An Introduction to the Semantic Web

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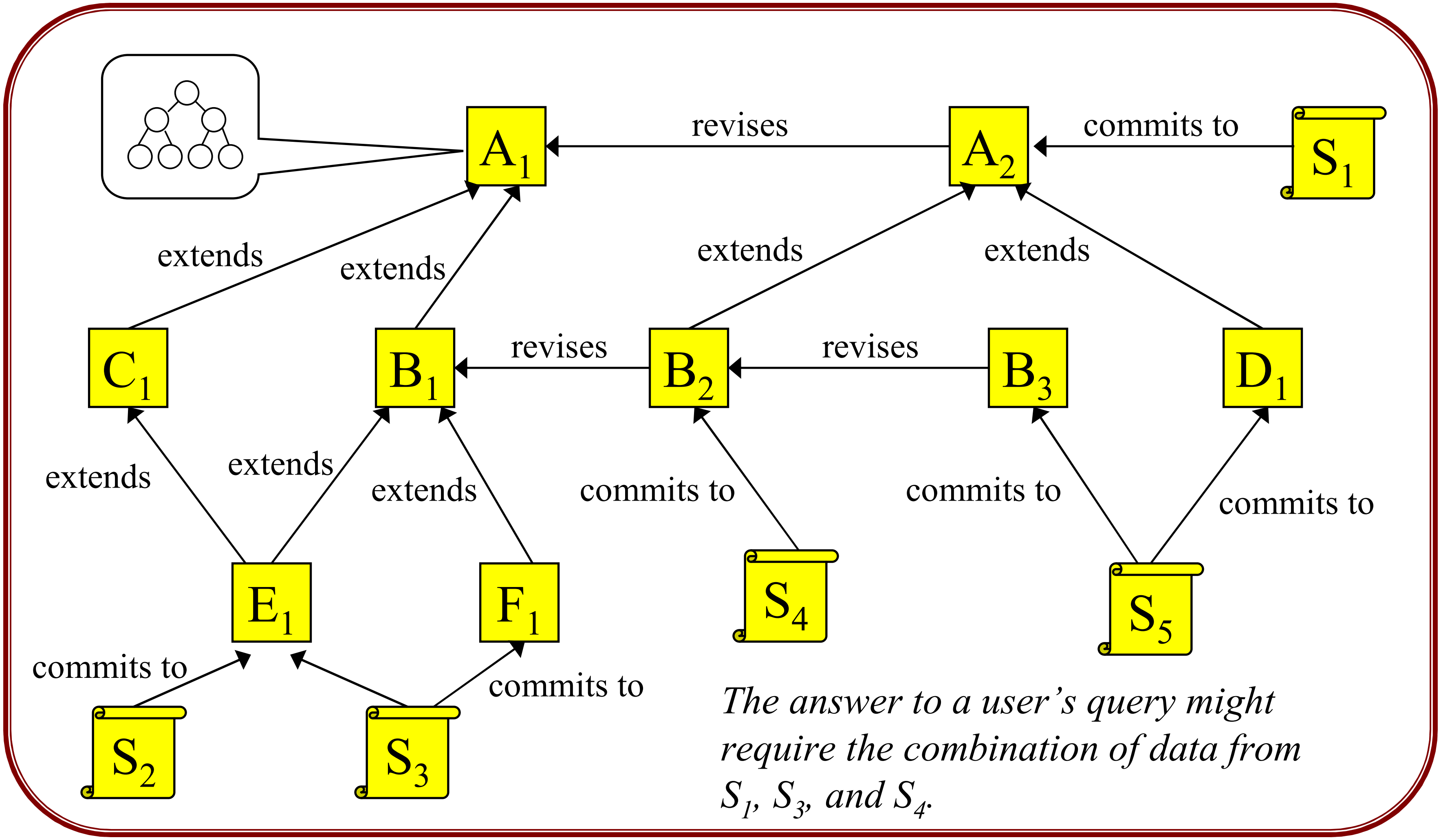
The Semantic Web

- Definition
  - The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation. (Berners-Lee et al., Scientific American, May 2001)
- Applications
  - managing corporate web sites (intranets)
  - more automatic generation of web portals
  - better indexing of multimedia resources
  - web agents and web services
  - ubiquitous computing

Ontology

- Definition
  - a logical theory that accounts for the intended meaning of a formal vocabulary (Guarino 98)
  - has a formal syntax and unambiguous semantics
  - inference algorithms can compute what logically follows
- Relevance to the Semantic Web:
  - ontologies define the semantics of the terms used in semi-structured web pages
  - identify context
  - provide shared definitions
  - ease the integration of distinct resources

A Web of Ontologies

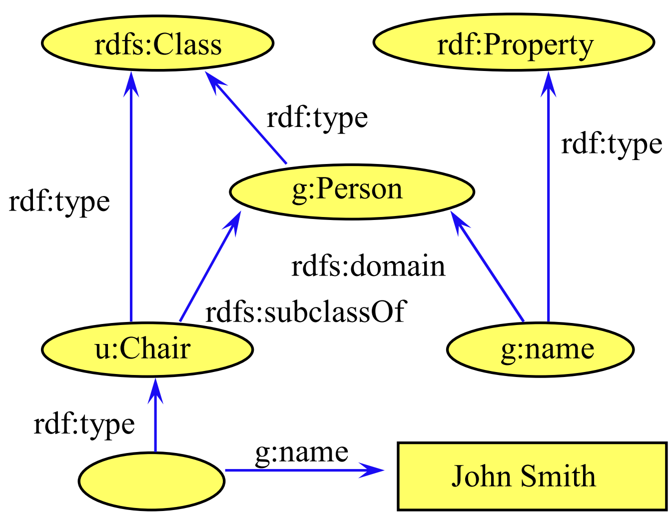


The answer to a user's query might require the combination of data from S_1, S_3, and S_4.

Semantic Web Standards

World Wide Web Consortium (W3C) Recommendations

- RDF(S) (1999, revised 2004)
  - essentially semantic networks with URIs
  - XML serialization syntax



- OWL (2004)
  - extends RDF with more semantic primitives
  - based on description logics (DLs)
  - has a model theoretic semantics

```
<owl:Class rdf:ID=”Band”>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource=”#hasMember” />
      <owl:allValuesFrom rdf:resource=”#Musician” />
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

A Band is a subset of the groups which only have Musicians as members

URIs and Namespaces

- URI
  - Uniform Resource Identifier
  - includes URLs
  - but also anything that you can design an identification scheme for
  - helps to prevent collision of names
  - all the “symbols” in RDF are either URIs or Literals
- Namespace
  - a mechanism for abbreviating URIs
  - by assigning a prefix for a URI fragment

Description Logic (DL)

- form of knowledge representation
  - useful for formally defining classes
  - studied extensively in 1990's
  - mature reasoning software
    - » e.g., FaCT, RACER, Pellet
- benefits
  - optimized computation of subsumption
    - » calculate implicit subClassOf relations
  - ontology integration
    - » if two ontologies use class expressions to define their vocabularies in terms of a third ontology, then subsumption can be used to compute an integrated ontology

OWL Class Constructors

Constructor	DL Syntax	Example
intersectionOf	$C_1 \sqcap \ldots \sqcap C_n$	Human $\sqcap$ Male
unionOf	$C_1 \sqcup \ldots \sqcup C_n$	Doctor $\sqcup$ Lawyer
complementOf	$\neg C$	$\neg$Male
oneOf	$\{x_1 \ldots x_n\}$	{john, mary}
allValuesFrom	$\forall P.C$	$\forall$hasChild.Doctor
someValuesFrom	$\exists P.C$	$\exists$hasChild.Lawyer
maxCardinality	$\leqslant n P$	$\leqslant$1hasChild
minCardinality	$\geqslant n P$	$\geqslant$2hasChild

borrowed from Ian Horrocks

OWL Axioms

Axiom	DL Syntax	Example
subClassOf	$C_1 \sqsubseteq C_2$	Human $\sqsubseteq$ Animal $\sqcap$ Biped
equivalentClass	$C_1 \equiv C_2$	Man $\equiv$ Human $\sqcap$ Male
disjointWith	$C_1 \sqsubseteq \neg C_2$	Male $\sqsubseteq \neg$Female
sameIndividualAs	$\{x_1\} \equiv \{x_2\}$	{President_Bush} $\equiv$ {G_W_Bush}
differentFrom	$\{x_1\} \sqsubseteq \neg\{x_2\}$	{john} $\sqsubseteq \neg${peter}
subPropertyOf	$P_1 \sqsubseteq P_2$	hasDaughter $\sqsubseteq$ hasChild
equivalentProperty	$P_1 \equiv P_2$	cost $\equiv$ price
inverseOf	$P_1 \equiv P_2^-$	hasChild $\equiv$ hasParent$^-$
transitiveProperty	$P^+ \sqsubseteq P$	ancestor$^+ \sqsubseteq$ ancestor
functionalProperty	$\top \sqsubseteq \leqslant 1 P$	$\top \sqsubseteq \leqslant 1$hasMother
inverseFunctionalProperty	$\top \sqsubseteq \leqslant 1 P^-$	$\top \sqsubseteq \leqslant 1$hasSSN$^-$

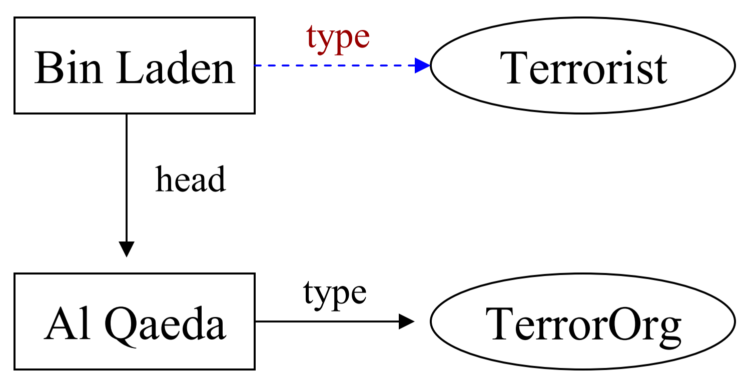
borrowed from Ian Horrocks

OWL Inference

```
<owl:Property rdf:about="&s;head">
  <rdfs:subPropertyOf
        rdfs:resource="&s;member" />
</owl:Property>

<owl:Class rdf:about="&t;Terrorist">
  <owl:sameClassAs>
     <owl:Restriction>
        <owl:onProperty
              rdf:resource="&s;member" />
        <owl:someValuesFrom
              rdf:resource="&s;TerroristOrg" />
     </owl:Restriction>
  </owl:sameClassAs>
</owl:Class>
```

- The head of an organization is also a member of it
- A member of a terror organization is a terrorist
- Therefore, the head of a terror organization is a terrorist



Is the Semantic Web a Fad?

- Analysts have estimated that 35-65% of system integration costs are due to **semantic** issues
- Companies that have invested in semantic solutions
  - Time Inc., BellSouth, Raytheon, Walt Disney Company, General Motors, Cisco Systems, Met Life, etc.
- Growth of the Semantic Web
  - 2005 → 350,000 RDF/OWL documents
  - Feb. 2006 → 1 million RDF/OWL documents
  - Nov. 2007 → 2.3 million RDF/OWL documents

For more information...

- For more on the Semantic Web
  - http://www.cse.lehigh.edu/~heflin/
  - http://www.semwebcentral.org/
  - http://www.w3.org/2001/sw/
  - http://www.daml.org/
  - http://www.semanticweb.org/