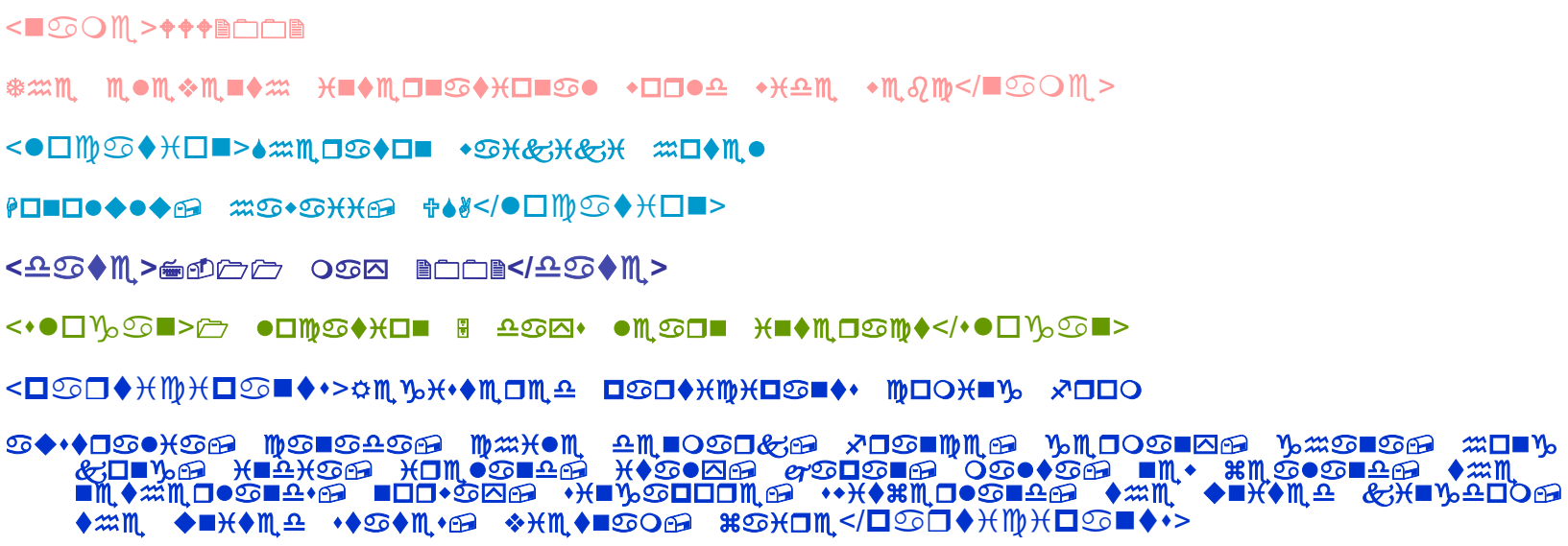
Programs See…



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Lecture Outline

- Motivation
- Introduction to RDF and OWL
  - The big picture
- Some More Details of RDF and OWL
- Practical

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Basic Ideas of RDF

- Basic building block: Subject-property-value triple
  - It is called a statement
  - E.g. Jeff teaches CS3025 is a statement

- RDF (Resource Description Framework) has been given a syntax in XML
  - This syntax inherits the benefits of XML
  - Other syntactic representations of RDF possible
    - such as Notation 3 (N3) syntax: [Subject property value .]

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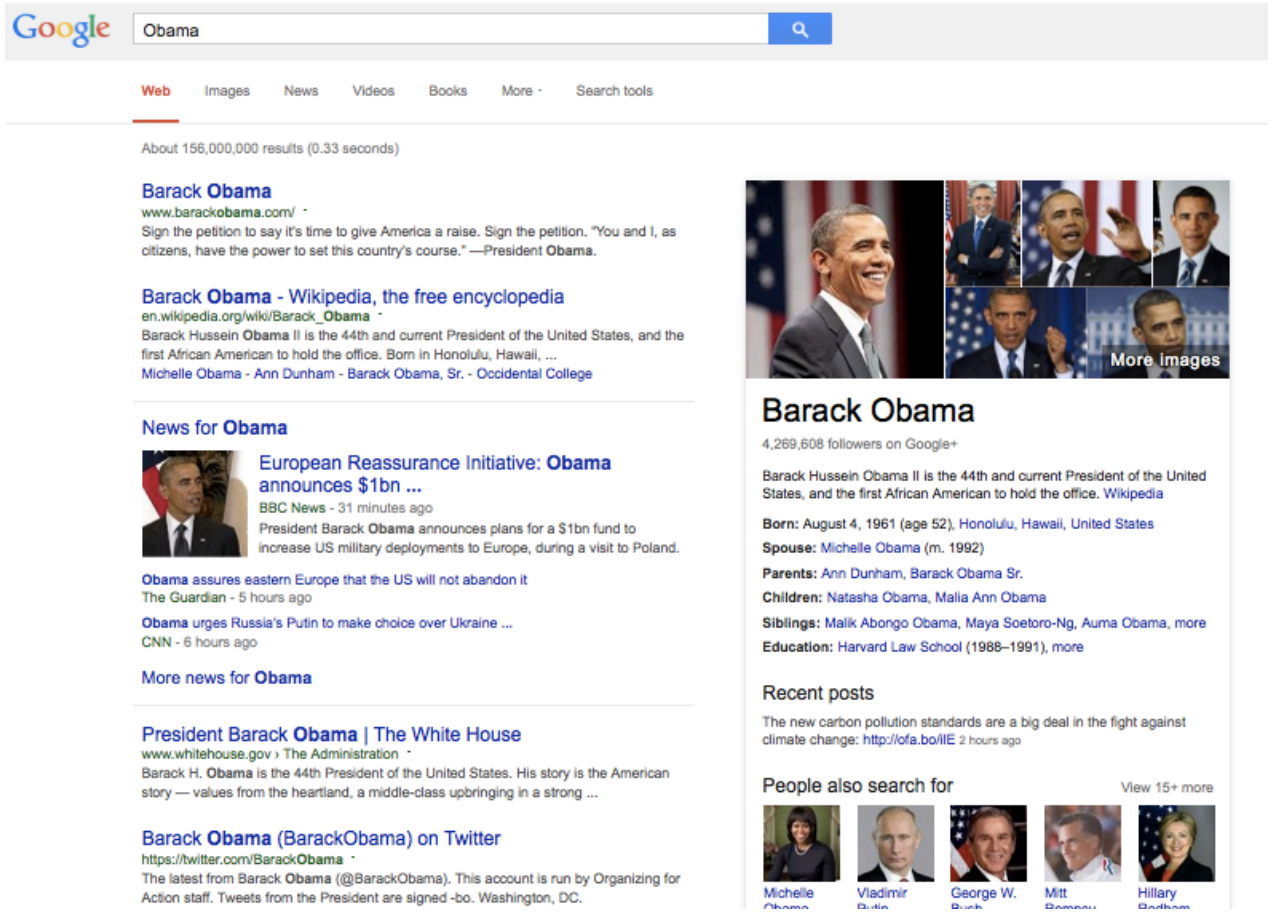
Basic Ideas of RDF (2)

- The fundamental concepts of RDF are:
  - resources
  - properties
  - statements



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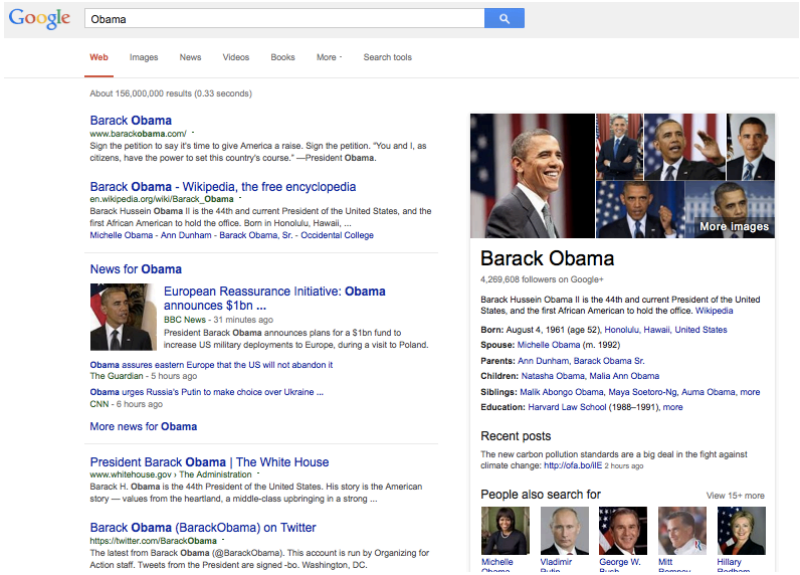
Resources

- We can think of a resource as an object, a “thing” we want to talk about
  - E.g. authors, books, publishers, places, people, hotels

- Every resource has a URI, a Universal Resource Identifier
- A URI can be
  - a URL (Web address) or
  - some other kind of unique identifier



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Properties

- Properties are a special kind of resources
- They describe relations between resources
  - E.g. “written by”, “age”, “title”, etc.
- Properties are also identified by URIs
- Advantages of using URIs:
  - A global, worldwide, unique naming scheme
  - Reduces the homonym problem of distributed data representation

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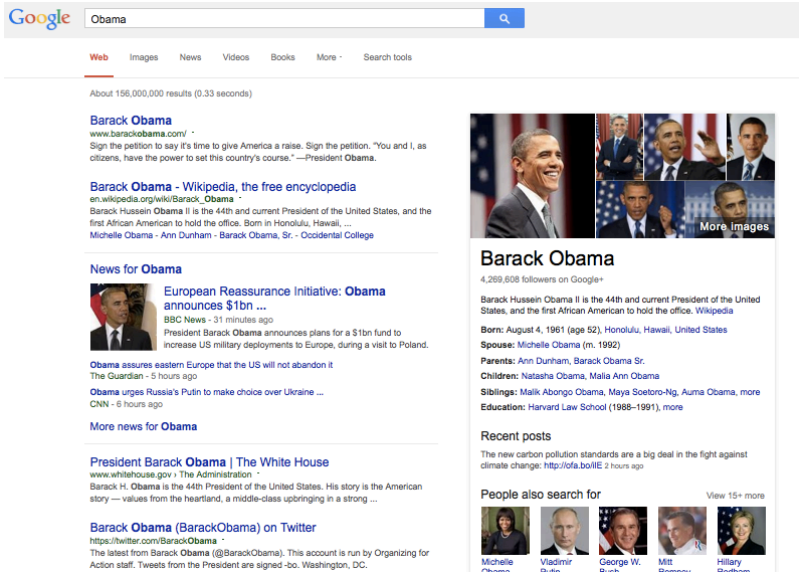
Statements

- Statements assert the properties of resources
- A statement is an resource-property-value triple
  - It consists of a resource, a property, and a value
- Values can be resources or **literals**
  - Type literals: “15”^^xsd:integer
  - Plain literals (strings): “Tom”



How to Enable Machine/Program Understandability

- To add annotations to Web resources
  - Describing their contents and functionalities
- To provide semantics for annotations

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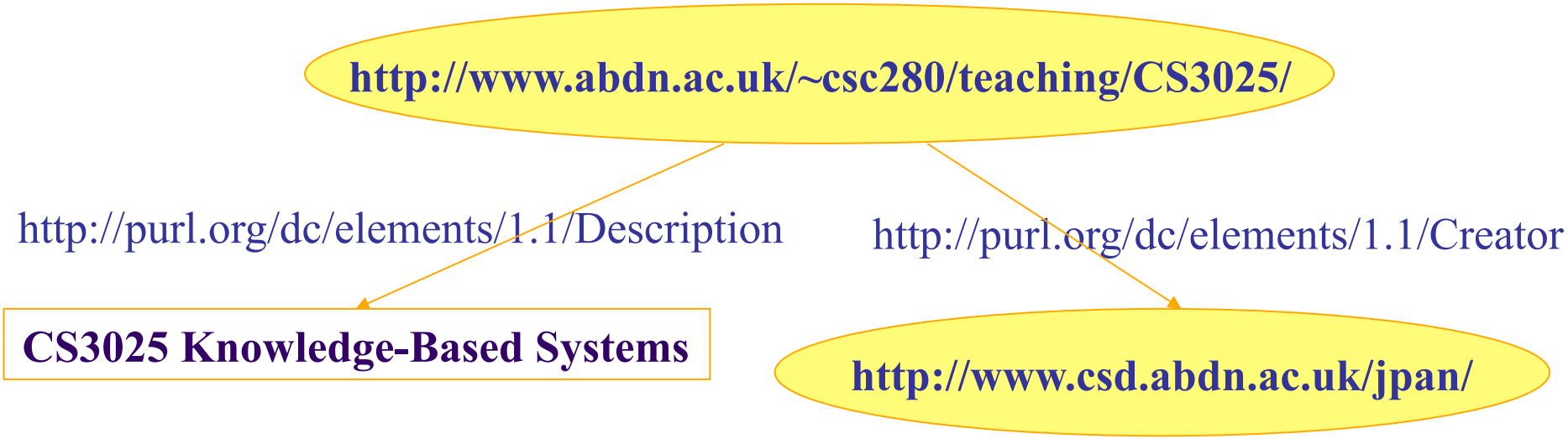
What do Annotations Look Like?

- Annotations are represented as RDF triples



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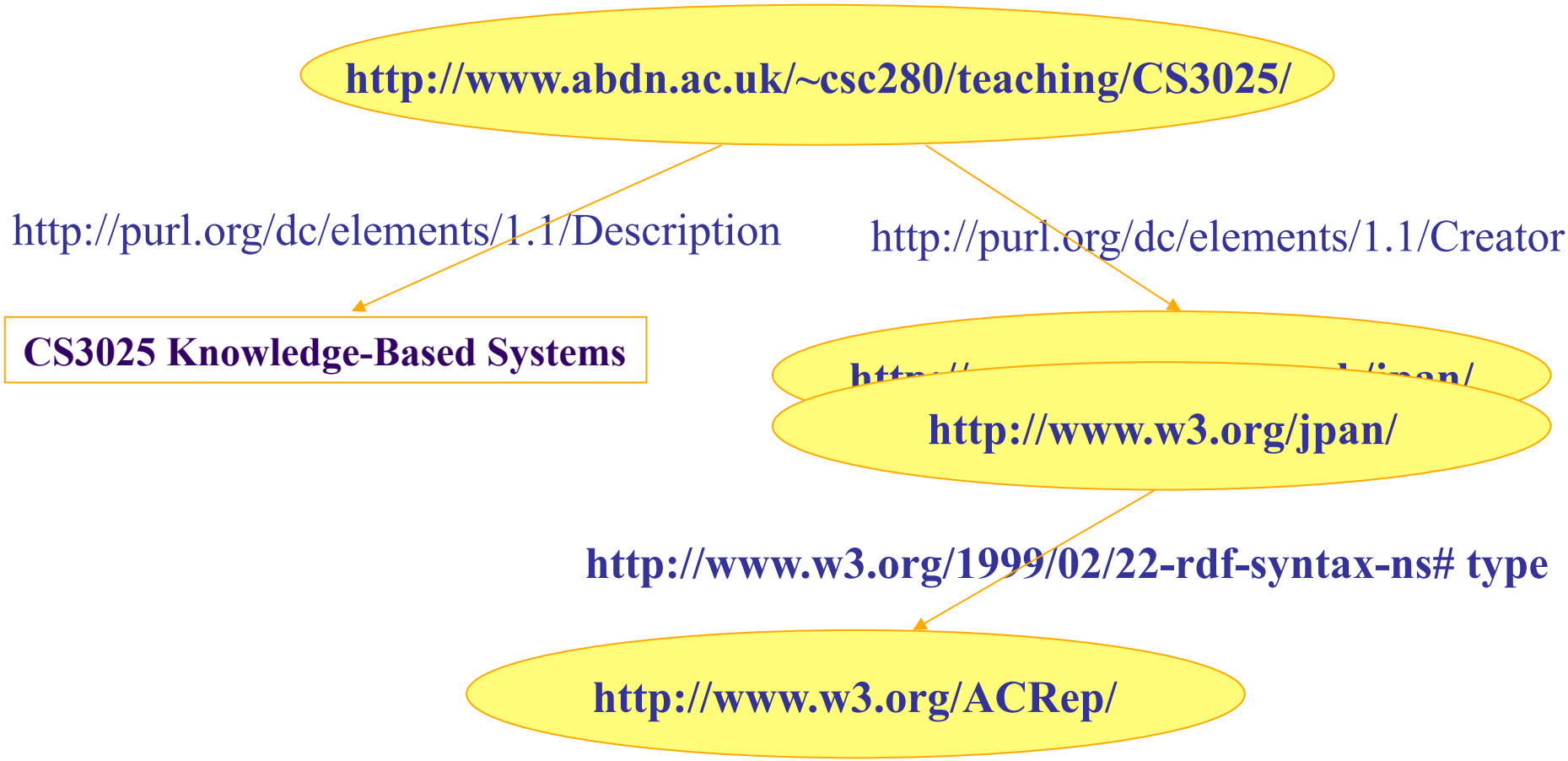
A Network of Annotations



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Example: RDF/XML Syntax


```
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:csd="http://www.csd.abdn.ac.uk/"
  >

<rdf:Description rdf:about="http://www.abdn.ac.uk/~csc280/
    teaching/CS3025/">
    <dc:Creator rdf:resource="http://www.csd.abdn.ac.uk/jpan/ ">
    <dc:Description> CS3025 Knowledge-Based Systems
</dc:Description>
</rdf:Description>

</rdf:RDF>
```

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Example: Notation 3 (N3) Syntax


```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns >
@prefix dc: <http://purl.org/dc/elements/1.1 >
@prefix csd: < http://www.csd.abdn.ac.uk/>

 [http://www.abdn.ac.uk/~csc280/teaching/CS3025/
 dc:Creator csd:jpan .]

[http://www.abdn.ac.uk/~csc280/teaching/CS3019/
 dc:Description “CS3025 Knowledge-Based Systems” .]
```

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What do Annotations Mean?

- So far we have used the following in our annotations
  - http://purl.org/dc/elements/1.1/Description
  - http://purl.org/dc/elements/1.1/Creator
  - http://www.w3.org/1999/02/22-rdf-syntax-ns#type
  - http://www.w3.org/ACRep/
- What do they mean?

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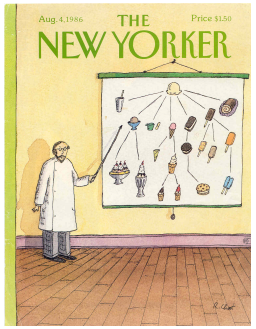
Ontology



- An ontology is a model of (some aspects of) the world:
  - It is constituted by a key vocabulary for the domain, plus
  - definition and constraints about the vocabulary, to capture the intended meaning of the vocabulary

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Requirements for Ontology Languages

- Ontology languages allow users to write explicit, formal conceptualisations of domain models
- The main requirements are:
  - a well-defined syntax
  - a formal semantics
  - efficient reasoning support
  - sufficient expressive power
  - convenience of expression

RDF Schema

- RDF Schema (RDFS)
  - Allow users to introduce vocabulary
- Key meta classes for declarations:
  - rdfs:Class, rdfs:Resource, rdfs:Property
- Key meta properties for basic axioms:
  - rdf:type, rdfs:subClassOf, rdfs:subPropertyOf, rdfs:domain, rdfs:range

- Examples:

[csd:Lecturer rdfs:subClassOf csd:AssistantProf .]
[csd:Lecturer rdfs:subClassOf csd:Staff .]
[csd:jpan rdf:type csd:Lecturer .]
[csd:AssistantProf rdfs:subClassOf csd:Lecturer .]

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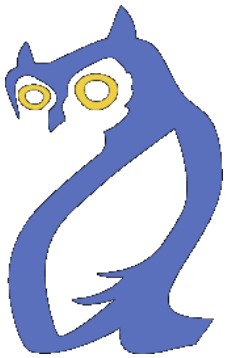
OWL: Web Ontology Language



- OWL is the W3C Web Ontology Language
  - Based on Description Logics
  - Has several syntax
    - RDF/XML
    - Abstract
    - DL
- Motivation: more expressive power, such as
  - Disjointness of classes
    - DisjointClasses (csd:Male csd:Female)
  - Equivalent individuals
    - SameIndividual (csd:jpan w3:jpan)
  - Boolean combination of classes
    - Class (Person complete unionOf (csd:Male csd:Female))
  - and many more …

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Lecture Outline

- Motivation
- Introduction to RDF and OWL
- Some More Details of RDF and OWL
- Practical

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Status of RDF and OWL

- Both are W3C recommendations
- Resource Description Framework (RDF)
  - http://www.w3.org/RDF/
  - **Primer**: http://www.w3.org/TR/REC-rdf-syntax/
- Web Ontology Language (OWL) 2.0
  - http://www.w3.org/TR/owl2-overview/

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How many facts?

Schema-like

```
(deftemplate person
     (slot name)
     (slot age)
     (slot gender)
     (slot partner)
     (multislot children))
```

Data

```
(assert (person
                    (name Michael)
                    (gender male)
                    (age 35)
                    (partner Diana)
                    (children Philip
Julia)))
<fact-0>
```

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Class Hierarchies

- Classes can be organised in hierarchies
  - A is a sub-class of B if every instance of A is also an instance of B
  - Then B is a super-class of A
- Sub-class-of relations are transitive

- Example

[csd:Lecturer rdfs:subClassOf csd:Staff .]
[csd:Staff rdfs:subClassOf csd:Person .]

[csd:jpan rdfs:type csd:Lecturer .]

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Property Hierarchies

- Properties can be organised in hierarchies
  - P is a sub-property of Q if Q(x,y) holds whenever P(x,y) holds
  - Then Q is a super-property of P
- Example

[hasGoodFriend rdfs:subPropertyOf hasFriend .]

[John hasGoodFriend Mary .]

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Domains of Properties

- A domain of a property P is
  - the class of those resources that
  - may appear as subjects
  - in a triple with property P
- If the range is not specified, then any resource can be the value

[csd:teach rdfs:domain csd:Lecturer .]

[csd:jpan teach csd:CS3025 .]

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Ranges of Properties

- A range of a property P is
  - the class of those resources that
  - may appear as values
  - in a triple with property P
- If the domain is not specified, then any resource can be the subject

[csd:teach rdfs:range csd:Course .]

[csd:jpan teach csd:CS3025 .]

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Practical

- How to construct OWL ontologies with ontology editors
- Go through tutorials of an ontology editor called Protégé
  - sub-class, super-class
  - disjoint classes
  - **Important**: report to the demonstrator about the your comments of the pizzas ontologies and any changes you want to make against them

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Summary

- RDF
  - Data model for the Semantic Web
    - and machine understandable data
  - Basic data language and schema language
- OWL
  - Web Ontology Language
  - Advanced data language and schema language
  - More expressive power but still decidable