Chapter 3
RDF Syntax
RDF Overview

- RDF Syntax -- the XML encoding
- RDF Syntax – variations including N3
- RDF Schema (RDFS)
- Semantics of RDF and RDFS
  - Axiomatic Semantics
  - Operational semantics based on rules
- Querying RDF via RQL and SPARQL
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
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

- 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 RDF documents: standards

http://w3.org/standards/techs/rdf
### Key RDF documents: notes

http://w3.org/standards/techs/rdf

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>2012-10-09</td>
<td>Microdata to RDF</td>
<td>HTML microdata is an extension to HTML used to embed machine-readable data into HTML documents. Whereas the microdata specification describes a means of markup, the output format is JSON. This specification describes processing rules that may be used to extract RDF [RDF-CONCEPTS] from an HTML document containing microdata.</td>
</tr>
<tr>
<td>2012-07-05</td>
<td>RDF Interfaces</td>
<td>The RDF Interfaces Specification defines a set of standardized interfaces for working with RDF data in a programming environment.</td>
</tr>
<tr>
<td>2011-03-03</td>
<td>Describing Linked Datasets with the VoID Vocabulary</td>
<td>VoID is an RDF Schema vocabulary for expressing metadata about RDF datasets. It is intended as a bridge between the publishers and users of RDF data, with applications ranging from data discovery to cataloging and archiving of datasets. This document is a detailed guide to the VoID vocabulary. It describes how VoID can be used to express general metadata based on Dublin Core, access metadata, structural metadata, and links between datasets. It also provides deployment advice and discusses the discovery of VoID descriptions.</td>
</tr>
<tr>
<td>2006-03-14</td>
<td>XML Schema Datatypes in RDF and OWL</td>
<td>This document addresses three questions left unanswered by these Recommendations: Which URIref should be used to refer to a user defined datatype? Which values of which XML Schema simple types are the same? How to use the problematic xsd:duration in RDF and OWL? In addition, we further describe how to integrate OWL DL with user defined datatypes.</td>
</tr>
<tr>
<td>2003-10-10</td>
<td>LBase: Semantics for Languages of the Semantic Web</td>
<td>This document describes a mechanism for providing a precise semantics for the Semantic Web Languages (referred to as SWELs) from now on. The purpose of this is to define clearly the consequences and allowed inferences from constructs in these languages.</td>
</tr>
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</table>

### Drafts

Below are draft documents: Last Call Drafts, other Working Drafts. Some of these may become Web Standards through the W3C Recommendation Track process. Others may be published as Group Notes or become obsolete specifications.
### Key RDF documents: drafts

http://w3.org/standards/techs/rdf

#### Last Call Drafts

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<tr>
<td>2012-12-06</td>
<td><strong>Internationalization Tag Set (ITS) Version 2.0</strong></td>
<td>This document defines data categories and their implementation as a set of elements and attributes called the Internationalization Tag Set (ITS) 2.0. ITS 2.0 is the successor of ITS 1.0; it is designed to foster the creation of multilingual Web content, focusing on HTML5, XML based formats in general, and to leverage localization workflows based on the XML Localization Interchange File Format (XLIFF). In addition to HTML5 and XML, algorithms to convert ITS attributes to RDFa and NIF are provided.</td>
</tr>
<tr>
<td>2012-07-10</td>
<td><strong>Turtle</strong></td>
<td>The Resource Description Framework (RDF) is a general-purpose language for representing information in the Web.</td>
</tr>
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#### Other Working Drafts

<table>
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<tr>
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<tbody>
<tr>
<td>2013-01-15</td>
<td><strong>RDF 1.1 Concepts and Abstract Syntax</strong></td>
<td>This document is work in progress towards a revision of the RDF Concepts and Abstract Syntax Recommendation, and is intended to eventually replace that document. It is part of a larger effort to revise the RDF specifications as published in 2004. The most significant changes from the 2004 edition are: modified string literals, a section on skolemization of blank nodes, and many updated references to other specifications (including a change in terminology from &quot;URI references&quot; to &quot;IRIs&quot;). A fuller list of changes that have been made to date is provided in Appendix A. Various areas of work to be tackled in upcoming working drafts are highlighted throughout the document, but should not yet be understood as an exhaustive list.</td>
</tr>
<tr>
<td>2012-10-25</td>
<td><strong>Linked Data Platform 1.0</strong></td>
<td>A set of best practices and simple approach for a read-write Linked Data architecture, based on HTTP access to web resources that describe their state using RDF.</td>
</tr>
<tr>
<td>2012-07-12</td>
<td><strong>JSON-LD Syntax 1.0</strong></td>
<td>A common JSON representation format for expressing directed graphs; mixing both Linked Data and non-Linked Data in a single JSON document.</td>
</tr>
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</table>
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 referenced 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

- A graph defined by a collection of triples
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

http://umbc.edu/~finin/talks/idm02/

dc:Title

“Intelligent Information Systems on the Web”

dc:Creator

bib:Aff

“Tim Finin”

bib:name

bib:email

“finin@umbc.edu”

http://umbc.edu/
- Graphs only allow binary relations
- Higher arity relations must be “reified” (i.e., turned into objects)
- Represent \texttt{give(John,Mary,Book32)} as three binary relations all involving a common object, \texttt{giveEvent32}
  - giver(\texttt{giveEvent45 , John } )
  - recipient( \texttt{giveEvent45 , Mary } )
  - gift(\texttt{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 based on binary relations
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
<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/">
  <rdf:Description about="http://umbc.edu/~finin/talks/idm02/">
    <dc:title>Intelligent Information Systems on the Web </dc:Title>
    <dc:creator>
      <rdf:Description >
        <bib:name>Tim Finin</bib:Name>
        <bib:email>finin@umbc.edu</bib:Email>
        <bib:aff resource="http://umbc.edu/" />
      </rdf:Description>
    </dc:creator>
  </rdf: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/">
    <rdf:Description about="http://umbc.edu/~finin/talks/idm02/">
        <dc:title>Intelligent Information Systems on the Web</dc:Title>
        <dc:creator>
            <rdf:Description>
                <bib:name>Tim Finin</bib:name>
                <bib:email>finin@umbc.edu</bib:email>
                <bib:aff resource="http://umbc.edu/"
            </rdf:Description>
        </dc:creator>
    </rdf: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 vocabulary
- One for the Bib vocabulary
An empty prefix means that this is the default namespace for the document
• Any non-literal symbols without a prefix are in this namespace
• E.g., <Description>
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
Every description makes a statement about a resource

There are different ways:

- An *about* attribute: referencing an existing resource
  
  `<rdf:Description rdf:about="http..."> ...`

- An *id* attribute: creating a new resource
  
  `<rdf:Description rdf:ID="foo3456"> ...`

- Without a name: creating an *anonymous* resource
  
  `<rdf:Description> ...`
An element **rdf:Description** has
- an **rdf:about** attribute indicating that the resource has been “defined” elsewhere
- An **rdf:ID** attribute indicating that the resource is defined

Formally, there is no such thing as “defining” an object in one place and referring to it elsewhere
- Sometimes is useful (for human readability) to have a defining location, while other locations state “**additional**” properties

A Description with neither produces a “blank node”
- It cannot be referred to either from outside the rdf document
XML encoding for RDF

```xml
<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#">
  <rdf:Description about="http://umbc.edu/~finin/talks/idm02/">
    <dc:title>Intelligent Information Systems on the Web</dc:title>
    <dc:creator>
      <rdf:Description>
        <bib:name>Tim Finin</bib:name>
        <bib:email>finin@umbc.edu</bib:email>
        <bib:aff resource="http://umbc.edu/"/>
      </rdf:Description>
    </dc:creator>
  </rdf:Description>
</rdf:RDF>
```

- dc:title is the property (or predicate)
- Its value is the literal string “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>`
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”.

```xml
<thing>
  <property>
    <thing>
      <property>
    </thing>
  </property>
</thing>
```
XML encoding for 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?

```xml
<bib:aff resource="http://umbc.edu/" />
```
RDF can be encoded as a set of triples.

\[ \text{<subject> <predicate> <object>} . \]

- 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://www.w3.org/1999/02/22-rdf-syntax-ns#type><Description> .


$http://umbc.edu/~finin/talks/idm02/$ <http://www.w3.org/1999/02/22-rdf-syntax-ns#type><Description> .

Note the gensym for the anonymous node _:j10949
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)

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
@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 ;

Note special [...] syntax for an anonymous node

thing
    prop_1 = value ;
    prop_2 = value ;
    ...
    prop_n = value .
Example of University Courses

<rdf:RDF
 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
 xmlns:uni="http://example.org/uni-ns">

 <rdf:Description rdf:about="949318">
   <uni:name>David Billington</uni:name>
   <uni:title>Associate Professor</uni:title>
   <uni:age rdf:datatype="&xsd:integer">27</uni:age>
 </rdf:Description>

</rdf:RDF>
<rdf:Description rdf:about="CIT1111">
  <uni:courseName>Discrete Maths</uni:courseName>
  <uni:isTaughtBy>David Billington</uni:isTaughtBy>
</rdf:Description>

<rdf:Description rdf:about="CIT2112">
  <uni:courseName>Programming III</uni:courseName>
  <uni:isTaughtBy>Michael Maher</uni:isTaughtBy>
</rdf:Description>

</rdf:RDF>
Data Types for Literals

- Data types are used in programming languages to allow interpretation.
- In RDF, typed literals are used.
- You can specify this with a special `^^` syntax:
- Or using the `rdf:datatype` attribute:
  - `<uni:age rdf:datatype="&xsd:integer">27<uni:age>`
Data Types for Literals

- ^^-notation indicates the type of a literal
- In practice, the most widely used data typing scheme will be the one by XML Schema
  - But the use of any externally defined data typing scheme is allowed in RDF documents
- XML Schema predefines a large range of data types
  - E.g. Booleans, integers, floating-point numbers, times, dates, etc.
XMLSchema Datatypes

http://www.w3.org/TR/xmlschema-2/
The relationships between courses and lecturers (in the example) were not formally defined but existed implicitly via the use of the same name.

The use of the same name may just be a coincidence.

We can denote that two entities are the same using the `rdf:resource` attribute.

- Later we’ll see that we can use an `owl:sameAs` assertion.

By design, RDF explicitly rules out the common *unique name assumption* found in many representation systems.
The rdf:resource Attribute

<rdf:Description rdf:about="CIT1111">
  <uni:courseName>Discrete Mathematics</uni:courseName>
  <uni:isTaughtBy rdf:resource="949318"/>
</rdf:Description>

<rdf:Description rdf:about="949318">
  <uni:name>David Billington</uni:name>
  <uni:title>Associate Professor</uni:title>
</rdf:Description>
Referencing Externally Defined Resources

- Refer to the externally defined resource CIT1111 using http://example.org/uni-ns#CIT1111 as the value of rdf:about
- Assuming that example.org/uni-ns is the URI where the definition of CIT1111 is found
- A description with an ID defines a fragment URI, which can be used to reference the defined description
<rdf:Description rdf:about="CIT1111">
  <uni:courseName>Discrete Maths</uni:courseName>
  <uni:isTaughtBy>
    <rdf:Description rdf:ID="949318">
      <uni:name>David Billington</uni:name>
      <uni:title>Associate Professor</uni:title>
    </rdf:Description>
  </uni:isTaughtBy>
</rdf:Description>
Nested Descriptions

- Descriptions may be defined within other descriptions
- Other courses, such as **CIT3112**, can still refer to the new resource with ID **949318**
- Although a description may be defined within another description, its scope is global
RDF types

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

```xml
<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 types, another syntax

<rdf:Description rdf:ID="CIT1111">
  <rdf:type rdf:resource="http://example.org/uni-ns#course"/>
  <uni:courseName>Discrete Maths</uni:courseName>
  <uni:isTaughtBy rdf:resource="#949318"/>
</rdf:Description>

<rdf:Description rdf:ID="949318">
  <rdf:type rdf:resource="http://example.org/uni-ns#lecturer"/>
  <uni:name>David Billington</uni:name>
  <uni:title>Associate Professor</uni:title>
</rdf:Description>
This abbreviated syntax is very common
So we have two simplification rules:

1. Childless property elements within description elements may be replaced by XML attributes

2. For description elements with a typing element we can use the name specified in the `rdf:type` element instead of `rdf:Description`

These rules create syntactic variations of the same RDF statement

- They are equivalent according to the RDF data model, although they have different XML syntax
<rdf:Description rdf:ID="CIT1111">
  <rdf:type rdf:resource="http://example.org/unins#course"/>
  <uni:courseName>Discrete Maths
    <uni:courseName>
    <uni:isTaughtBy rdf:resource="#949318"/>
  </uni:courseName>
</rdf:Description>
Application of First Simplification Rule

.rdf:Description rdf:ID="CIT1111"
  uni:courseName="Discrete Maths">
    rdf:type rdf:resource="http://example.org/uni-ns#course"/>
    uni:isTaughtBy rdf:resource="#949318"/>
</rdf:Description>
Application of 2nd Simplification Rule

<uni:course rdf:ID="CIT1111"
  uni:courseName="Discrete Maths">
  <uni:isTaughtBy rdf:resource="#949318"/>
</uni:course>
Collect a number of resources or attributes about which we want to make statements as a whole

E.g., we may wish to talk about the courses given by a particular lecturer

The content of container elements are named `rdf:_1`, `rdf:_2`, etc.
  - Alternatively `rdf:li`

Containers seem a bit messy in RDF, but are needed
Three Types of Container Elements

- **rdf:Bag** an unordered container, allowing multiple occurrences
  - E.g., members of the faculty board, documents in a folder

- **rdf:Seq** an ordered container, which may contain multiple occurrences
  - E.g., modules of a course, items on an agenda, an alphabetized list of staff members (order is imposed)

- **rdf:Alt** a set of alternatives
  - E.g. the document home and mirrors, translations of a document in various languages
Example for a Bag

<uni:lecturer
    rdf:ID="949352" uni:name="Grigoris Antoniou"
    uni:title="Professor">
    <uni:coursesTaught>
        <rdf:Bag>
            <rdf:_1 rdf:resource="#CIT1112"/>
            <rdf:_2 rdf:resource="#CIT3116"/>
        </rdf:Bag>
    </uni:coursesTaught>
</uni:lecturer>
Example for Alternative

<uni:course rdf:ID="CIT1111"
    uni:courseName="Discrete Mathematics">
    <uni:lecturer>
        <rdf:Alt>
            <rdf:li rdf:resource="#949352"/>
            <rdf:li rdf:resource="#949318"/>
        </rdf:Alt>
    </uni:lecturer>
</uni:course>
<uni:lecturer rdf:ID="949318"
    uni:name="David Billington">
    <uni:coursesTaught>
        <rdf:Bag rdf:ID="DBcourses">
            <rdf:_1 rdf:resource="#CIT1111"/>
            <rdf:_2 rdf:resource="#CIT3112"/>
        </rdf:Bag>
    </uni:coursesTaught>
</uni:lecturer>
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
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>
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

- Sometimes we wish to make **statements** about other statements
- We must be able to refer to a statement using an identifier
- RDF allows such reference through a reification mechanism which turns a statement into a resource
Reify

- Etymology: Latin *res* thing
- Date: 1854
- to regard (something abstract) as a material or concrete thing
Reification is the act of making an abstract concept or low-level implementation detail of a programming language accessible to the programmer, often as a first-class object. For example,

- The C programming language reifies the low-level detail of memory addresses.
- The Scheme programming language reifies continuations (approximately, the call stack).
- In C#, reification is used to make parametric polymorphism implemented as generics a first-class feature of the language.
- …
Reification Example

<rdf:Description rdf:about="#949352">
  <uni:name>Grigoris Antoniou</uni:name>
</rdf:Description>

reifies as

<rdf:Statement rdf:ID="StatementAbout949352">
  <rdf:subject rdf:resource="#949352"/>
  <rdf:predicate rdf:resource="http://example.org/uni-ns#name"/>
  <rdf:object>Grigoris Antoniou</rdf:object>
</rdf:Statement>
Reification

- **rdf:subject**, **rdf:predicate** and **rdf:object** allow us to access the parts of a statement.
- The **ID** of the statement can be used to refer to it, as can be done for any description.
- We write an **rdf:Description** if we don’t want to talk about a statement further.
- We write an **rdf:Statement** if we wish to refer to a statement.
Properties are special kinds of resources
- Properties can be used as the object in an object-attribute-value triple (statement)
- They are defined independent of resources

This possibility offers flexibility
But it is unusual for modelling languages and OO programming languages
It can be confusing for modellers
RDF Critique: Binary Predicates

- RDF uses only binary properties
  - This is a restriction because often we use predicates with more than two arguments
  - But binary predicates can simulate these

- **Example**: `referee(X,Y,Z)`
  - X is the referee in a chess game between players Y and Z
We introduce:
- a new auxiliary resource `chessGame`
- the binary predicates `ref`, `player1`, and `player2`

We can represent `referee(X,Y,Z)` as:
The reification mechanism is quite powerful. It appears misplaced in a simple language like RDF. Making statements about statements introduces a level of complexity that is not necessary for a basic layer of the Semantic Web. Instead, it would have appeared more natural to include it in more powerful layers, which provide richer representational capabilities.
The simple graph or network representation has more drawbacks.

Linear languages introduce ways to represent this with parentheses or a way to represent a block structure.

Scoping, for example, is clumsy at best in RDF.

Some of these are addressed through the notion of a *named graph* in RDF.
RDF Critique: Summary

- RDF has its idiosyncrasies and is not an optimal modeling language **but**
- It is already a de facto standard
- It has sufficient expressive power
  - At least as for more layers to build on top
- Using RDF offers the benefit that information maps unambiguously to a model