Semantic Web
Knowledge Representation in the Web Context

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- Ian Horrocks (Manchester U.K.)
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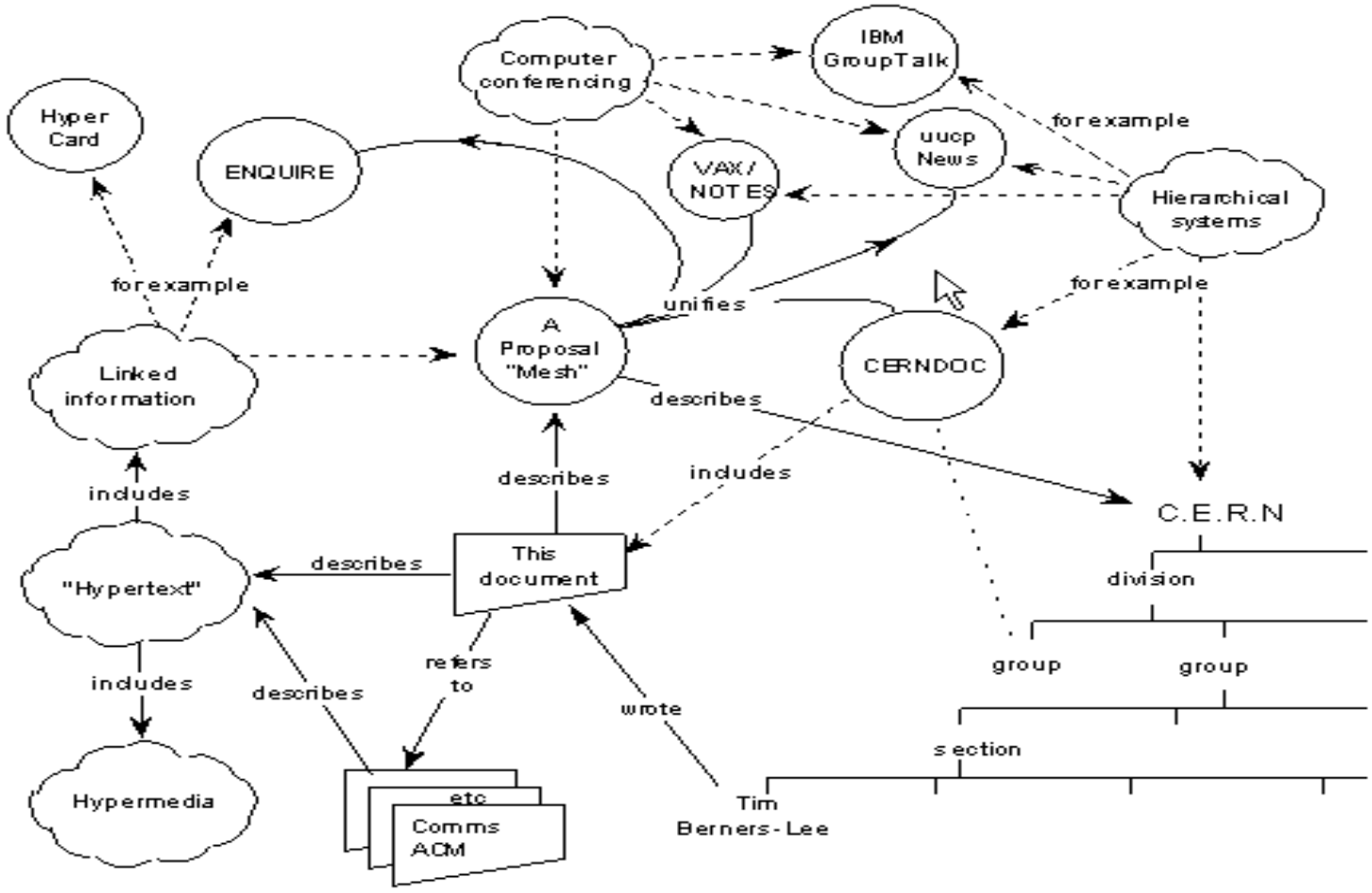
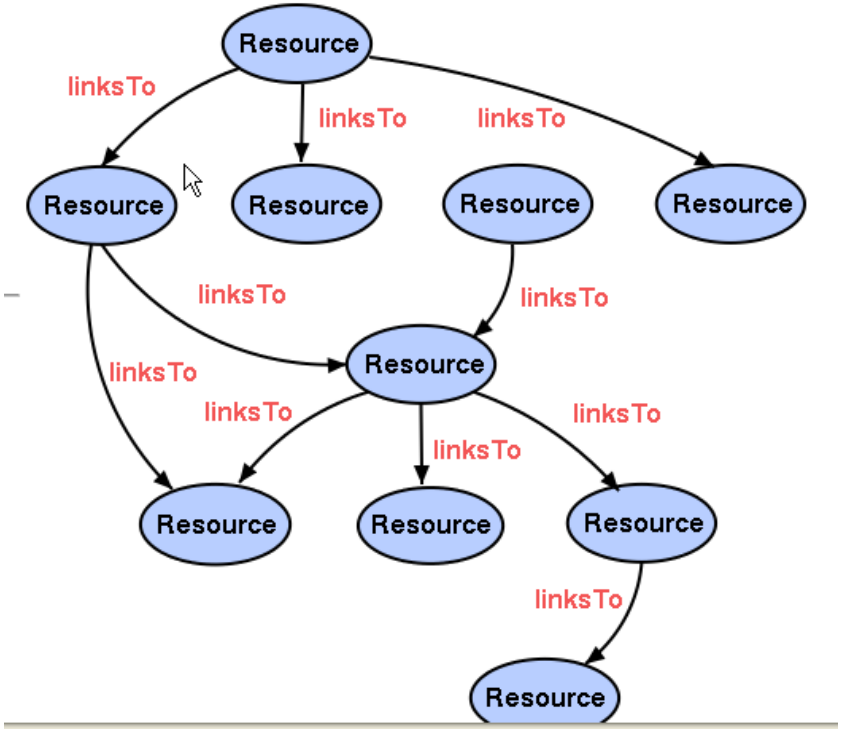
- Volker Haarslev (Montreal)

Original Web Vision
Web of relationships amongst named objects



Current Web ("Syntactic" Web)

- Untyped resources named by URLs
- Untyped relationships (href with anchor text)
- User oriented – document rendering
- Machines must infer information

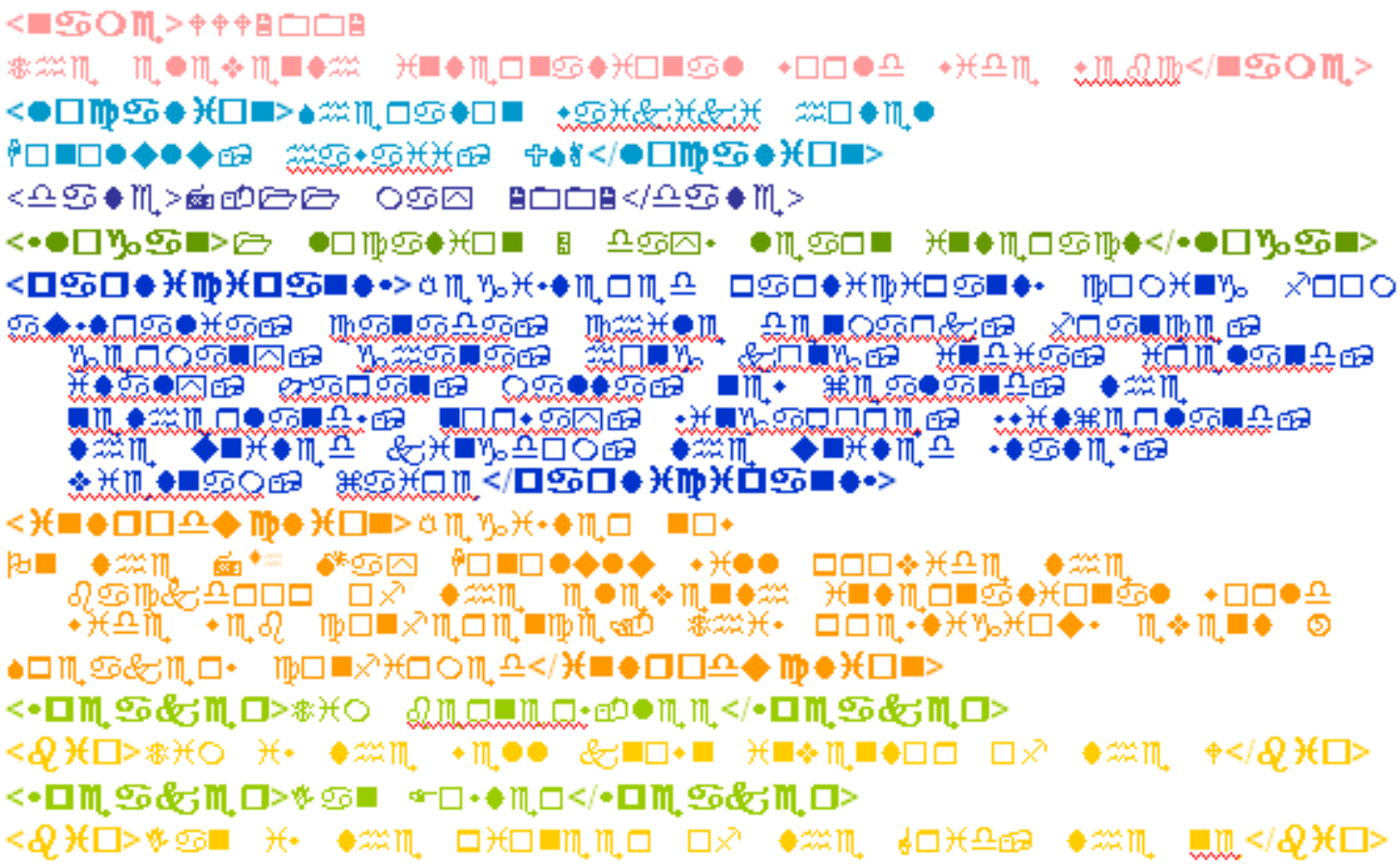


The Information in a Web Page

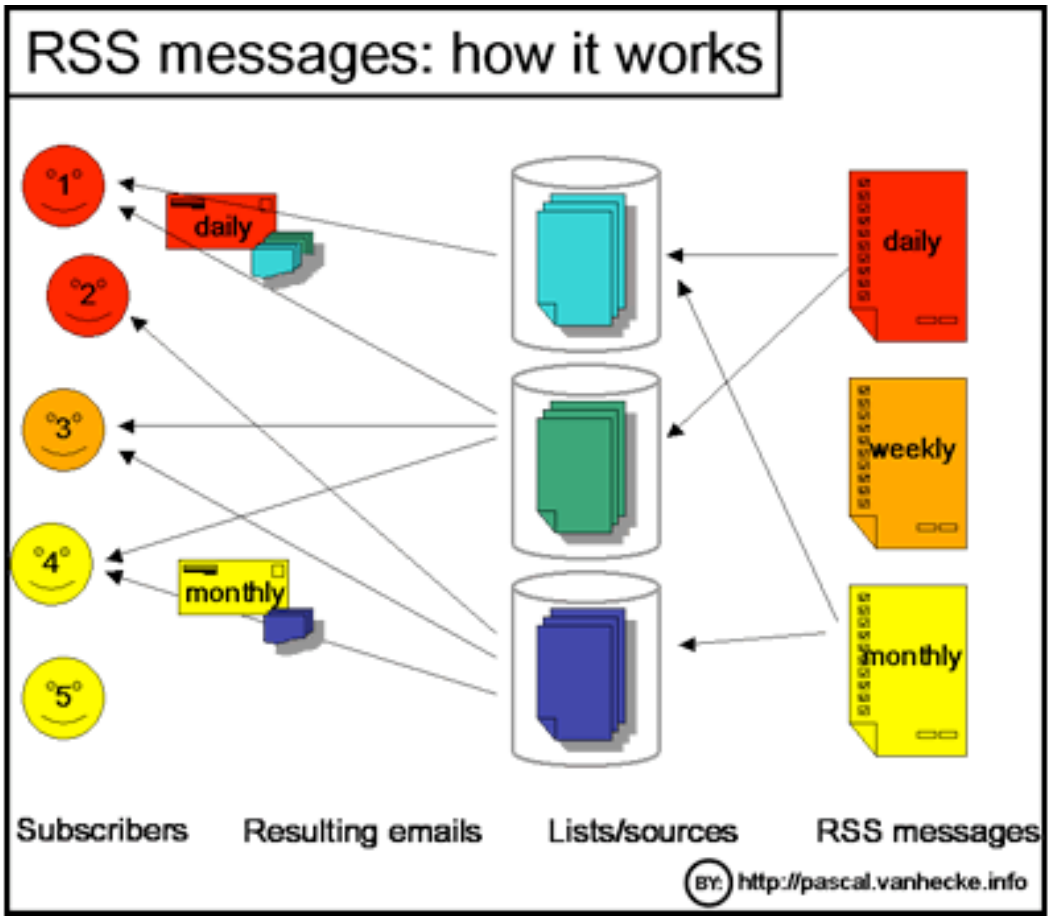
- Markup connotes semantics (bold, colors, font…)
- Humans interpret semantics
- Rendering semantics is not clear or available to machines

Why is XML not enough?

but from the machines point of view…

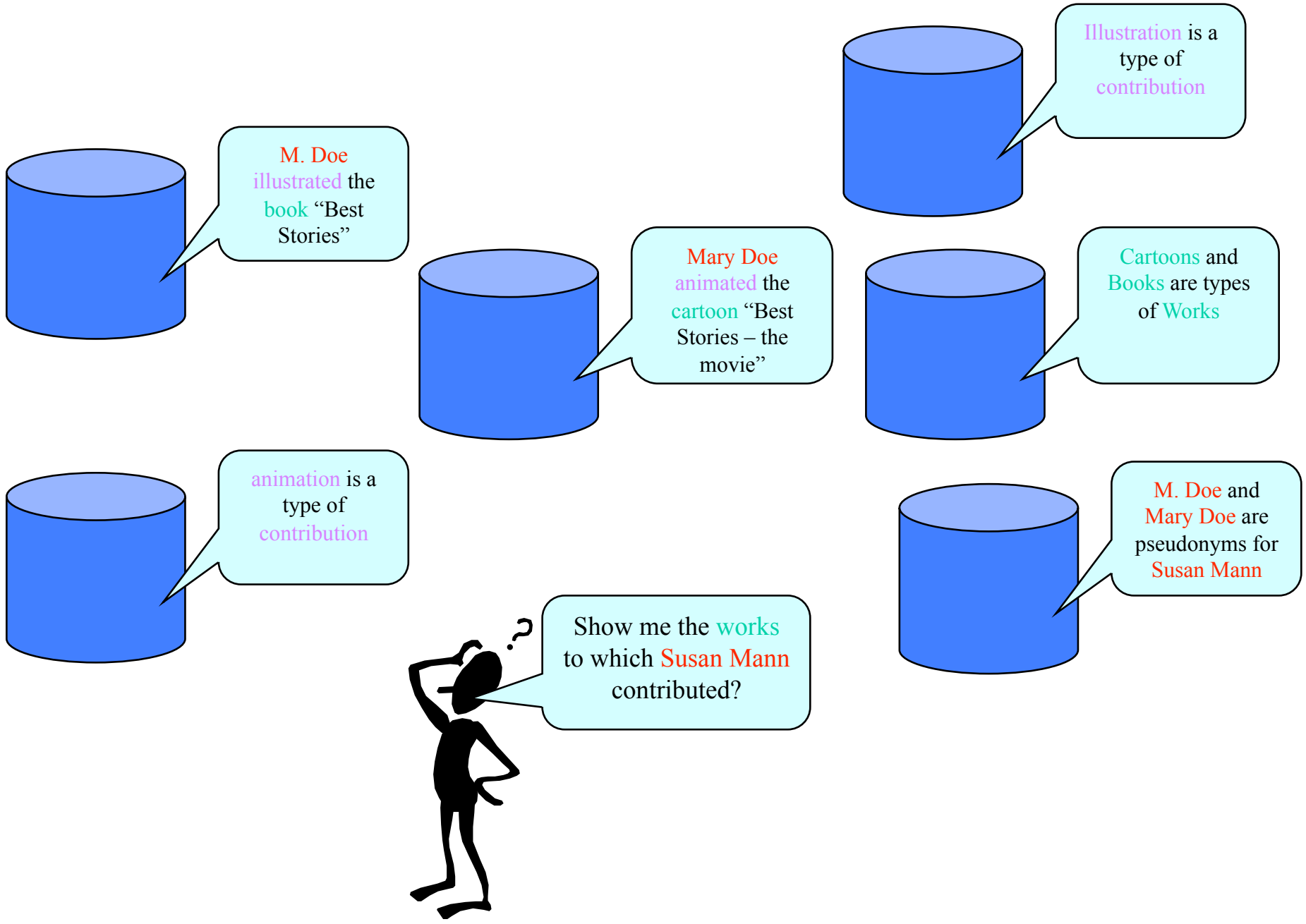


XML and Syndication (RSS, Atom) are a big step forward



XMLs and namespaces help but not enough…

- Descendent of DTD's
  - Mostly a structuring language
  - Doesn't express "meaning" of structure
- Problems with knowledge representation
  - Poor expression of concepts, relationships, and subsumption (sub-classing)
  - No basis in formal logic, limited if any basis for reasoning
  - So, can't do:
    - Fact: Ford is a "kind of" car
    - Fact: VW is a "kind of" car
    - Fact: Joe "has a" Ford
    - Fact: Sue "has a" VW
    - Infer: Joe and Sue both have cars


M. Doe illustrated the book “Best Stories”
Illustration is a type of contribution
Mary Doe animated the cartoon “Best Stories – the movie”
Cartoons and Books are types of Works
animation is a type of contribution
M. Doe and Mary Doe are pseudonyms for Susan Mann
Show me the works to which Susan Mann contributed?

The Semantic Web is a web of data. There is lots of data we all use every day, and its not part of the web. I can see my bank statements on the web, and my photographs, and I can see my appointments in a calendar. But can I see my photos in a calendar to see what I was doing when I took them? Can I see bank statement lines in a calendar?

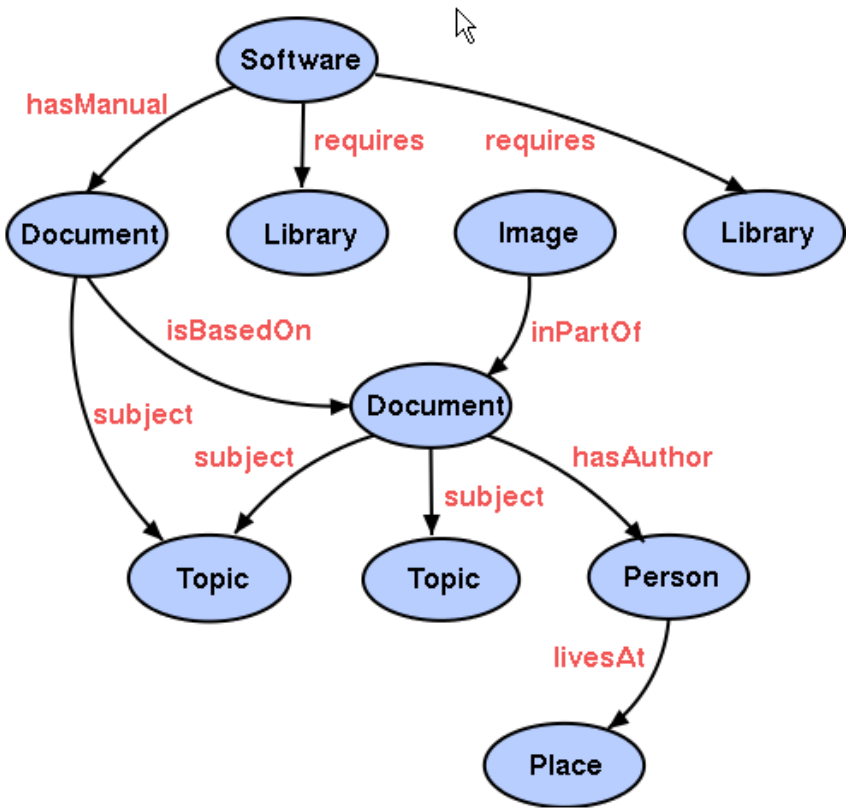
Why not? Because we don't have a web of data. Because data is controlled by applications, and each application keeps it to itself.

The Semantic Web is about two things. It is about common formats for integration and combination of data drawn from diverse sources, where on the original Web mainly concentrated on the interchange of documents. It is also about language for recording how the data relates to real world objects. That allows a person, or a machine, to start off in one database, and then move through an unending set of databases which are connected not by wires but by being about the same thing.

http://www.w3.org/2001/sw/

Semantic Web

- Resources typed, types defined by URIs
- Relationships typed, types defined by URIs
- Types are structured and are first-class
- Machines can inference



Scientific American, May 2001:

PHOTO CREDIT HERE

Beware of the Hype

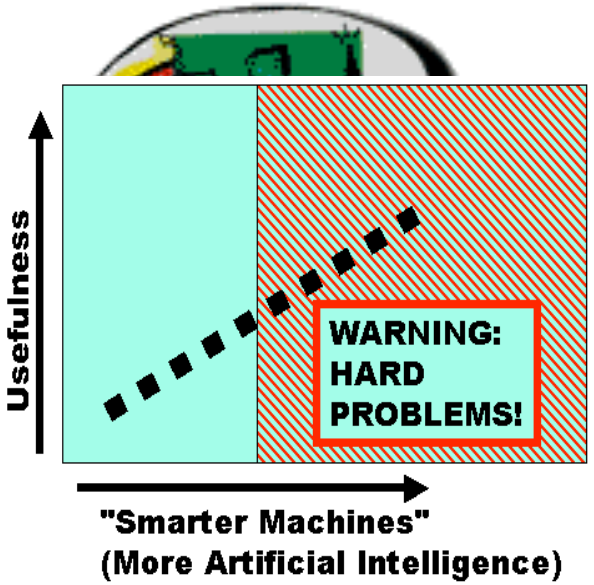
THE SEMANTIC WEB

A new form of Web content
that is meaningful to computers
will unleash a revolution of new abilities

by
TIM BERNERS-LEE,
JAMES HENDLER and
ORA LASSILA

Beware of the Hype

- Hype seems to suggest that Semantic Web means: "semantics + web = AI"
  - "A new form of Web content that is meaningful to computers will unleash a revolution of new abilities"
- More realistic to think of it as meaning: "semantics + web + AI = more useful webs"



Images from Christine Thompson and David Booth

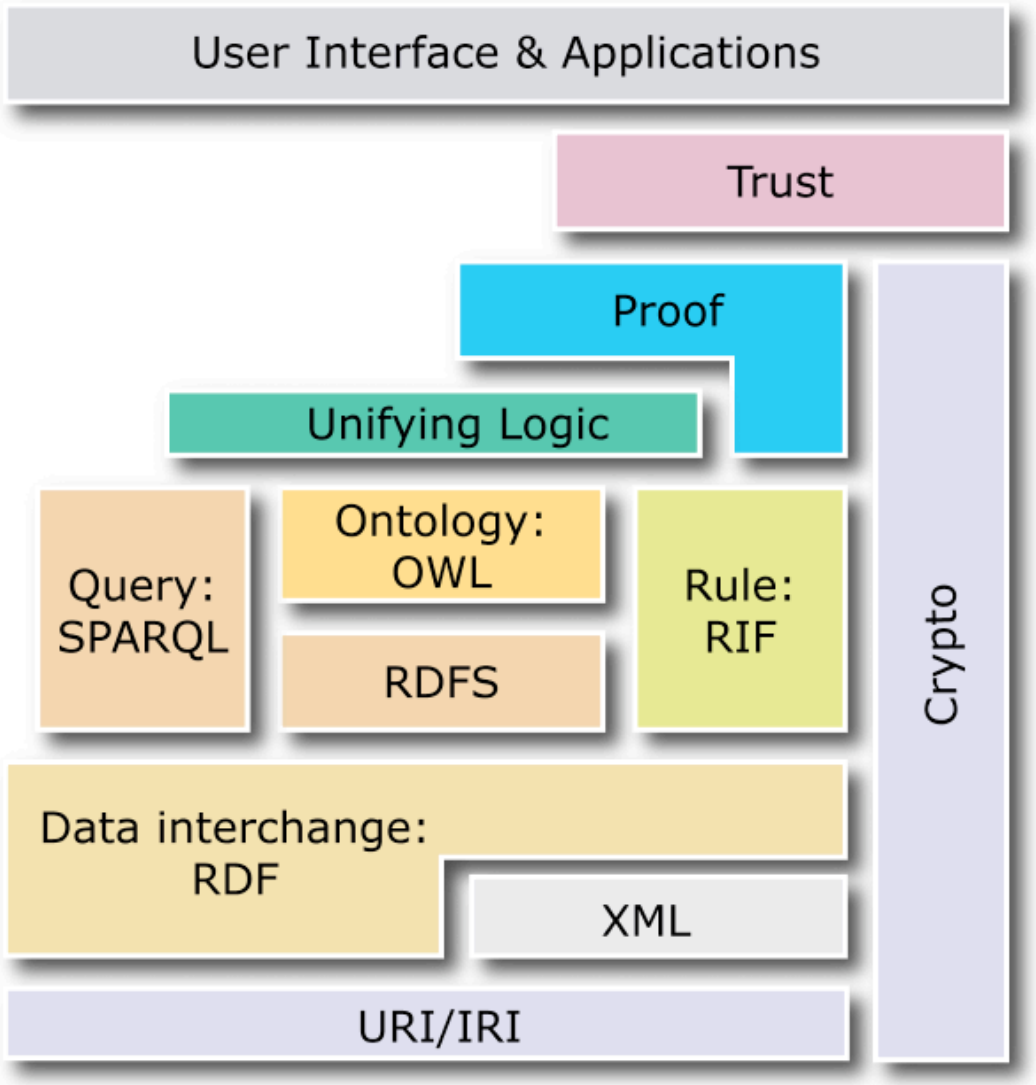
Some comments on the reality of the semantic web

- Lots of the hype seems to imply that the "whole web" will become a semantic web
- But too much implies that this will happen through "better metadata"
  - By whom!
- Keyword "whole web" search engines keep getting remarkably better and will continue to dominate
- But…
  - High recall, low precision
  - Results sensitive to vocabulary
  - Result granularity is single web page

But…

- In constrained domains (b2b, enterprise search, scholarship) better information management, knowledge representation makes sense
- Notions like ontologies are very useful and important
- There is lots of room for automated learning techniques to be applied to the problem
- Some of the tools are very useful right now and being used in large scale:
  - Network analysis
  - eScholarship
  - Project 2

Semantic Web "Layer Cake"

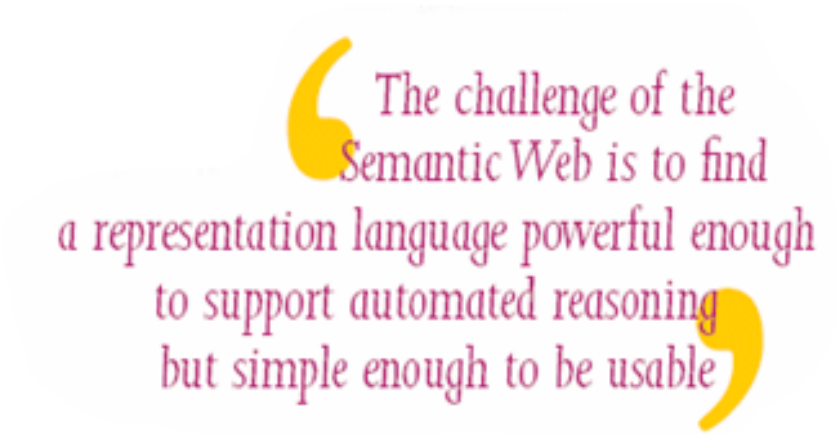


Knowledge Representation

- Objects/Instances/Individuals
  - Elements of the domain of discourse
  - Equivalent to constants in FOL
- Types/Classes/Concepts
  - Sets of objects sharing certain characteristics
  - Equivalent to unary predicates in FOL
- Relations/Properties/Roles
  - Sets of pairs (tuples) of objects
  - Equivalent to binary predicates in FOL

- Such languages are/can be:
  - Well understood
  - Formally specified
  - (Relatively) easy to use
  - Amenable to machine processing

There has been lots of work on Knowledge Representation but…



"All tractable languages are useless;
all useful languages are intractable"

Challenges of Web to KR

- Scale
- Distributed
- Dynamic
- Paradoxes
- Incomplete language
  - Closed world vs. open world assumptions

Modeling & Encoding Knowledge: RDF

- RDF (Resource Description Framework)
- Provides enabling technology for richly-structured information
  - Support for and integration of multiple independent vocabularies
- Rich data model supporting notions of distinct entities and properties
  - Formal model with basis in logic
- Expressible in machine readable manner (e.g., XML)

RDF Components

- Formal data model
- Syntax for interchange of data
- Schema Type system (schema model)
- Syntax for machine-understandable schemas
- Query and profile protocols

- Ontologies layered on top via extensions to base RDF language (OWL)

RDF Data Model

- Provides underlying structural foundation for the expression of application (instance) data models
  - for consistent encoding, exchange and processing of information
  - Provides for a basis for interoperability
- Individual communities can then define and express semantics on the basic model
- Model is distinct from the syntax for expressing it
  - XML
  - N3
  - triple notation
  - relational databases (triple-stores in tables)

RDF Data Model

- Binary Relationships
  - **Triples**
  - <subject> <predicate> <object>
    - Carl livesIn Ithaca
    - Ithaca hasWeather Terrible

RDF Data Model

- URIs for subjects, predicates, and objects allows joins
- Joins produce directed labeled graphs
- Graphs allow deductive inferences

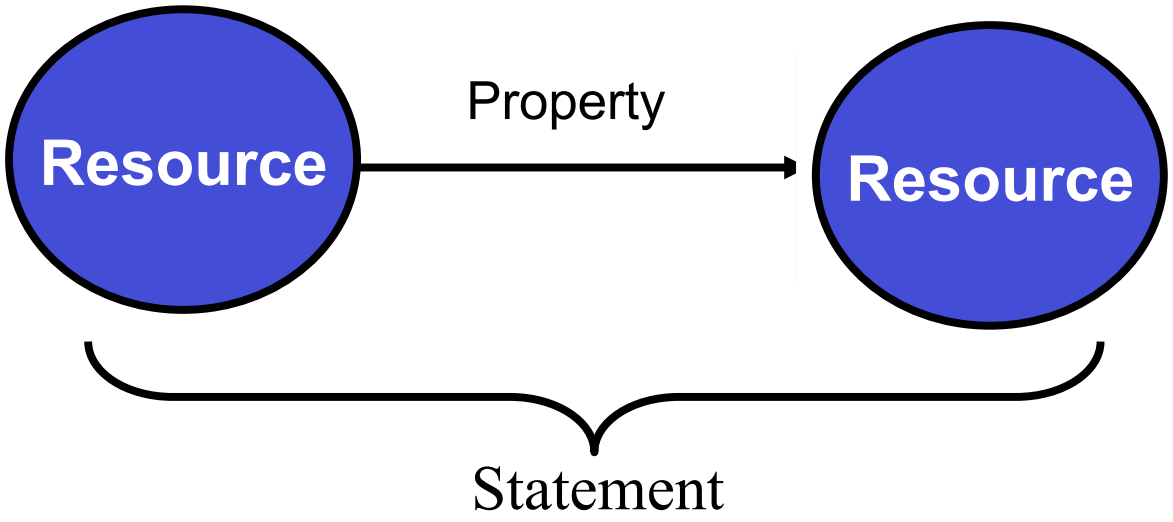
RDF Model Elements

- Resource
- Property
- Value
- Statement
- Containers

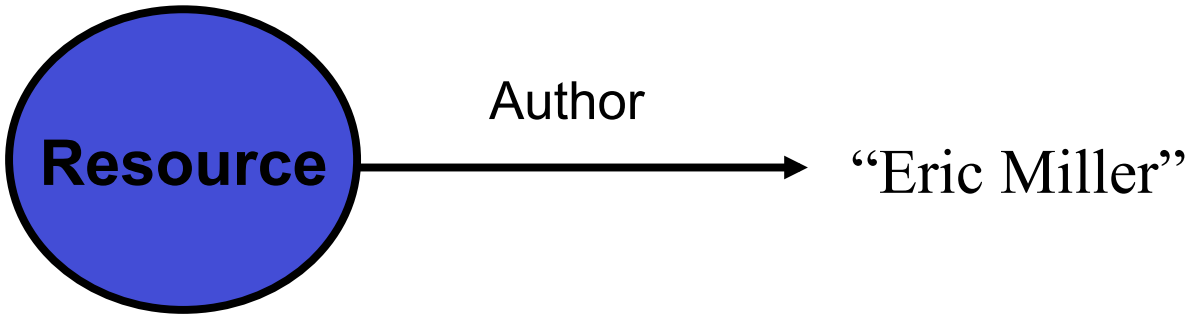
Isaviz – RDF authoring tool

- http://www.w3.org/2001/11/IsaViz/

RDF Model Primitives



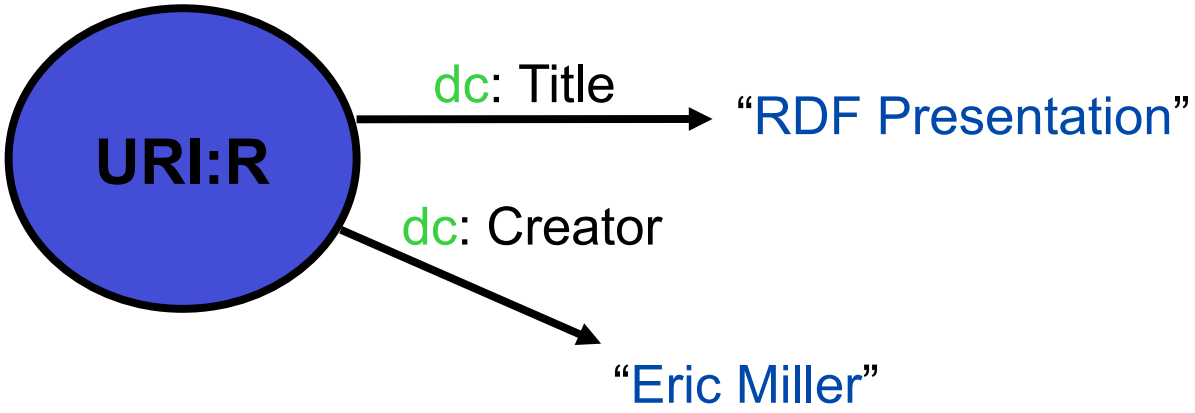
Simple Example



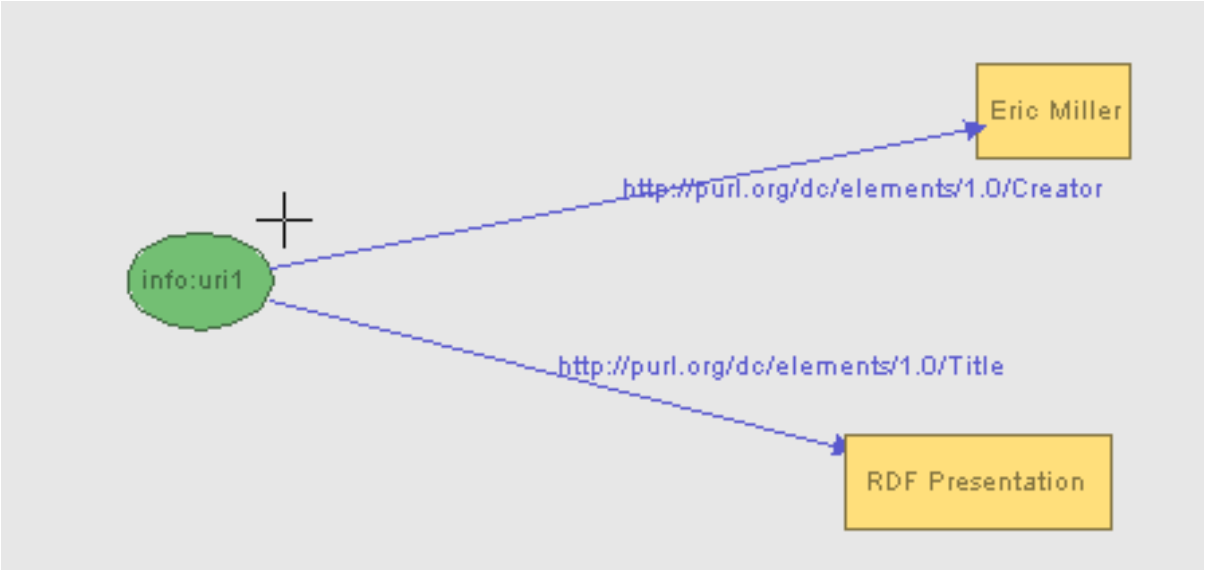
RDF Syntax

- RDF Model defines a formal relationships among resources, properties and values
- Syntax is required to...
  - Store instances of the model into files
  - Communicate files from one application to another
- XML is one well-supported syntax, N3 is another

RDF Model Example #1



RDF Syntax Example #1



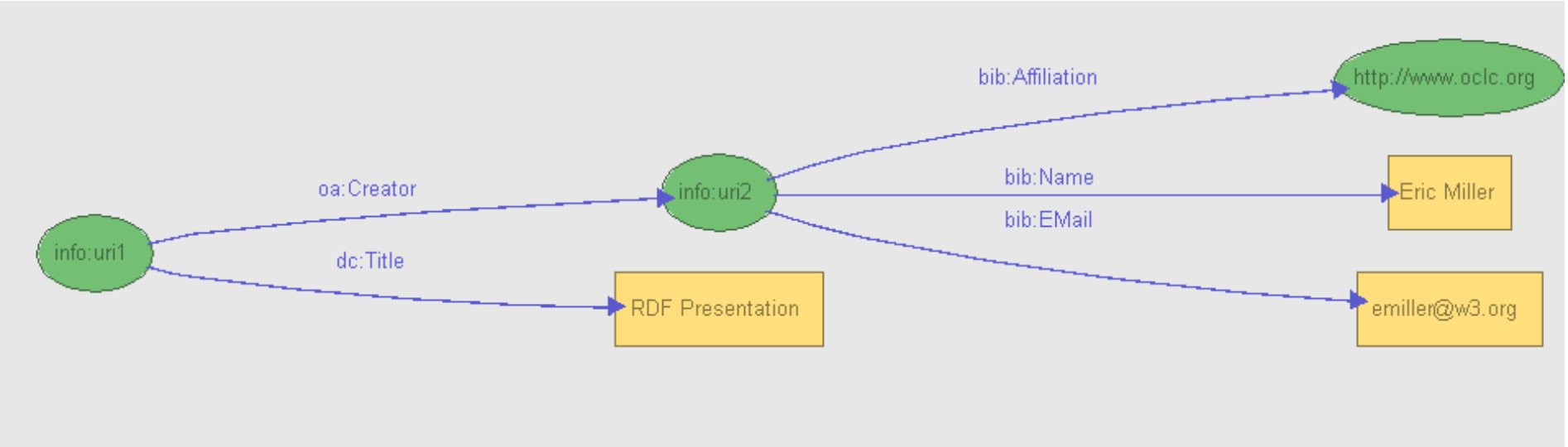

```
<?xml version="1.0"?>
<rdf:RDF xmlns:gss="http://www.w3.org/2001/11/IsaViz/graphstylesheets#"
 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:xsd="http://www.w3.org/2001/XMLSchema#" xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
 xmlns:dc="http://purl.org/dc/elements/1.0/">
 <rdf:Description rdf:about="info:uri1">
  <dc:Title>RDF Presentation</dc:Title>
  <dc:Creator>Eric Miller</dc:Creator>
 </rdf:Description>
</rdf:RDF>
```

N3 Syntax – Example #1

```
@prefix :        <#> .

<info:uri1>
      <http://purl.org/dc/elements/1.0/Creator>
               "Eric Miller" ;
      <http://purl.org/dc/elements/1.0/Title>
               "RDF Presentation" .
```

RDF Model Example #2



RDF/XML Syntax Example #2

```
<?xml version="1.0"?>
<rdf:RDF xmlns:gss="http://www.w3.org/2001/11/IsaViz/graphstylesheets#"
 xmlns:oa="http://agents.org/elements#" xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:xsd="http://www.w3.org/2001/XMLSchema#" xmlns:bib="http://www.bib.org/persons#"
 xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#" xmlns:dc="http://purl.org/dc/elements/1.0/"
 xml:base="file:/C:/IsaViz/tmp/tmp41406.rdf">
 <rdf:Description rdf:about="info:uri2">
  <bib:Affiliation rdf:resource="http://www.oclc.org"/>
  <bib:EMail>emiller@w3.org</bib:EMail>
  <bib:Name>Eric Miller</bib:Name>
 </rdf:Description>
 <rdf:Description rdf:about="info:uri1">
  <oa:Creator rdf:resource="info:uri2"/>
  <dc:Title>RDF Presentation</dc:Title>
 </rdf:Description>
</rdf:RDF>
```

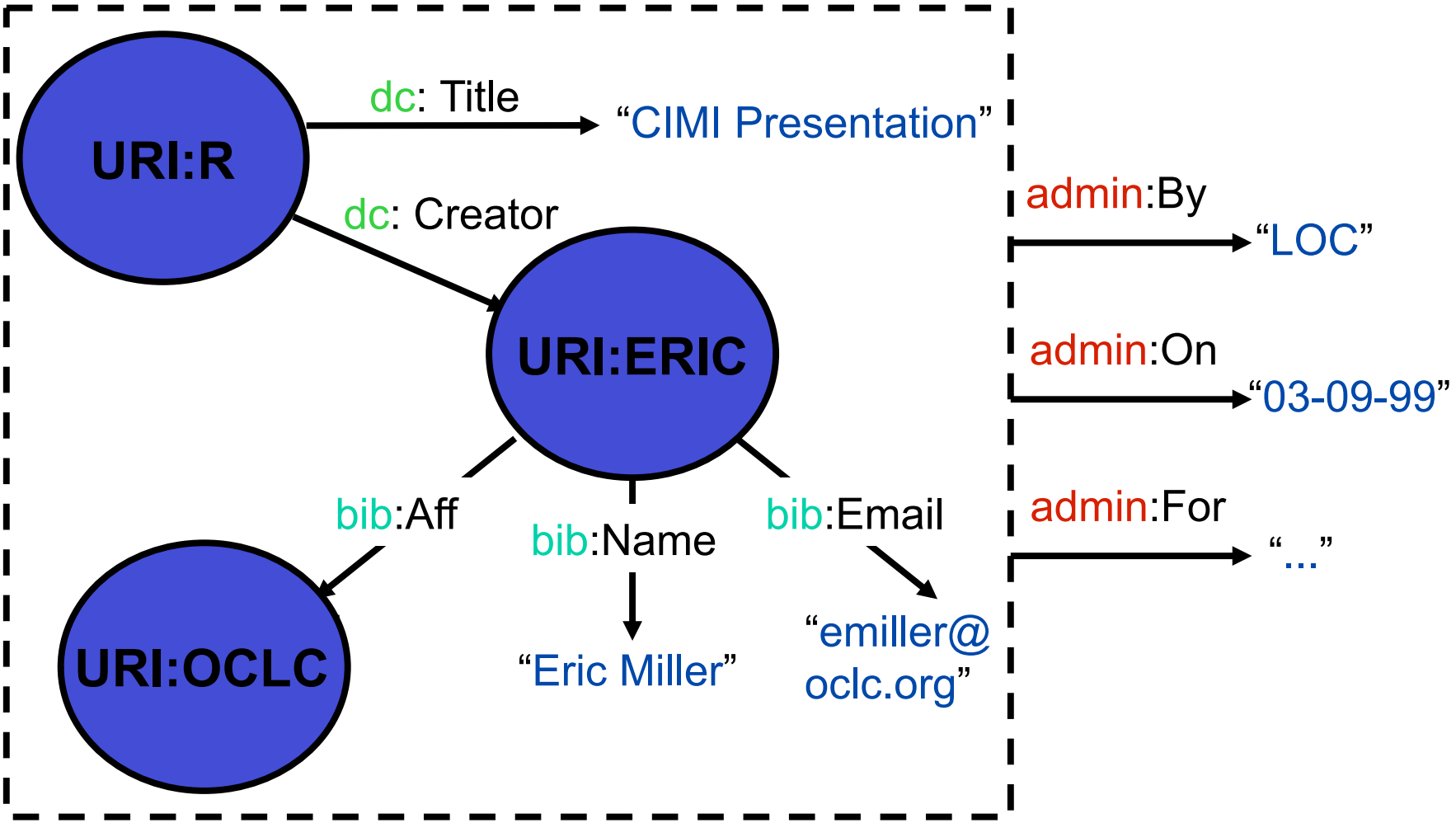
N3 Syntax Example #2

```
@prefix oa: <http://agents.org/elements#> .
@prefix bib: <http://www.bib.org/persons#> .
@prefix dc: <http://purl.org/dc/elements/1.0/> .
@prefix :         <#> .

<info:uri2>
      <bib:Affiliation>
              <http://www.oclc.org> ;
      <bib:EMail>
              "emiller@w3.org" ;
      <bib:Name>
              "Eric Miller" .

<info:uri1>
      <oa:Creator>
              <info:uri2> ;
      <dc:Title>
              "RDF Presentation" .
```

RDF Model Example #3
Reification



RDF Containers

- Permit the aggregation of several values for a property
- Express multiple aggregation semantics
  - unordered
  - sequential or priority order
  - alternative

RDF Containers

- Bag
  - unordered grouping
- Sequence
  - ordered grouping
- Alternatives
  - alternate values
    - need to choose
  - at least one value
  - first value is default or preferred value

RDF - Bag

- Unordered group
- "Carl Lagoze and Stuart Weibel are co-authors"

```
<BIB:Author>
  <Bag>
    <li> Carl Lagoze </li>
    <li> Stuart Weibel </li>
</Bag>
</BIB:Author>
```

RDF - Sequence

- Ordered or priority group
- "Carl Lagoze is primary author and Stuart Weibel is second author"

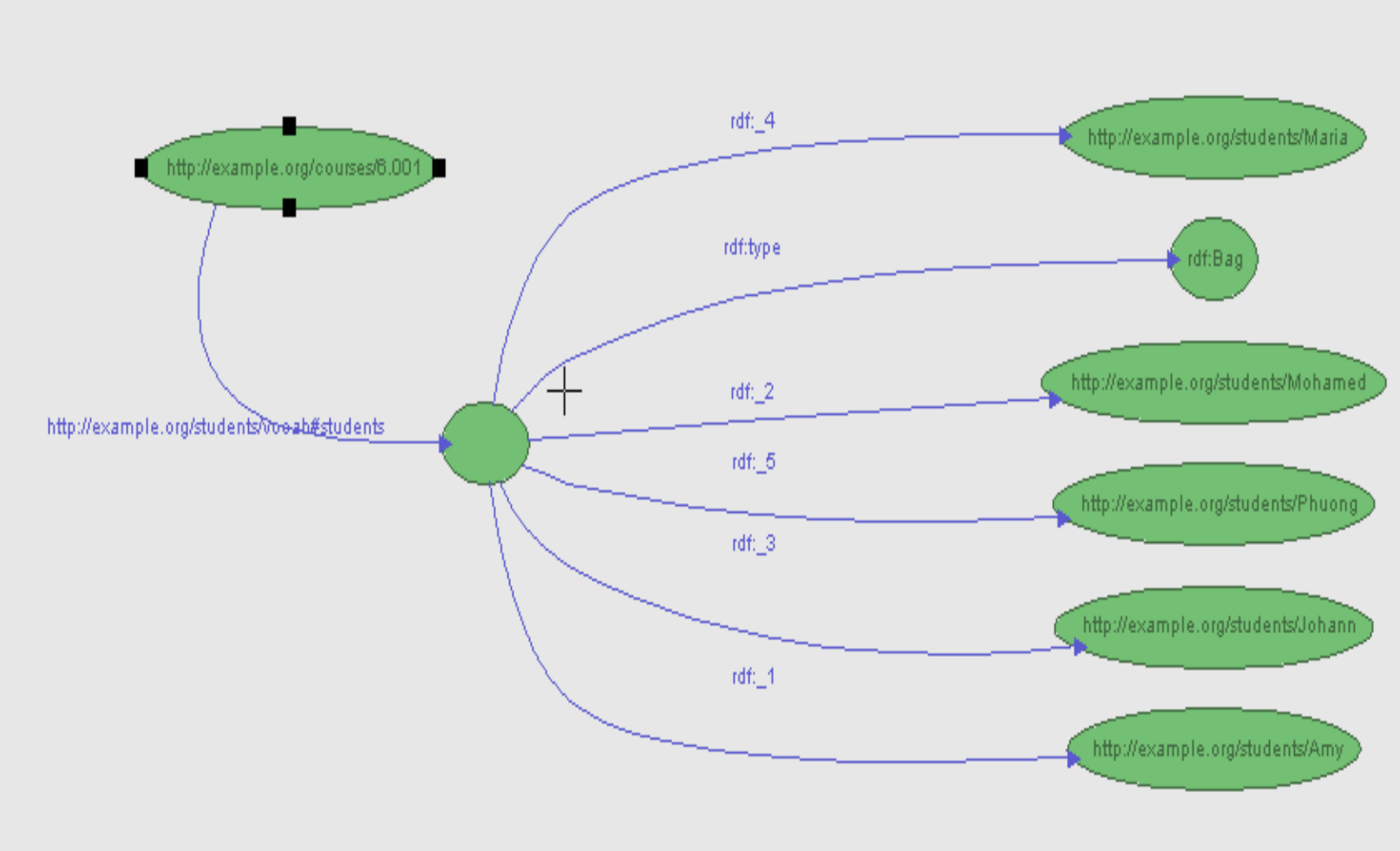
```
<BIB:Author>
 <Seq>
   <li> Carl Lagoze </li>
   <li> Stuart Weibel </li>
</Seq>
</BIB:Author>
```

RDF - Alt

- Client chooses one of several values
- First value is default
- "The distance is 15 kilometers or 9.3 miles"

```
<DC:Coverage>
  <Alt>
    <li> 15KM </li>
    <li> 9.3M </li>
</Alt>
</DC:Coverage>
```

Container Example



RDF/XML for Container

```
<?xml version="1.0"?>
<rdf:RDF xmlns:gss="http://www.w3.org/2001/11/IsaViz/graphstylesheets#"
 xmlns:j.0="http://example.org/students/vocab#" xmlns:oa="http://agents.org/elements#"
 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:xsd="http://www.w3.org/2001/XMLSchema#" xmlns:bib="http://www.bib.org/persons#"
 xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#" xmlns:s="http://example.org/packages/vocab#"
 xmlns:dc="http://purl.org/dc/elements/1.0/"
 xml:base="file:/C:/Documents and Settings/Carl Lagoze/Desktop/ex2rdf.n3">
  <rdf:Description rdf:about="http://example.org/courses/6.001">
    <j.0:students>
      <rdf:Bag>
        <rdf:li rdf:resource="http://example.org/students/Amy"/>
        <rdf:li rdf:resource="http://example.org/students/Mohamed"/>
        <rdf:li rdf:resource="http://example.org/students/Johann"/>
        <rdf:li rdf:resource="http://example.org/students/Maria"/>
        <rdf:li rdf:resource="http://example.org/students/Phuong"/>
      </rdf:Bag>
    </j.0:students>
  </rdf:Description>
</rdf:RDF>
```

N3 for Container

```
# Base: file:/C:/Documents and Settings/Carl Lagoze/Desktop/ex2rdf.n3
@prefix :        <#> .

<http://example.org/courses/6.001>
      <http://example.org/students/vocab#students>
               [ a       <http://www.w3.org/1999/02/22-rdf-syntax-ns#Bag> ;
                 <http://www.w3.org/1999/02/22-rdf-syntax-ns#_1>
                          <http://example.org/students/Amy> ;
                 <http://www.w3.org/1999/02/22-rdf-syntax-ns#_2>
                          <http://example.org/students/Mohamed> ;
                 <http://www.w3.org/1999/02/22-rdf-syntax-ns#_3>
                          <http://example.org/students/Johann> ;
                 <http://www.w3.org/1999/02/22-rdf-syntax-ns#_4>
                          <http://example.org/students/Maria> ;
                 <http://www.w3.org/1999/02/22-rdf-syntax-ns#_5>
                          <http://example.org/students/Phuong>
               ] .
```

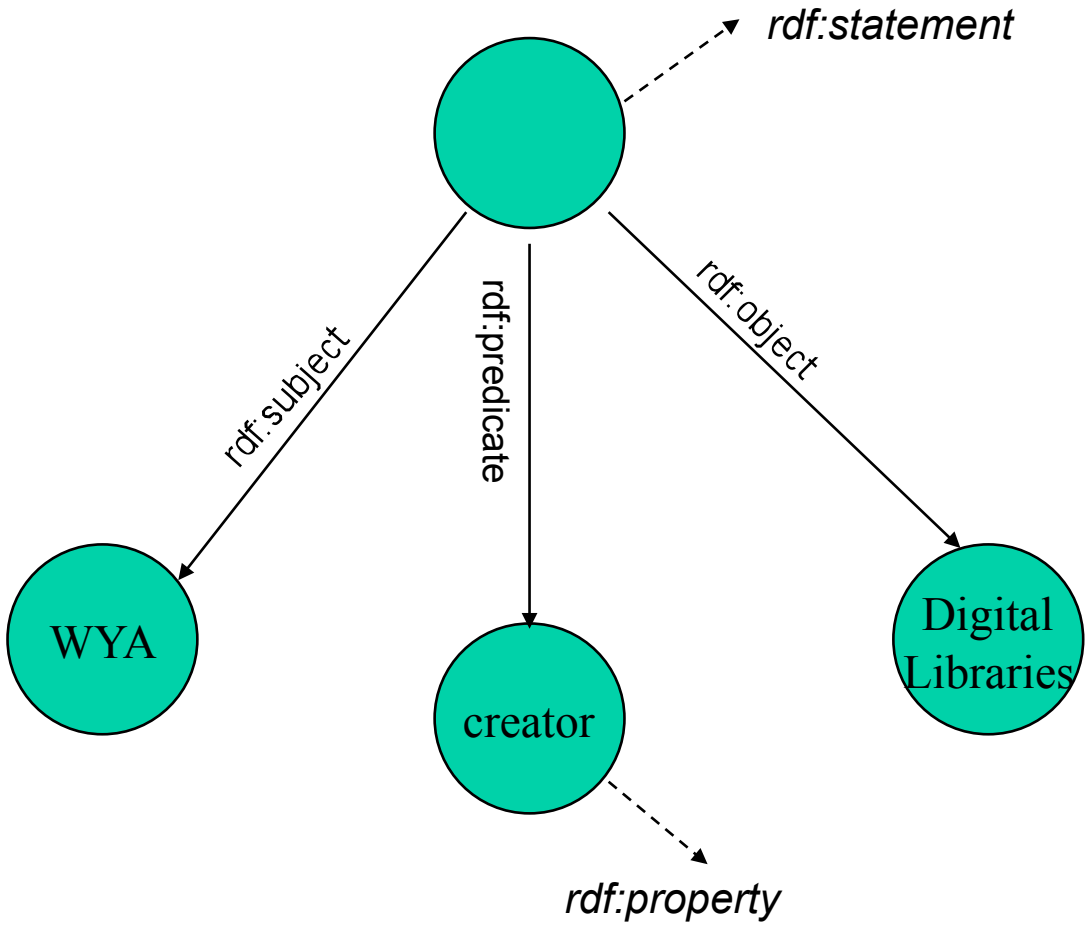
RDF meta-model

- RDF basic types
  - rdf:Resource – everything that can be identified (with a URI)
  - rdf:Property – specialization of a resource expressing a binary relation between two resources
  - Rdf:type – predefined property to express that subject of property is considered to be an **instance** of that category or class defined by the value of the property
  - rdf:statement – a triple with properties rdf:subject, rdf:predicate, rdf:object
- An RDF statement is a triple consisting of a resource (subject), a property and a second resource (object)
  - (:s :p :o)
- Expressible also as binary relations
  - P(S,O) – e.g., Title(R, "War & Peace")

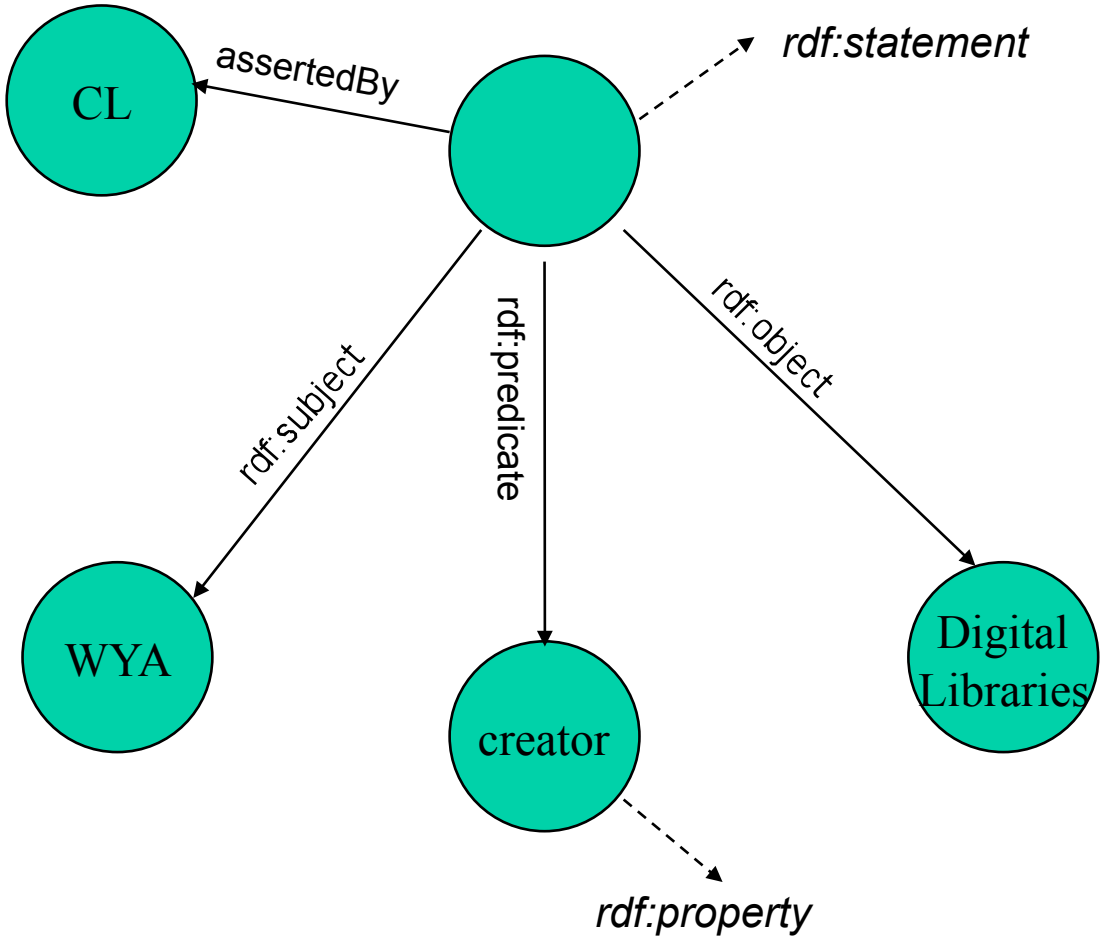
RDF triple model

explicit triple	Allows inference
(:s :p :o)	(:s rdf:type rdf:Resource) (:p rdf:type rdf:Property) (:o rdf:type rdf:Resource)

RDF statements and basic types



Reification – Statements about statements



"CL says 'WYA wrote Digital Libraries'"