Introduction to the Semantic Web and RDF

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The Semantic Web has been a W3C project since around 1999.

The existing Web of HTML documents is good for humans:

- Needs only a single program to access it: the browser.
- Programs have a harder time with it; it's too messy.
- Screen-scrapers can extract information from HTML, but they're hard to write.

The Semantic Web will augment the existing human-readable Web with structured data that's easy for software to process.

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Layers of the Semantic Web

The Semantic Web is split into three layers:

Web Ontology Language (OWL) Relationships between vocabularies	• "Persons" in vocabulary A are the same thing as "Users" in vocabulary B. • Resource X and resource Y are referring to the same thing.
RDF Schema: Vocabulary definitions	• There is a class called "Person". • Resource X is an instance of "Person".
Resource Description Framework (RDF) Assertions of facts	Resource X is named "Drew".

Overview of RDF

RDF is a specification that defines a model for representing the world, and a syntax for serializing and exchanging the model.

Facts are 3-tuples of (subject, property, object).

Subject* has a *property* of *object
Resource X has a *name* of *"Drew"*
ISBN 1234567890 has an *author* of *resource X*
Resource X has a *type* of *Person*

Noteworthy RDF vocabularies

Dublin Core

- Namespace: `http://purl.org/dc/elements/1.1/`
- Properties: title, creator, publisher, subject, identifier

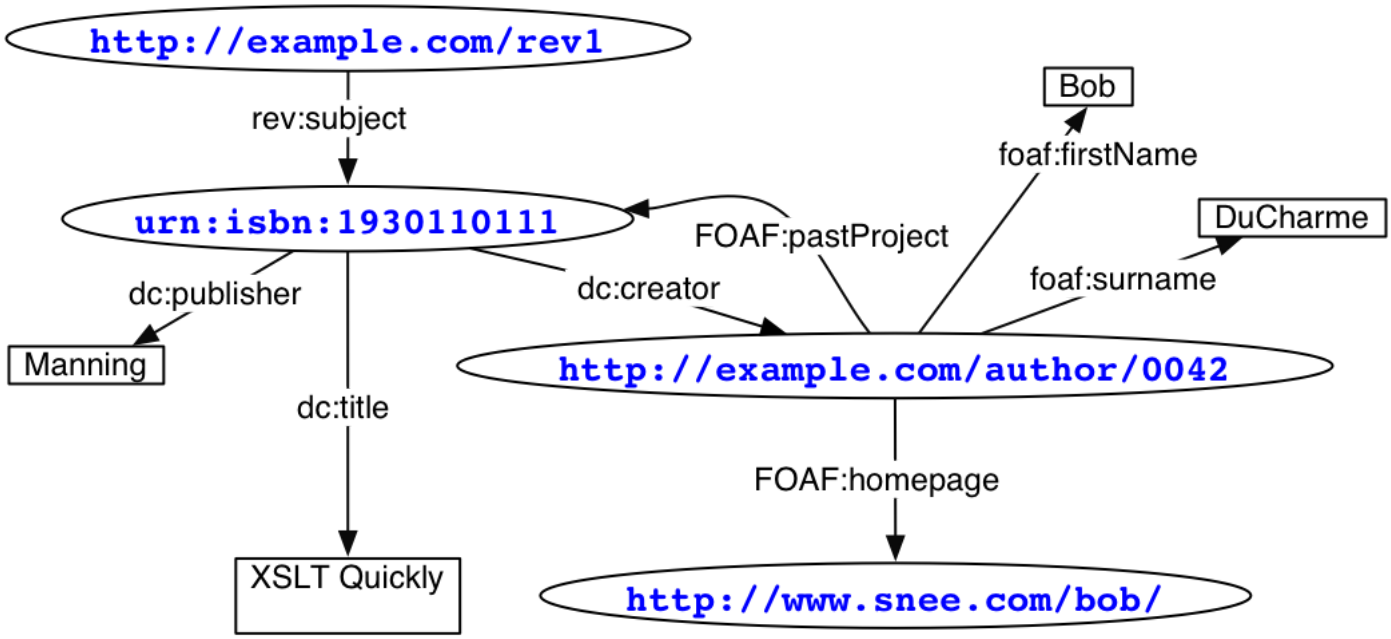
FOAF (Friend-of-a-friend)

- Describes people
- Classes: Person
- Properties: name, interest, mbox, schoolHomepage, workplaceHomepage
- Namespace: `http://xmlns.com/foaf/0.1/`

DOAP (Description of a Project)

- Describes open source projects
- Classes: Project, Repository
- Properties: name, homepage, mailing-list, license, maintainer
- Namespace: `http://usefulinc.com/ns/doap#`

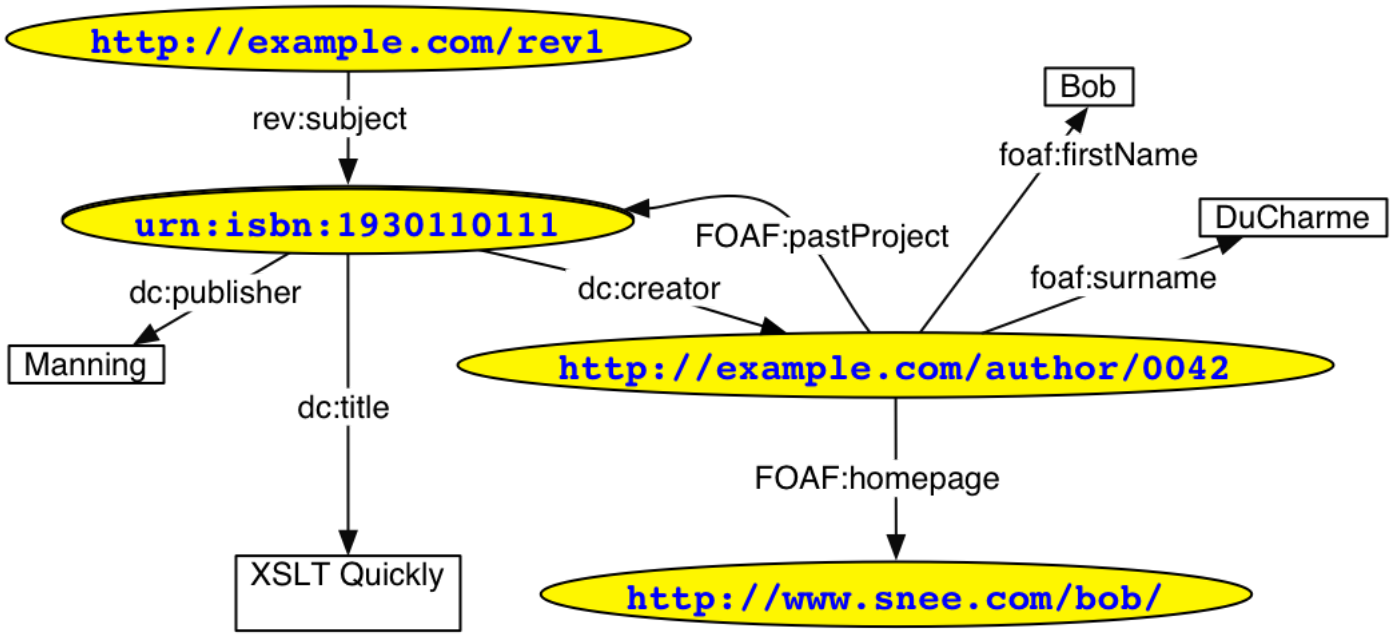
An Example RDF Graph



RDF Graph: Resources

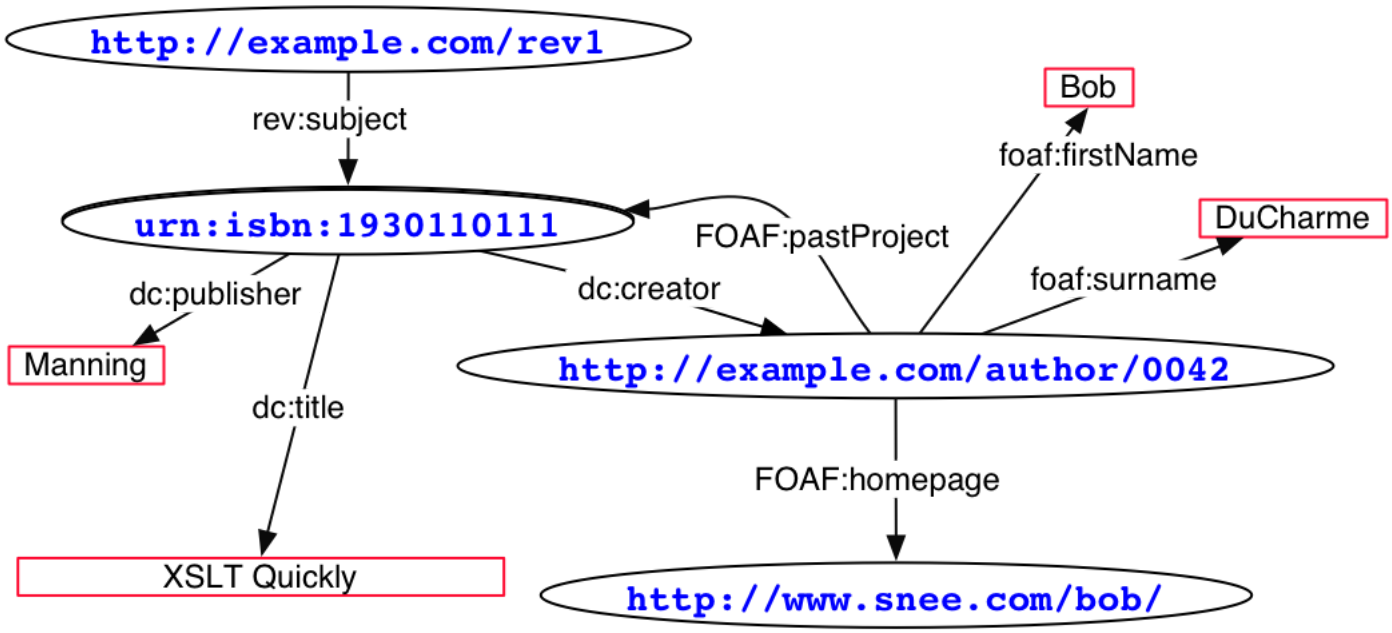
Resources are identified by URIs

- e.g. `http://example.com/person/0042`, `urn:isbn:1930110111`



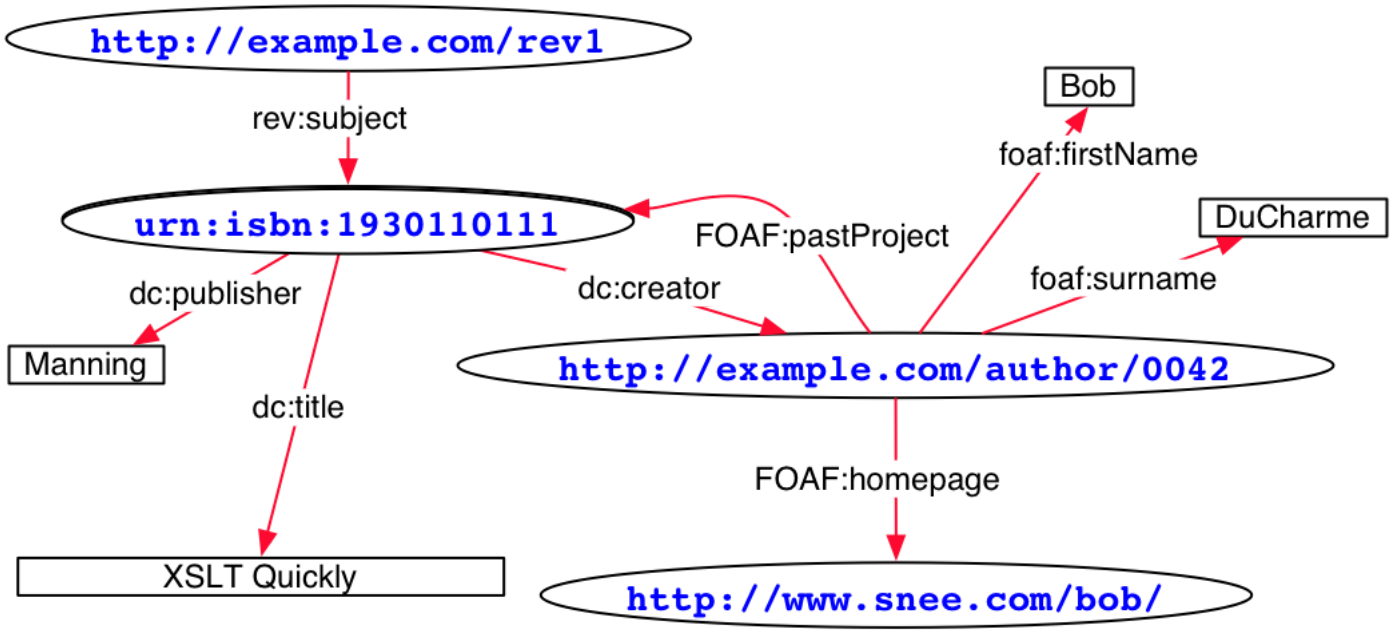
RDF Graph: Literals

- A primitive string value.
- The interpretation of the string is up to your application.



RDF Graph: Properties

- An attribute or aspect of a resource.
- A property value can be a literal or another resource.
- Multiple values are allowed; no value at all is also legal.



RDF Graph: Property URIs

How are properties identified? They could be just names or serial numbers, but that wouldn't be very scalable.

Instead, properties have URIs just like resources.

- Pick a base URI for your RDF vocabulary:
  `http://amk.ca/xml/review/1.0#`
- The base URI is assigned to a prefix, such as "rev".
- Properties are then referenced as 'rev:subject', 'rev:topic', etc.
- The RDF parser will concatenate the base URI (from the prefix) and the name:
  - rev:subject → `http://amk.ca/xml/review/1.0#subject`

RDF statements and triples

Graphs are usually represented as a bunch of (subject,property,object) 3-tuples.

Subject	Property	Object
`http://example.com/rev1`	`rev:subject` → `http://amk.ca/xml/review/1.0#subject`	`urn:isbn:1930110111`
`urn:isbn:1930110111`	`dc:title` → `http://purl.org/dc/elements/1.1/title`	"XSLT Quickly"
`urn:isbn:1930110111`	`dc:creator` → `http://purl.org/dc/elements/1.1/creator`	`http://example.com/author/0042`
`http://example.com/author/0042`	`FOAF:surname` → `http://xmlns.com/foaf/0.1/surname`	DuCharme
`http://example.com/author/0042`	`FOAF:homepage` → `http://xmlns.com/foaf/0.1/homepage`	`http://www.snee.com/bob/`
`http://example.com/author/0042`	`FOAF:pastProject` → `http://xmlns.com/foaf/0.1/pastProject`	`urn:isbn:1930110111`

RDF syntaxes: RDF/XML

RDF Core defines an XML-based serialization for RDF.

```
<rdf:RDF
    xmlns:FOAF="http://xmlns.com/foaf/0.1/"
    xmlns:dc="http://purl.org/dc/elements/1.1/"
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:rev="http://amk.ca/xml/review/1.0#">

    <!-- Implies rdf:type property is rev:Review -->
    <rev:Review rdf:about="http://example.com/rev1">
        <rev:subject rdf:resource="urn:isbn:1930110111"/>
    </rev:Review>

    <rdf:Description rdf:about="http://example.com/author/0042">
        <FOAF:firstName>Bob</FOAF:firstName>
        <FOAF:homepage rdf:resource="http://www.snee.com/bob/"/>
        <FOAF:pastProject rdf:resource="urn:isbn:1930110111"/>
        <FOAF:surname>DuCharme</FOAF:surname>
    </rdf:Description>
</rdf:RDF>
```

RDF syntaxes: Notation-3 (or N3)

An informal syntax that's easier to read and easier to scribble.

```
@prefix rev: <http://amk.ca/xml/review/1.0#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix FOAF: <http://xmlns.com/foaf/0.1/> .

<http://example.com/author/0042>
    FOAF:firstName "Bob";
    FOAF:surname "DuCharme";
    FOAF:homepage <http://www.snee.com/bob/>;
    FOAF:pastProject <urn:isbn:1930110111> .

<http://example.com/rev1> rev:subject [
   = <urn:isbn:1930110111>;
   dc:title "XSLT Quickly";
   dc:creator <http://example.com/author/0042>;
   dc:publisher "Manning" ] .
```

RDF's Sins and Virtues

Virtues:

- RDF exists and is strictly specified.
- Conceptually the graph model is pretty simple.
- RDF has a number of implementations.
- RDF is decentralized:
    - Anyone can create a vocabulary.
    - Anyone can publish data about other resources.

Sins:

- RDF/XML is rather verbose, and tedious to read/write by hand.
- Programming interfaces require you to know about triples, URIs, and all these low-level details.

Available RDF Software

The most basic form of RDF software is simply an RDF parser. Parsers are available for most of the languages you might need:

- Python (rdflib, 4RDF, pyrple, cwm)
- Perl (RDF::Core)
- C (Redland, libwww)
    - Thanks to SWIG, Redland also has interfaces for most of the other scripting languages.
- Java (Jena, Sesame)
- PHP, Ruby, Prolog all have RDF parsers.

Example code: Initializing an RDF database

Here's a Python example using rdflib 2.0.4 (www.rdflib.net).

```
#
# Initial setup -- create a TripleStore to hold RDF data
#

from rdflib.TripleStore import TripleStore
store = TripleStore()
```

You can add the contents of several URLs, parsing the data as RDF/XML:

```
store.load('http://www.amk.ca/amk.rdf')
store.load('http://www.python.org/pypi/?project=Twisted?format=doap')
store.load(...)
```

You can output the contents of a store:

```
print store.serialize(format='xml')
```

Example code: Modifying the database

You can add triples to a store:

```
from rdflib.URIRef import URIRef
from rdflib.Literal import Literal
from rdflib.Namespace import Namespace

REVIEW_NS = Namespace('http://amk.ca/xml/review/1.0#')
REVIEW_SUBJECT = REVIEW_NS['subject']
# Equivalent to:
##REVIEW_SUBJECT = URIRef('http://amk.ca/xml/review/1.0#subject')

book_uri = URIRef('urn:isbn:0609602330')

t = (URIRef('http://www.amk.ca/books/h/Isaacs_Storm.html'),
     REVIEW_SUBJECT, book_uri)
store.add(t)
```

You can also remove a triple:

```
store.remove(t)
```

Example code: Querying the database

The most general query method is triples(), which takes a (subject, property, object) 3-tuple, returning an iterator over the matching triples.

- Each element of the tuple can contain a URIRef or Literal instance, or None to match anything.

For example, to list all things which have a dc:title property:

```
>>> DC_TITLE = DC_NS['title']
>>> for s,p,o in store.triples((None, DC_TITLE, None)):
...     print s,p,o
...
urn:isbn:0609602330 http://purl.org/dc/elements/1.1/title \
   Isaac's Storm
urn:isbn:1930110111 http://purl.org/dc/elements/1.1/title \
   XSLT Quickly
>>>
```

Someday, there will be a query language (SPARQL example):

```
SELECT ?title
WHERE (<urn:isbn:1930110111> dc:title ?title)
```

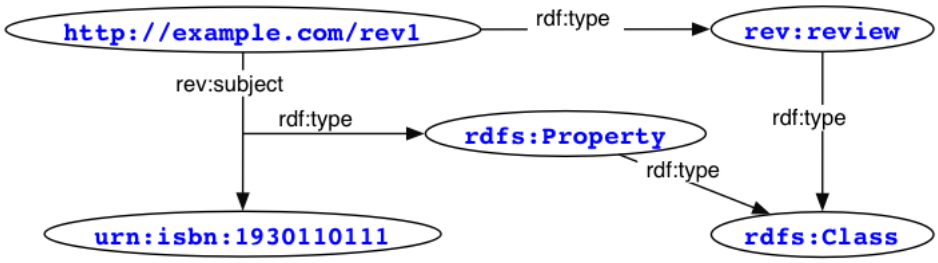
RDF Schema

Lets us define vocabularies (sets of classes and/or properties).

Example vocabulary:

- Some resources (web pages, articles, books) are reviews of other resources (books, music, articles, web pages).
  - Implies a `Review` class.
- A review has one or more subjects that are the items being reviewed.
  - Implies a `subject` property.

RDF Schema: Using rdf:type



RDF Schema: Describing a resource

First, define a prefix for the schema's namespace URI:

```
@prefix rev: http://amk.ca/xml/review/1.0#
```

To declare that a particular resource is a rev:Review, assert that the resource's rdf:type property is the class:

```
# Declare a resource
<http://example.com/review1> rdf:type rev:Review .
```

Describe what this resource is reviewing; what's the subject?

```
# Supply subject
<http://example.com/review1> rev:subject
      <http://www.music.com/album/6542>.
<http://example.com/review1> rev:subject <urn:isbn:1930110111>.
```

RDF Schema: Classes

So how do we define the class?

```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix rev: <http://amk.ca/xml/review/1.0#> .

# Declare a Review class

rev:Review  # class URI: http://amk.ca/xml/review/1.0#Review
   rdf:type rdfs:Class ;
   rdf:ID "Review" ;
   rdfs:comment """Reviews are resources that express an opinion
about some other resource.""" ;
.

# Declare a subclass of Review.
rev:ComparativeReview
   rdf:type rdfs:Class ;
   rdfs:subClassOf rev:Review .
   rdfs:comment """Comparative reviews examine multiple resources,
comparing their relative merits and usually offering an opinion
about which one is the best.""" ;
```

rdfs:Property

You can also specify properties in a vocabulary. The following fragment defines the rev:subject property:

```
rev:subject
    rdf:type rdf:Property;
    rdfs:label "Subject property" ;
    # Resources which can have this property
    rdfs:domain rev:Review ;
    # Values this property can take
    rdfs:range rdfs:Resource ;
    rdfs:comment "Value is the resource being reviewed." ;
    .

rev:title
    rdf:type rdf:Property;
    # This property only takes literal values
    rdfs:range rdfs:Literal;
    .
```

OWL: Connecting vocabularies

With RDF Schema, we know:

- Which classes exist,
- What their properties are.

We don't know:

- When are two classes the same?
- Can properties have multiple values?
  - e.g. Can a book have more than one author?
  - ... no authors?
  - ... more than one publisher?
- If X *prop* Y and Y *prop* Z are both true, which of the following are true?
  - X *property* Z (transitivity)
  - Y *property* X (symmetry)
  - Z *property* X

OWL: Web Ontology Language

OWL is a W3C language for defining this sort of relationship. Possible relationships:

- For classes:
  - equivalentClass
  - disjointWith
- For properties:
  - equivalentProperty
  - inverseOf
  - TransitiveProperty
  - SymmetricProperty
  - minCardinality
  - maxCardinality
- For resources:
  - sameAs
  - differentFrom

OWL: Defining a class

Here's an OWL declaration of a class representing persons:

```
@prefix gen: <http://genealogy.example.com/schema#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .

gen:Person
    rdf:type owl:Class;
    rdf:ID "person" ;
    rdfs:comment "Resource representing a person." ;
    owl:equivalentClass foaf:Person;
    .
```

OWL: Property declaration

Define a property:

```
gen:ancestor
    # Declare as a transitive property:
    # X -> Y, Y -> Z implies X -> Z
    rdf:type owl:TransitiveProperty;
    rdfs:domain gen:Person;
    rdfs:range gen:Person;

    # Declare as inverse of some other property
    owl:inverseOf gen:descendant;
    .
```

Web ontology: What's the point?

OWL adds the ability to indicate when two classes or properties are identical.

- This lets bodies of data in different vocabularies be linked together.
- Anyone can do this by publishing the right snippet of RDF.

OWL declarations provide additional information to let rule-checking and theorem-proving systems work with RDF data.

- e.g. the 'ancestor' property is transitive.
- If (X ancestor Y) and (Y ancestor Z) are true, a system could infer that (X ancestor Z) is also true.

What should you care about?

So how much of this stuff do you need to learn about and use?

- RDF
  - Yes, definitely!
  - It's the base of the pyramid, and is widely implemented.
- RDF Schema
  - Useful for documentation.
  - Will likely be important in future.
  - But... you *can* get useful work done without it.
- OWL
  - Few libraries support OWL
  - Implementations are largely research projects.
  - For many applications theorem-proving will be irrelevant.

Why hasn't RDF caught on yet?

- HTML was much easier to learn; RDF is more abstract.
- There's no obvious killer application.
- RDF software APIs require you to know too much.
- Introductory tutorials are few.

Starting Small

But we don't need to aim for the stars. Simple things can be done without much effort, and can still be useful:

- Do you have some data that can be published as RDF?
- Can you invent a vocabulary for a new application domain?
- Write Semantic Web-enabled applications that store data as RDF, or provide export/import to RDF.
- Can you link two different data sets to do something interesting?

There are signs of life: FOAF has caught on, DOAP is rising, and many small projects are using RDF internally.

- So the Semantic Web *is* coming... slowly.

Demos

- Welkin -- a generic RDF browser.
- LiveJournal has FOAF files; try `http://<whatever>.livejournal.com/data/foaf`.
  - example link
- lorebot -- an IRC bot
- My family pictures -- password required
  - Schema in N3

Questions, comments?

These slides: www.amk.ca/talks/2004-12-02

For further information:

- The W3C's RDF Primer is good: www.w3.org/TR/rdf-primer/.
- The Jena project's tutorial: jena.sourceforge.net/tutorial/RDF_API.
- A lengthy presentation: www.w3.org/Consortium/Offices/Presentations/RDFTutorial/
- The O'Reilly book, *Practical RDF*, is decent but not great.

What Python library to use?

- rdflib (www.rdflib.net) is the most commonly used; complicated, though.
- Redland (www.librdf.org) is a widely-used C library with Python bindings.
- A number of small libraries exist (rdfxml.py, pyrple); Google for "python rdf".
- Java libraries (Jena, Kowari) can be used from Jython.

PyCon reminder

PyCon will be March 23-25 at GWU's Cafritz Center.

Deadline for proposals: Dec. 31st.

Call for papers:
`http://www.python.org/pycon/2005/cfp.html`

Proposal submissions: `http://submit.pycon.org`