Chapter 3

RDF

Introduction

- Problem: What does an XML document mean?
  - XML is about data structures
  - Their meaning (semantics) is not apparent to a machine
- RDF is more a data model than a language
  - Is realized in many different formats
- RDF define basic semantics
  - RDFS and OWL define more RDF vocabulary for building rich data models
- RDF remains domain independent

Example

```
<academicStaffMember> Grigoris Antoniou
</academicStaffMember>
<professor> Michael Maher </professor>
<course name="Discrete Mathematics">
  <isTaughtBy> David Billington </isTaughtBy>
</course>
```

- What does this mean?
  - Are professors also academic staff members?
  - If someone teaches a course, are they an academic staff member?
- Can't say in XML, but can say so in RDFS

Example

```
<course name="Discrete Mathematics">
   <lecturer>David Billington</lecturer>
</course>
<lecturer name="David Billington">
   <teaches>Discrete Mathematics</teaches>
</lecturer>
<teachingOffering>
    <lecturer>David Billington</lecturer>
    <course>Discrete Mathematics</course>
</teachingOffering>
```

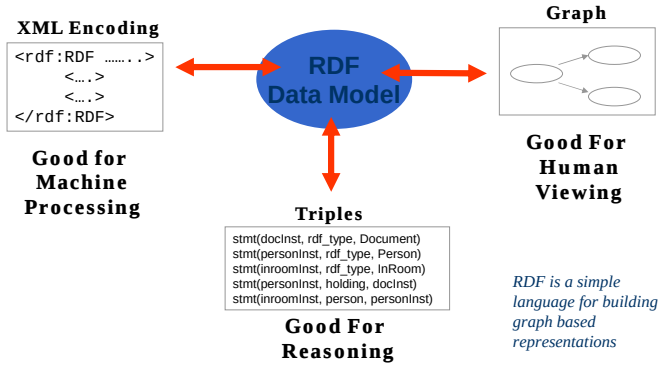
- Embedding of elements is just a syntactic constraint
- No meaning is defined
- It's in the documentation or the mind of the viewer
- Does the machine have a mind?

Key Documents

All at http://www.w3.org/RDF/

- RDF/XML Syntax Specification (Revised)
  Dave Beckett, ed.
- RDF Vocabulary Description Language 1.0: RDF Schema
  Dan Brickley, R.V. Guha, eds.
- RDF Primer
  Frank Manola, Eric Miller, eds.
- Resource Description Framework (RDF): Concepts and Abstract Syntax
  Graham Klyne, Jeremy Carroll, eds.
- RDF Semantics
  Patrick Hayes, ed.
- RDF Test Cases
  Jan Grant, Dave Beckett, eds.

RDF is the first SW language



The RDF Data Model

- An RDF document is an unordered collection of statements, each with a **subject**, **predicate** and **object** (aka **triples**)
- A triple can be thought of as a labelled arc in a graph
- Statements describe properties of web **resources**
- A resource is any object that can be pointed to by a **URI**:
  - a document, a picture, a paragraph on the Web, …
  - E.g., http://umbc.edu/~finin/cv.html
  - a book in the library, a real person (?)
  - isbn://5031-4444-3333
  - …

- Properties themselves are also resources (URIs)

RDF Building Blocks

- Resources
  - Things we can talk about, URIs
- Properties
  - Special things that represent binary relations
- Literal data
  - Strings, integers, dates, … xmldatatypes
- Statements, aka triples
  - Subject Predicate Object or
  - Subject Property Value

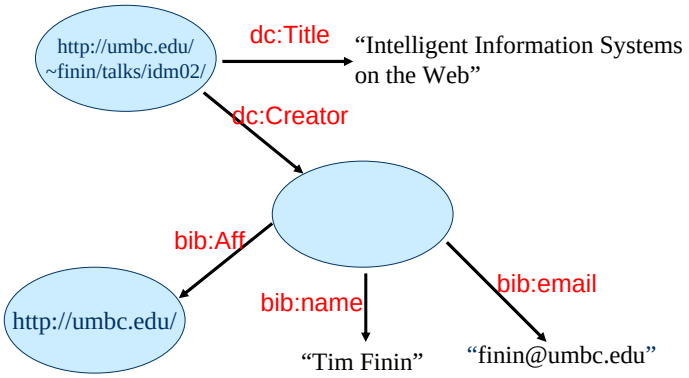
URIs are a foundation

- URI = **Uniform Resource Identifier**
  - "The generic set of all names/addresses that are short strings that refer to resources"
  - URLs (Uniform Resource Locators) are a subset of URIs, used for resources that can be *accessed* on the web
- URIs look like "normal" URLs, often with fragment identifiers to point to a document part:
  - http://foo.com/bar/mumble.html#pitch
- URIs are unambiguous, unlike natural language terms
  - the web provides a global **namespace**
  - We assume references to the same URI are to the same thing

What does a URI mean?

- Sometimes URIs denote a web resource
  - http://umbc.edu/~finin/finin.jpg denotes a file
  - We can use RDF to make assertions about the resource, e.g., it's an image and depicts a person with name Tim Finin, …
- Sometimes concepts in the external world
  - E.g., http://umbc.edu/ denotes a particular University located in Baltimore
  - This is done by social convention
- Cool URIs don't change
  - http://www.w3.org/Provider/Style/URI

Simple RDF Example



RDF Data Model is a Graph

- Graphs only allow binary relations
- Higher arity relations must be "reified" (i.e., turned into objects)
- Represent give(John,Mary,Book32) as three binary relations all involving a common object, giveEvent32
  - giver(giveEvent45 , John)
  - recipient(giveEvent45 , Mary)
  - gift(giveEvent45 , Book32)
- When using RDF, this has to be part of your vocabulary design
- This is a price we have to pay for using a simple representation

RDF Statements

- RDF has one predefined scheme (syntax and semantics) for the reification of RDF statements themselves
- Needed to support assertions about triples
  - Document32 asserts *"John gave Mary a book"*
  - Tom believes *John gave Mary a book*
  - *"John gave Mary a Book" has 0.33 probability*

XML encoding for RDF

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:dc="http://purl.org/dc/elements/1.1/"
   xmlns:bib="http://daml.umbc.edu/ontologies/bib/">
<description about="http://umbc.edu/~finin/talks/idm02/">
  <dc:title>Intelligent Information Systems on the Web </dc:Title>
  <dc:creator>
    <description >
      <bib:name>Tim Finin</bib:Name>
      <bib:email>finin@umbc.edu</bib:Email>
      <bib:aff resource="http://umbc.edu/" />
    </description>
  </dc:creator>
</description>
</rdf:RDF>
```

XML encoding for RDF

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:dc="http://purl.org/dc/elements/1.1/"
   xmlns:bib="http://daml.umbc.edu/ontologies/bib/">
<description about="http://umbc.edu/~finin/talks/idm02/">
  <dc:title>Intelligent Information Systems on the Web </dc:Title>
  <dc:creator>
    <description >
      <bib:name>Tim Finin</bib:Name>
      <bib:email>finin@umbc.edu</bib:Email>
      <bib:aff resource="http://umbc.edu/" />
    </description>
  </dc:creator>
</description>
</rdf:RDF>
```

Note that the document is a single RDF element which has attributes defining several namespaces.

- One for the rdf vocabulary
- One for the dublin core
- One for the bib vocabulary

XML encoding for RDF

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:dc="http://purl.org/dc/elements/1.1/"
   xmlns:bib="http://daml.umbc.edu/ontologies/bib/">
<description about="http://umbc.edu/~finin/talks/idm02/">
  <dc:title>Intelligent Information Systems on the Web </dc:Title>
  <dc:creator>
    <description >
      <bib:name>Tim Finin</bib:Name>
      <bib:email>finin@umbc.edu</bib:Email>
      <bib:aff resource="http://umbc.edu/" />
    </description>
  </dc:creator>
</description>
</rdf:RDF>
```

- Here's the general way to introduce a "named subject" about which we want to assert some properties and values.
- We name subjects by referring to their URI.
- An element in the description tag specify a property and its value

Descriptions

- Every description makes a statement about a resource
- There are different ways:
  - an about attribute: referencing to an existing resource
    <rdf:description rdf:about="http…"> …
  - an id attribute: creating a new resource
    <rdf:description ID="foo3456"> …
  - without a name: creating an anonymous resource
    <rdf:description> …

XML encoding for RDF

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:dc="http://purl.org/dc/elements/1.1/"
   xmlns:bib="http://daml.umbc.edu/ontologies/bib/"
   xmlns:xsd="http://www.w3.org/2001/XMLSchema#" >
<description about="http://umbc.edu/~finin/talks/idm02/">
  <dc:title>Intelligent Information Systems on the Web </dc:Title>
  <dc:creator>
    <description >
      <bib:name>Tim Finin</bib:Na
      <bib:email>finin@um
      <bib:aff resource="ht
    </description>
  </dc:creator>
</description>
</rdf:RDF>
```

- dc:title is the property (or predicate)
- It's value is the literal string "dc:title>Intelligent Information Systems on the Web"
- By default we assume the datatype is string
  - <ex:age rdf:datatype="&xsd;integer> 22 </ex:age>
  - <ex:age> "27"^^xsd:integer> 22 </ex:age>

XML encoding for RDF

```
<rdf:RDF xmlns:rdf="
   xmlns:dc="http://pu
   xmlns:bib="http://d
   xmlns:xsd="http://ww
<description about=
  <dc:title>Intellige
  <dc:creator>
    <description >
      <bib:name>Tim Finin</bib:Name>
      <bib:email>finin@umbc.edu</bib:Email>
      <bib:aff resource="http://umbc.edu/" />
    </description>
  </dc:creator>
</description>
</rdf:RDF>
```

- The value of creator is defined by the nested RDF
- The nameless description produces a "blank node"
- In this case, "a thing with a name="Tim Finin" and …"
- This style of XML encoding is called "striped"

```
<thing>
  <property>
    <thing>
      <property>
```

XML encoding for RDF

```
<rdf:RDF xmlns:rdf="
   xmlns:dc="http://pu
   xmlns:bib="http://d
   xmlns:xsd="http://ww
<description about="
  <dc:title>Intelligent
  <dc:creator>
    <description >
      <bib:name>Tim Finin</b      me>
      <bib:email>finin@umbc.edu</bib:Email>
      <bib:aff resource="http://umbc.edu/" />
    </description>
  </dc:creator>
</description>
</rdf:RDF>
```

- Note the "self closing" tag
- The value of the bib:aff property is a resource, not a string
- Every resource has a URI, every URI refers to a resource
- How would this be interpreted?
  <bib:aff> http://umbc.edu/ </bib:aff>

N triple representation

- RDF can be encoded as a set of **triples**.
  <subject> <predicate> <object> .

<http://umbc.edu/~finin/talks/idm02/> <http://purl.org/dc/elements/1.1/Title>
"Intelligent Information Systems on the Web" .
_:j10949 <http://daml.umbc.edu/ontologies/bib/Name> "Tim Finin" .
_:j10949 <http://daml.umbc.edu/ontologies/bib/Email> "finin@umbc.edu" .
_:j10949 <http://daml.umbc.edu/ontologies/bib/Aff> <http://umbc.edu/> .
_:j10949 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type><Description> .
<http://umbc.edu/~finin/talks/idm02/> <http://purl.org/dc/elements/1.1/Creator> _:j10949 .
<http://umbc.edu/~finin/talks/idm02/> <http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
<Description> .

Note the gensym for the anonymous node :j10949

Triple Notes

- **RDF triples have one of two forms:**
  - <URI> <URI> <URI>
  - <URI> <URI> <quoted string>
- **Triples are also easily mapped into logic**
  - <subject> <predicate> <object> becoming:
    - <predicate>(<subject>,<object>)
    - With type(<S>,<O>) becoming <O>(<S>)
  - Example:
    - subclass(man,person)
    - sex(man,male)
    - domain(sex,animal)
    - man(adam)
    - age(adam,100)

; Note: we're not
; showing the actual
; URIs for clarity

- **Triples are easily stored and managed in DBMS**
  - Flat nature of a triple a good match for relational DBs

N3 notation for RDF

- N3 is a compact notation for RDF that is easier for people to read, write and edit.
- Aka Notation 3, developed by TBL himself.
- Translators exist between N3 and the XML encoding, such as the web form on
  - http://www.w3.org/DesignIssues/Notation3.html
- So, it's just "syntactic sugar"
- But, XML is largely unreadable and even harder to write

N3 Example

@prefix rdf: http://www.w3.org/1999/02/22-rdf-syntax-ns# .
@prefix dc: http://purl.org/dc/elements/1.1/ .
@prefix bib: http://daml.umbc.edu/ontologies/bib/ .

< http://umbc.edu/~finin/talks/idm02/ >
dc:title "Intelligent Information Systems on the Web" ;
dc:creator
[bib:Name "Tim Finin" ;
bib:Email finin@umbc.edu ;
bib:Aff: "http://umbc.edu/"] .

Note special […] syntax for an anonymous node

thing
$prop_1$ = value ;
$prop_2$ = value ;
…
$prop_n$ = value .

RDF types

```
<rdf:Description rdf:about="CIT1111">
   <rdf:type rdf:resource="&uni;Course"/>
   <uni:courseName>Discrete Mathematics</uni:courseName>
   <uni:isTaughtBy rdf:resource="949318"/>
</rdf:Description>
<rdf:Description rdf:about="949318">
   <rdf:type rdf:resource="&uni;Lecturer"/>
   <uni:name>David Billington</uni:name>
   <uni:title>Associate Professor</uni:title>
</rdf:Description>
```

- RDF has a trivial type system
- RDFS and OWL extend it greatly

RDF types – Syntax

```
<uni:Course ID="CIT1111">
   <uni:courseName>Discrete Mathematics</uni:courseName>
   <uni:isTaughtBy rdf:resource="949318"/>
</uni:Course>

<uni:Lecturer ID="949318">
   <uni:name>David Billington</uni:name>
   <uni:title>Associate Professor</uni:title>
</uni:Lecturer>
```

- This abbreviated syntax is very common

RDF Container Elements

- rdf:Bag
  - unordered
  - may contain multiple occurrences
- rdf:Seq
  - ordered
  - may contain multiple occurrences
- rdf:Alt
  - a set of alternatives
- Content of container elements are named rdf:_1, rdf:_2, ...
- Containers seem a bit messy in RDF, but are needed

RDF Container Example

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:uni="http://www.mydomain.org/#">

 <uni:lecturer rdf:about="949352" uni:name="Grigoris Antoniou" uni:title="Professor">

   <uni:coursesTaught>
      <rdf:Bag>
         <rdf:_1:rdf:resource="CIT1112"/>
         <rdf:_2:rdf:resource="CIT1113"/>
      </rdf:Bag>
   </uni:coursesTaught>
 </uni:lecturer>

 <uni:course rdf:about="CIT1111" uni:courseName="Discrete Mathematics">
   <uni:lecturer>
      <rdf:Alt>
         <rdf:_1:rdf:resource="949352"/>
         <rdf:_2:rdf:resource="949318"/>
      </rdf:Alt>
   </uni:lecturer>
 </uni:course>
</rdf:RDF>
```

Bags and Seqs are never full!

- RDF's semantics is "open world", so…
  - There is no possibility "to close" the container, to say: "these are **all** elements, there are no more"
  - RDF is a graph, so: there is no way to exclude the possibility that there is another graph somewhere that describes additional members
- Collections for groups with only the specified members are described via a predefined collection vocabulary of the types:
  - rdf:List, rdf:first, rdf:rest, rdf:nil

RDF Lists

CIT 2112 is exclusively taught by teachers 949111, 949352, 949381

```
<rdf:Description rdf:about="CIT2112">
 <uni:isTaughtBy>
  <rdf:List>
   <rdf:first><rdf:Description rdf:about="949111"/></rdf:first>
   <rdf:rest>
    <rdf:List>
     <rdf:first><rdf:Description rdf:about="949352"/></rdf:first>
      <rdf:rest>
       <rdf:List>
        <rdf:first><rdf:Description rdf:about="949318"/></rdf:first>
        <rdf:rest><rdf:Description rdf:about="&rdf;nil"/></rdf:rest>
       </rdf:List>
      </rdf:rest>
     </rdf:List>
    </rdf:rest>
   </rdf:List>
  </uni:isTaughtBy>
</rdf:Description>
```

Yuck!

RDF Lists Syntactic Sugar

The the rdf:parseType attribute helps

```
<rdf:Description rdf:about="CIT2112">
   <uni:isTaughtBy rdf:parseType="Collection">
      <rdf:Description rdf:about="949111"/>
      <rdf:Description rdf:about="949352"/>
      <rdf:Description rdf:about="949318"/>
   </uni:isTaughtBy>
</rdf:Description>
```

Reification

The description

```
<rdf:Description rdf:about="949318">
  <uni:name>David Billington</uni:name>
</rdf:Description>
```

reifies to

```
<rdf:Statement rdf:about="StatementAbout949318">
  <rdf:subject rdf:resource="949318" />
  <rdf:predicate rdf:resource="&uni;name" />
  <rdf:object rdf:resource="David Billington" />
</rdf:Statement>
```

- The statement ID can be used to refer to it
- If more than one property elements is contained in a description element: they belong to more than one statement! In this case, these statements can be places in a bag, or can be reified separately

Conclusions

- RDF is a simple data model based on a graph
  - Independent on any serialization (e.g., XML or N3)
- RDF has a formal semantics providing a dependable basis for reasoning about the meaning of RDF expressions
- RDF has an extensible URI-based vocabulary
- RDF has an XML serialization and can use values represented as XML schema datatypes
- Anyone can make statements about any resource (open world assumption)
- RDFS and OWL build on RDF's foundation by adding vocabulary with well defined semantics (e.g., Class, subClass, etc.)