Semantic Integration of XML Using a RDF Global Mediator

Feihong Hsu

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Why Semantic Integration? (1)

- XML documents are scattered throughout the web—but there is a lot of heterogeneity in terms of their schemas!
- We want to use the information contained within them, but we don't have the time to translate each and every document to "our" format.

Why Semantic Integration? (2)

- We would like to be able to take advantage of common data among documents.
- We would like to be able to ask higher-level queries.

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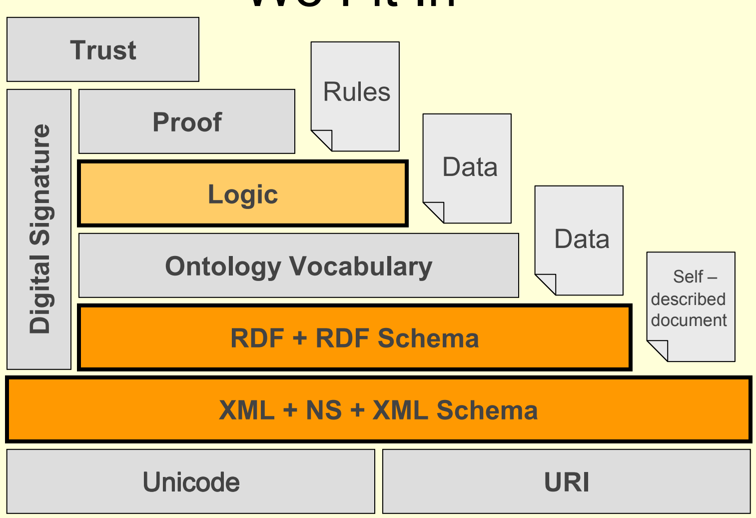
The Semantic Web Stack – Where We Fit In



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Key Problems in Semantic Integration

- Schematic Heterogeneity
- Semantic Heterogeneity
- Semantic Relationships
- Object Identity

Schematic Heterogeneity

<actors>	<films>
<actor name=”B. del Toro”>	<film title=”21 Grams”>
<films>	<actor name=”B. del Toro”/>
<film title=”21 Grams”/>	</film>
<film title=”Traffic”/>	<film title=”Traffic”>
</films>	<actor name=”B. del Toro”/>
</actor>	</film>
</actors>	</films>

Documents can contain the same element and attribute names but have different nested structures.

Semantic Heterogeneity (1)

```
<employees>
  <employee>
    <name first="Feihong"
             last="Hsu"/>
    <role>Janitor</role>
    <salary>90000</salary>
  </employee>
</employees>
```

```
<workers>
  <worker>
    <name>Feihong Hsu</name>
    <job>Janitor</job>
    <comp>90000</comp>
  </worker>
</workers>
```

Documents can have the same semantics but have different names for elements and attributes.

Semantic Heterogeneity (2)

```
<stars>
  <star name="Betelgeuse">
    <distance>425 light years
    </distance>
    <luminosity from="40000"
                to="100000"/>
  </star>
</stars>
```

```
<stars>
  <star name="Eva Gardner">
    <born>1922-12-24</born>
    <died>1990-01-25</died>
  </star>
</stars>
```

Documents can have the same names for elements and attributes but have different semantics.

Semantic Relationships (1)

```
<cars>
  <car model=”Miata MX-5”>
    <manuf>Mazda</manuf>
    <msrp>$22,388</msrp>
  </car>
</cars>
```

```
<trucks>
  <truck model=”Ram SR-10”>
    <manuf>Dodge</manuf>
    <msrp>$45,000</msrp>
  <truck>
</trucks>
```

What if you wanted to do a search for information involving Automobiles (a hypernym of Car and Truck)?

Semantic Relationships (2)

```
<cars>
  <car model=”Miata MX-5”>
    <manuf>Mazda</manuf>
    <doors>2</doors>
  </car>
  <car model=”EuroVan MV”>
    <manuf>VW</manufact>
    <doors>4</doors>
  </car>
</cars>
```

What if you wanted to do a search for Coupes?

(Coupe is a hyponym of Car—it’s a Car that has only 2 doors.)

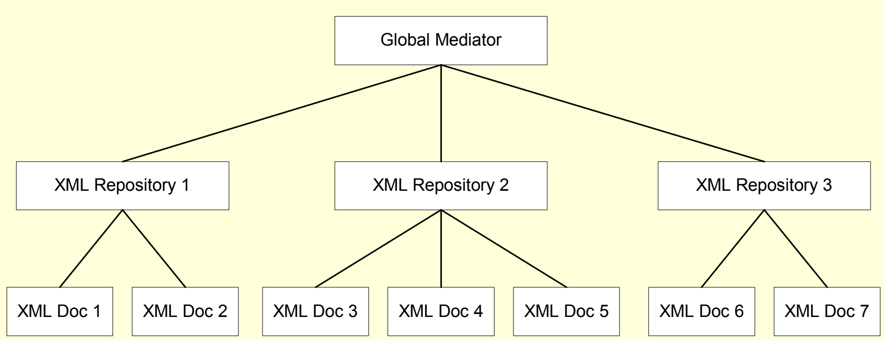
Object Identity

<employees>
  <employee>
    <name>B. Banner</name>
    <dept>Physics</dept>
    <salary>40000</salary>
  </employee>
</employees>

<scientists>
  <scientist>
    <name>B. Banner</name>
    <area>Physics</area>
    <degree>PhD</degree>
  </scientist>
</scientists>

How do we figure out that the two XML snippets describe the same person?

Architecture of the Semantic Integration Framework (1)



Architecture of the Semantic Integration Framework (2)

Layers:

- RDF Global Mediator – provides view of the data as a conceptual model
- XML Repository – provides view of homogeneous documents as a single document
- XML Local Data Source – provides the actual information

RDF Global Mediator

- Simulates an RDF repository
- Accepts RDQL queries, and returns RDQL result tables
- Provides a global ontology in the form of RDF Schema
- Keeps track of mappings between the global ontology and the local schema through mapping structures

Mapping Structures

- Owned by the RDF Global Mediator
- Bridge the gap between the global ontology (RDFS) and the local schemas (XMLS)
- Not a separate layer because they are static data structures
- Currently have to be constructed by hand

XML Repository

- Simulates a single, monolithic XML document
- Accepts XQuery expressions
- Returns DOM trees
- Handles distributed XQuery processing
- Provides a schema for its local data sources

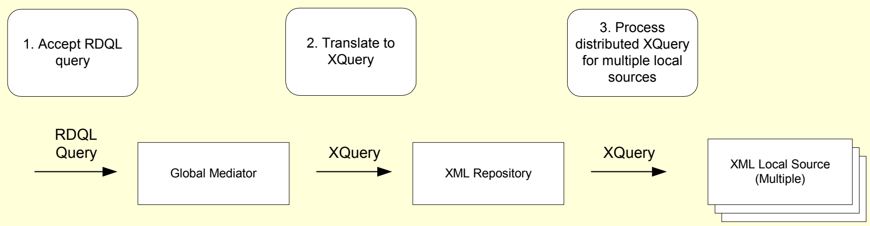
XML Local Data Source

- Does not simulate anything; it's the source of the data
- Can run XQuery expressions on it
- Results of XQuery (DOM tree) sent back to XML Repository
- Conforms to the schema of its XML Repository

Semantic Integration Process

- Query Translation:
  RDQL → XQuery → Distributed XQuery
- Result Transformation:
  DOM Tree → Merged DOM tree → RDQL Result Table + RDF Model

Query Translation



Anatomy of an RDQL Query

Clauses:

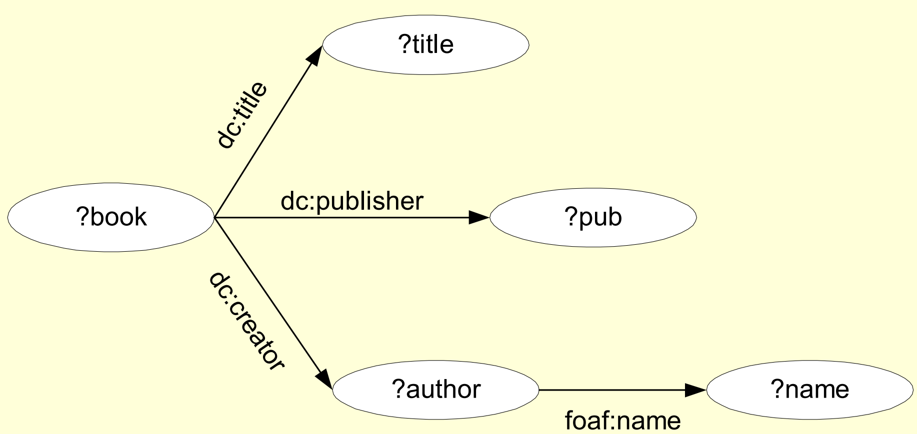
- SELECT – list of variables for output
- WHERE – RDF subgraph constraints
- AND – boolean expression constraints
- USING – namespace prefixes

A sample RDQL Query

```
SELECT ?title, ?pub
WHERE (?book dc:title ?title),
      (?book dc:creator ?author),
      (?book dc:publisher ?pub)
      (?author foaf:name ?name)
AND   ?name eq "Neil Gaiman"
USING dc AS <http://purl.org/dc/elements/1.1/>,

      foaf AS <http://xmlns.cm/foaf/0.1/>
```


Graph of WHERE clause



Anatomy of an XQuery Expression

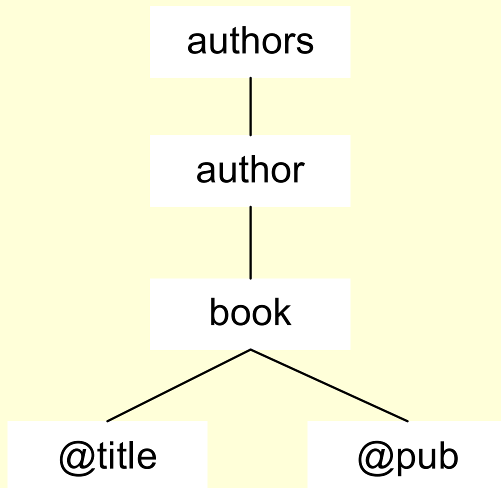
Clauses:

- let – bind variables
- for – bind variables, iterate over nodes
- where – boolean expression constraints
- return – list of variables to output

A Sample XQuery Expression

```
let $authors := doc("authors.xml")/authors
for $author in $authors, $name in $author/@name
  for $book in $author/book
    for $title in $book/@title,
        $pub in $book/@publisher
where $name = "Neil Gaiman"
return ($title, $pub)
```

Tree of For Clauses



Mapping of Clauses

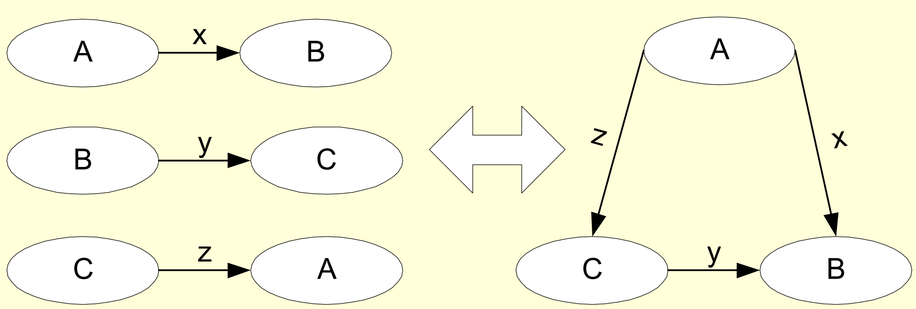
Conceptually, the algorithm can proceed by mapping an RDQL clause with its equivalent XQuery clause(s):

- SELECT → return
- WHERE → for (multiple)
- AND → where
- USING → [none]

Mapping the WHERE Clause to For Clauses

- Need to map a graph to a tree
- Can break down an RDF graph into triples
- Can break down an XML tree into path expressions
- Map triples to path expressions using a pattern-matching technique!

Break RDF Graph into Triples

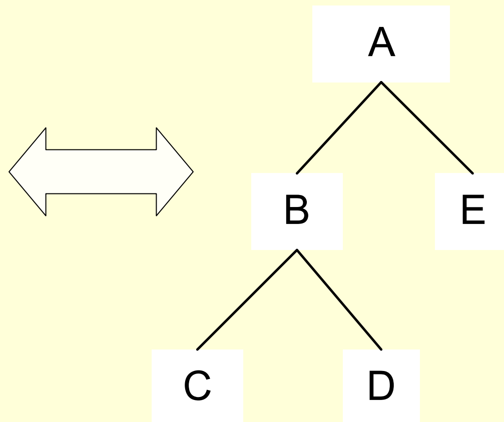


Break XML Tree into Path Expressions

A/B/C

A/B/D

A/E



Pattern Matching with the Mapping Structure

- We want to map triples to path expressions
- But we must respect the class hierarchy and the property hierarchy
- Therefore, do sub-triple matching

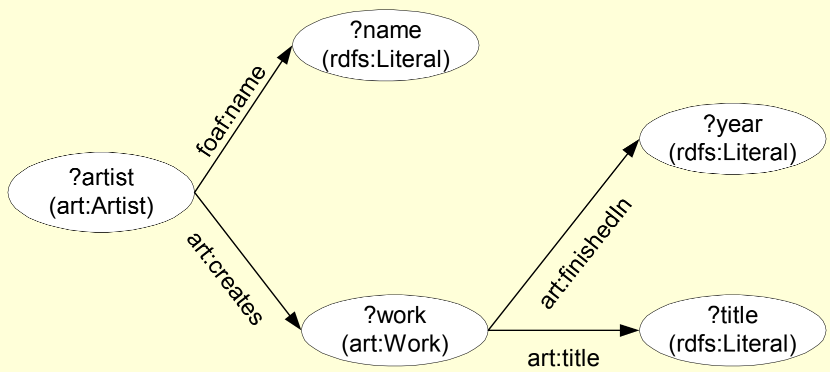
What Is a Sub-Triple?

- A sub-triple is a specialization of another triple.
- So (A, b, C) is a sub-triple of (X, y, Z) iff
  - A is subclass of X
  - b is subproperty of y
  - C is subclass of Z
- Example: (Painter, paints, Painting) is a subclass of (Artist, creates, Work).

Pattern Matching Example (1)

```
SELECT ?name, ?title, ?year
WHERE (?artist foaf:name ?name),
      (?artist art:creates ?work),
      (?work art:finishedIn ?year),
      (?work art:title ?title)
USING art AS <http://example.org/art/>
      foaf AS <http://xmlns.com/foaf/0.1/>
```

Pattern Matching Example (2)

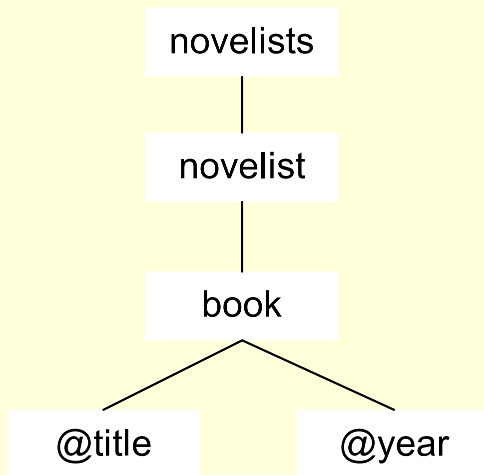


Perform type resolution using the global ontology (in RDF Schema)

Pattern Matching Example (3)

art:Novelist, art:writes, art:Book	/novelists/novelist/book
art:Novelist, foaf:name, rdfs:Literal	/novelists/novelist/@name
art:Book, art:title, rdfs:Literal	/novelists/novelist/book/@title
art:Book, art:finishedIn, rdfs:Literal	/novelists/novelist/book/@year

Pattern Matching Example (4)



Pattern Matching Example (5)

```
let $novelists := doc("novelists.xml")/novelists
for $novelist in $novelists/novelist,
    $name in $novelist/@name
  for $book in $novelist/book,
      $title in $book/@title,
      $year in $book/@year
  return ($name, $title, $year)
```

Result Transformation

- XQuery produces DOM trees
- XML repository merges DOM trees from each local source
- Merged DOM tree is converted to RDF graph
- RDF graph from each XML repository is added to the result RDF graph

Converting DOM Tree to RDF Model

- We can reuse the Mapping Structure
- Map path expressions to RDF triples
- Based on same principles as query translation

Advantages (1)

- Layered architecture provides modularization, separation of concerns
- Query translation is fast
- Takes advantage of high-level query languages

Advantages (2)

- Provides end-to-end solution
- Extensible, more layers can be added on top
- Uses currently-available languages and tools

Disadvantages

- Result transformation is slow
- Cannot deal with semantic relationships that are not length-one paths
- Mapping structure limits the types of schemas that can be handled

Related Work (1)

- Camillo, Heuser, & Mello:
  - Global ontology uses ER variant
  - CXPath to XPath
  - Mapping views
- Amann, Beeri, Fundulaki, & Scholl:
  - Global ontology is generic ontology model
  - OQL to XQuery
  - Mapping rules

Related Work (2)

- Lakshmanan & Sadri:
  - Global ontology is generic ontology model
  - XQuery to XQuery
  - Mapping catalog
- Patel-Schneider & Siméon:
  - Global ontology is RDF Schema
  - XQuery to XQuery
  - Mapping rules

Future Work

- Complete the implementation that deals with conversion of XML data to RDF
- Use a tree regular expression structure for the mapping structure instead of a table
- Add the OWL layer on top of the current framework

What the OWL Layer Would Give Us

- OWL has more ways to express axioms, such as disjoint, union, etc.
- OWL properties can be symmetric, transitive, functional, etc.
- OWL has the sameIndividualAs property, which gives us a means to make statements about object identity

What Is It Good For? Potential Applications

- Publishing Framework
- Sensor Network
- Software Agents
- Multimedia Integration