INFO216:
Knowledge Graphs

Andreas L. Opdahl
<Andreas.Opdahl@uib.no>

Lecture 2

- Themes:
  - Resource Description Framework (RDF)
    - a normal form for semantic data
    - a central semantic standard
  - RDFLib's basic API
    - creating and deleting graphs, input/output, listing statements, managing literals, type mappings
  - The group projects
    - practical information
    - aid for project idea
    - *more later!*

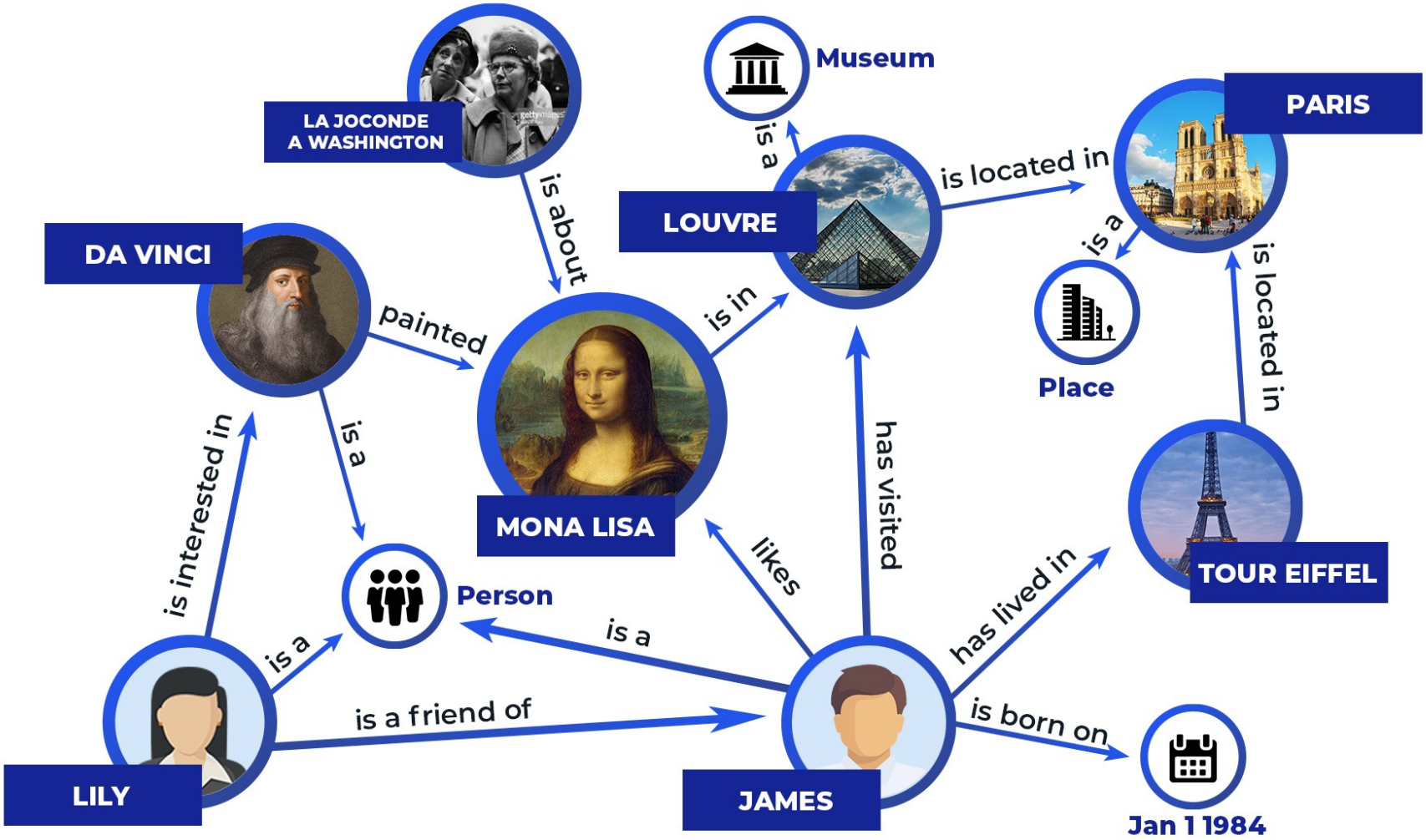
Reading

- Sources:
  - Blumauer & Nagy (2020):
    Knowledge Graph Cookbook – Recipes that Work
    (for example pages 92-100, 125-128)
  - Allemang & Hendler (2011):
    Semantic Web for the Working Ontologist
    chapter 3 (page 31-44)
  - materials in the wiki: *wiki.uib.no/info216*
    - RDF Primer
    - rdflib documentation

Resource Description Framework (RDF)

Resource Description Framework (RDF)

- Semantic data
  - treated as a set of *triples*
  - can be physical (native) or virtual
- The relations form a *directed graph*:
  - "nodes" connected by "arrows"
- "Nodes" can represent either
  - *resources* or
  - *literal values* (text strings, numbers, logicals...)
- "Arrows" represent
  - relations between resources and literals

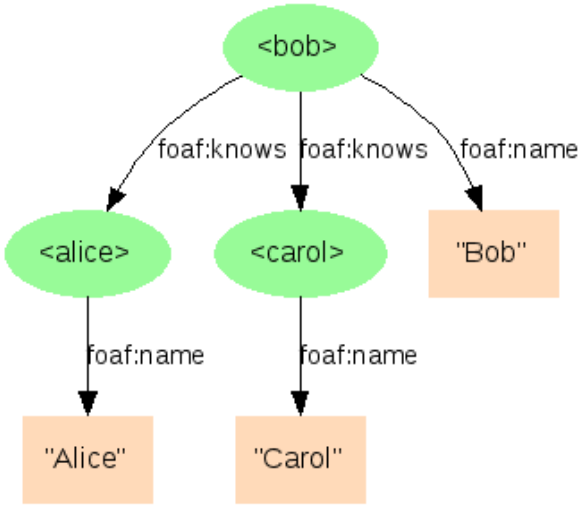


- *Graphs* of "*nodes*" connected by directed "*edges*"
- Represents *knowledge* as connected *facts*
- "Nodes" repr. *resources* or *values*, "edges" repr. *relations*

Statements (triples)

- Triples of *subject predicate object* .
  - ...or *subject predicate literal* .
- The subject:
  - must be a *resource* (→ rdfs:Resource)
  - *named* by an URI or *anonymous* (*blank node*)
- The predicate:
  - must be a *property* (→ rdf:Property)
  - properties are resources too!
- The object:
  - either a resource (→ rdfs:Resource)
  - or a constant *value* (→ rdfs:Literal)

- Triples of *subject predicate object .*
  - ...or of *subject predicate literal* .
  - Uniform Resource Identifiers (URIs)
  - serialisations, e.g., in *Turtle*:




```
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:bob    foaf:name       "Bob" .
:bob    foaf:mbox       <mailto:alice@example.org> .
:bob    foaf:knows      :alice .
:bob    foaf:knows      :carol .
```

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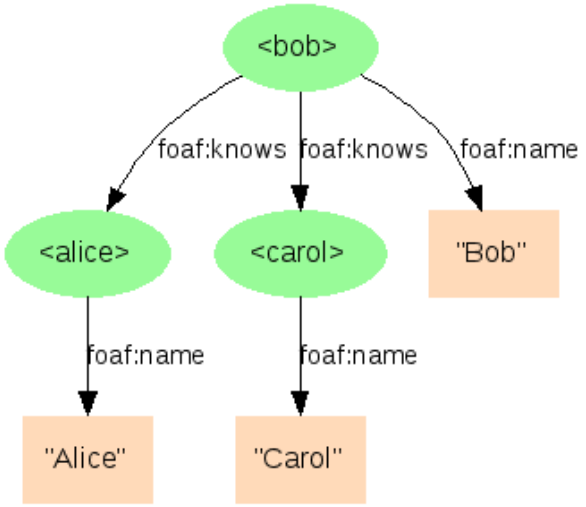


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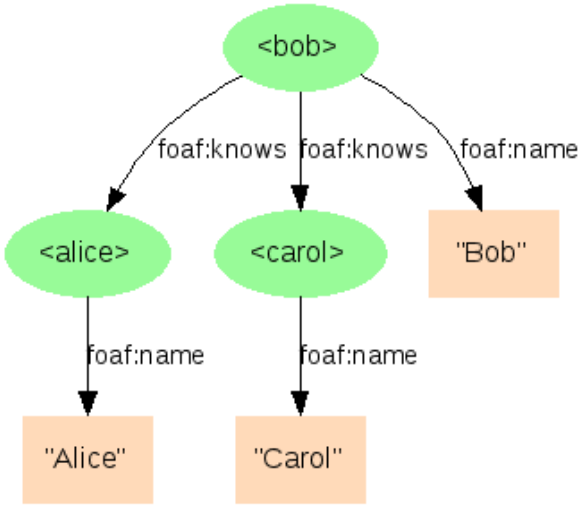


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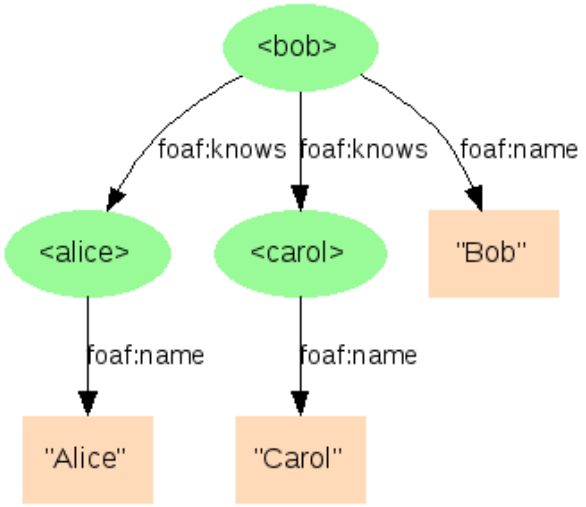


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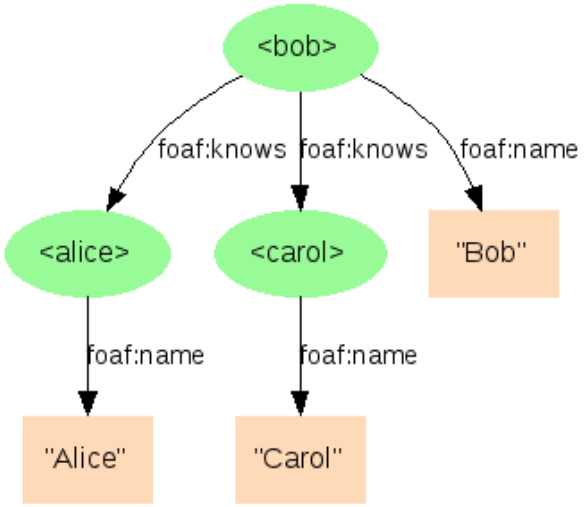


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        foaf:name   "Bob" ;
        foaf:mbox   <mailto:alice@example.org> ;
        foaf:knows  :alice ,
                    :carol .
```

Prefixing

- XML Qualified Name (QName):
  - from “eXtensible Markup Language” (XML)
  - provides short forms for much used URI bases
- Much used prefixes (here in Turtle syntax):

```
@prefix rdf: http://www.w3.org/1999/02/22-rdf-syntax-ns# .
@prefix rdfs: http://www.w3.org/2000/01/rdf-schema# .
@prefix dc: http://purl.org/dc/elements/1.1/ .
@prefix owl: http://www.w3.org/2002/07/owl# .
@prefix ex: http://www.example.org/ .
@prefix xsd: http://www.w3.org/2001/XMLSchema# .
```

  - ...or self-defined prefixes
  - see http://*prefix.cc*
- Example:
  http://www.w3.org/2001/XMLSchema#string
  can now be written *xsd:string*

Semantic graphs and data sets

- *Graph*:
  - a collection of *triples/statements* (possibly none)
  - *"knowledge graphs"*
- *Data set (or "Conjunctive graph")*:
  - a collection of graphs (at least one)
  - one of the graphs is *default/unnamed*
  - the others are *named*
  - from triples/statements:
    - *(subject, predicate, object)*
  - to quadruples *(quads):*
    - *(graph/"context", subject, predicate, object)*

Resources (→ rdfs:Resource)

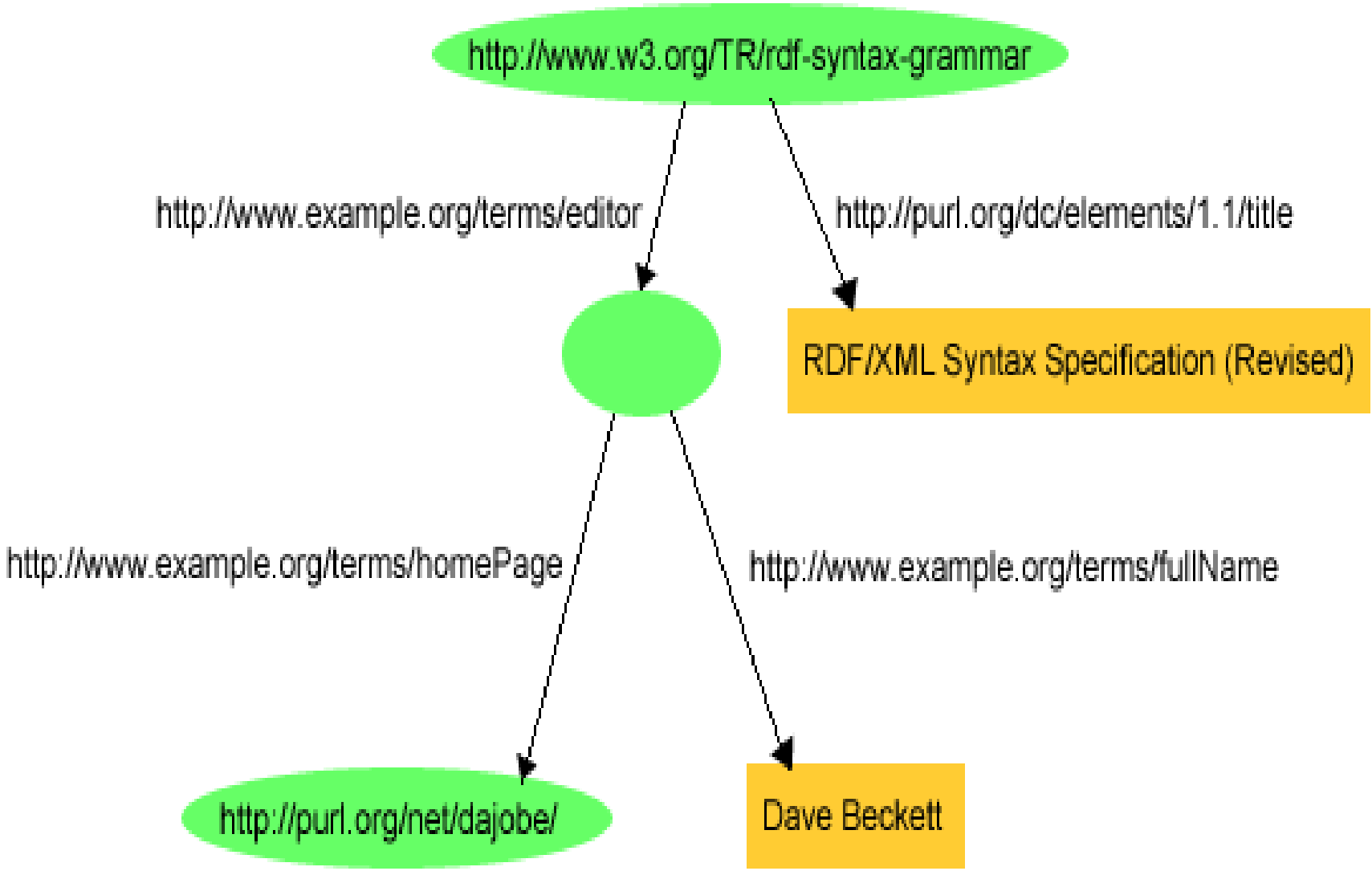
- Resources may be physical phenomena (including people and artefacts), information resources, concepts, constructs...
  - ...most things, really :-)
  - ...and information about them
- Can be the *subject* or *object* in a statement
  - but only rdf:Property can be *predicate*
- Can be:
  - *named* by an URI
  - *anonymous* (blank *node*)
- Resources can have one or more *rdf:type*-s
  - dbpedia:Magnus_Carlsen rdf:type dbpedia:ChessPlayer

Uniform Resource Identifier (URI)

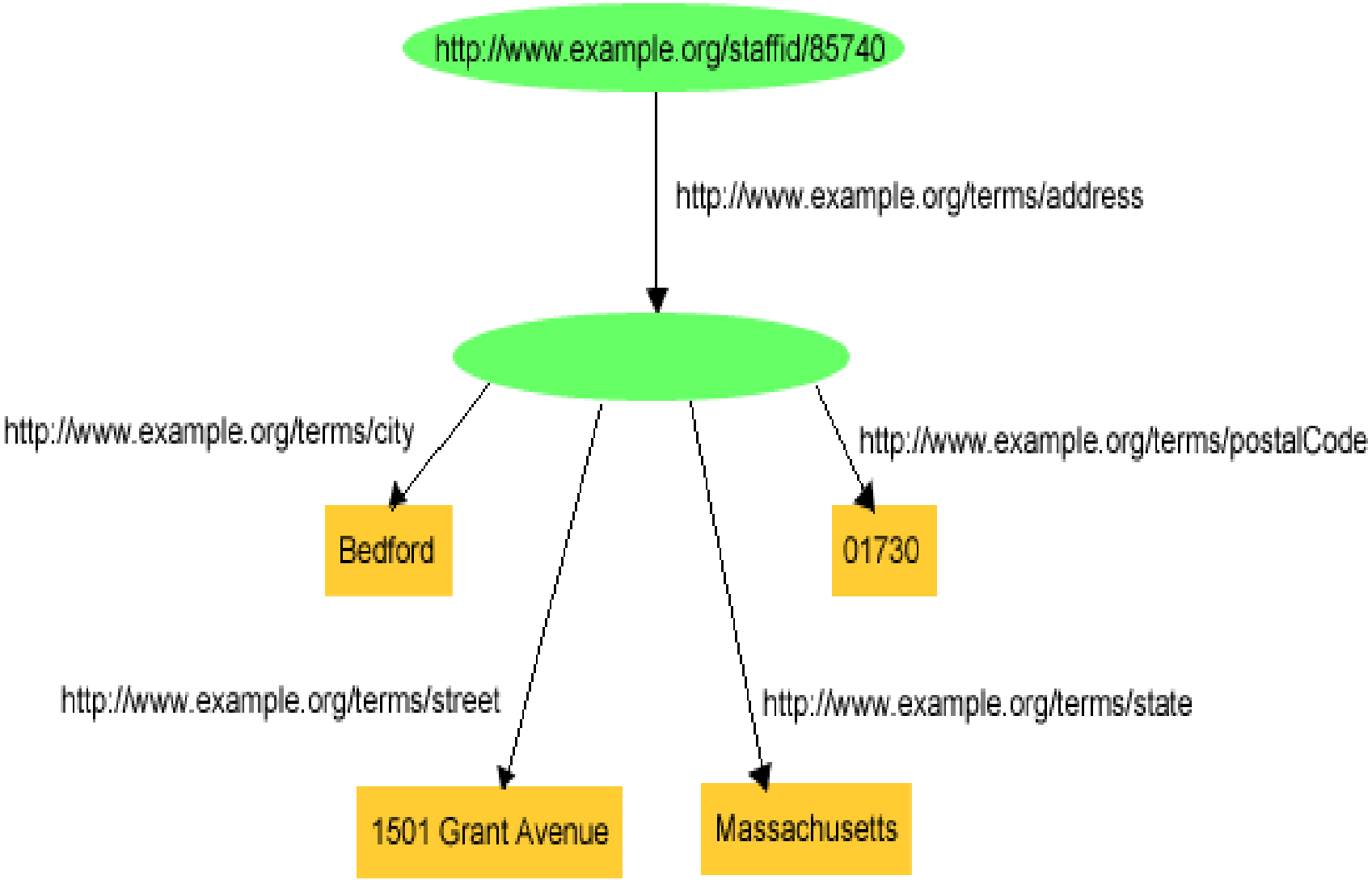
- Used to name (identify) resources:
  - URI – Uniform Resource Identifier
  - URL – a URI that is *dereferencable* (“Locator”)
  - URN – a URI that is used to name something
  - initially based on limited ASCII-character sets...
- Generalised into *International Resource Identifier (IRI)*
  - based on a *Unicode-character set* (UTF-8)
    - major security issue: homographic attacks
    - which domain is this? uib.no
  - also IRL, IRN...

Anonymous resources (blank nodes)

- Some nodes have no URIs:
  - cannot be referenced by other data sets
  - *can* be referenced by graphs in same data set
- Can have a (non-URI) identifier, but
  - local identifier only meaningful inside the data set
  - *cannot be used to merge nodes from different data sets*
- Uses:
  - you are not sure of the URI
  - you do not want to provide an URI
  - logical grouping of related properties
  - *not supported by all RDF technologies*



From http://www.w3.org/TR/rdf-primer/



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Turtle syntax for blank nodes

<http://www.w3.org/TR/rdf-syntax-grammar>
    <http://purl.org/dc/elements/1.1/title>
        "RDF/XML Syntax Specification (Revised)" .
<http://www.w3.org/TR/rdf-syntax-grammar>
    <http://www.example.org/terms/editor>
        [] .
[]
    <http://www.example.org/terms/homePage>
        <http://purl.org/net/dajobe> .
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        "Dave Beckett" .

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        [] .

Each represents a *different* anon. node...

[]
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                     <http://www.example.org/terms/fullName>
                           "Dave Beckett"   ] .
```

Properties (rdf:Property)

- Properties are resources that
  - express a relationship between resources
  - ...or between resources and literal values
- Is used as a *predicate* (or as subject or object)
- Example:
  - *name* is a property in the Dublin Core vocabulary
  - it can also be the subject in RDF statements:
    - dc:name rdf:type rdf:Property .

- *Convention: properties are written with small initial letters*

Literals (rdf:Literal)

- Untyped (simple) literals: only a character string
  - f eks “29”
  - *strings can have a language code!*
    “Göteborg”@”se”, “Gothenburg”@”en”
- Typed literals: a string + an URI (ref)
  - the type is defined of the URI
  - XML Schema Definition (XSD) language is common
  - two built-in RDF types: rdf:XMLLiteral, rdf:HTML
  - ...but other types can also be used
- Syntax depends on the serialisation, e.g., TURTLE:
  - "29"^^<http://www.w3.org/2001/XMLSchema#integer>
  - or with a prefix: "29"^^<xsd:integer>

XML Schema Definition (XSD)

- XSD types that can be used in RDF:
  xsd:string, xsd:boolean, xsd:decimal, xsd:integer, xsd:float, xsd:double, xsd:dateTime, xsd:dateTimeStamp, xsd:time, xsd:date, xsd:gYearMonth, xsd:gYear, xsd:gMonthDay, xsd:gDay, xsd:gMonth, xsd:duration, xsd:yearMonthDuration, xsd:dayTimeDuration, xsd:hexBinary, xsd:base64Binary, xsd:anyURI, xsd:normalizedString, xsd:token, xsd:language, xsd:NMTOKEN, xsd:Name, xsd:NCName, xsd:positiveInteger, xsd:nonPositiveInteger, xsd:negativeInteger, xsd:long, xsd:int, xsd:short, xsd:byte, xsd:nonNegativeInteger, xsd:unsignedLong, xsd:unsignedInt, xsd:unsignedShort, xsd:unsignedByte
- Not all XML Schema types can be used in RDF:
  - *must be a set of string values*
  - *...that can be mapped into*
  - *...a well-defined value space*

Literals that represent measures

- Some literals represent measures:
  - examples: 180cm, 75kg, 10Tb, 3.44GHz
  - represented as a *magnitude* and a *unit of measurement*
  - such literals can be represented by anonymous nodes having one *rdf:value* and one *unit* property
- Without unit:

```
exproduct:item10245    exterms:weight  "2.4"^^xsd:decimal .
```

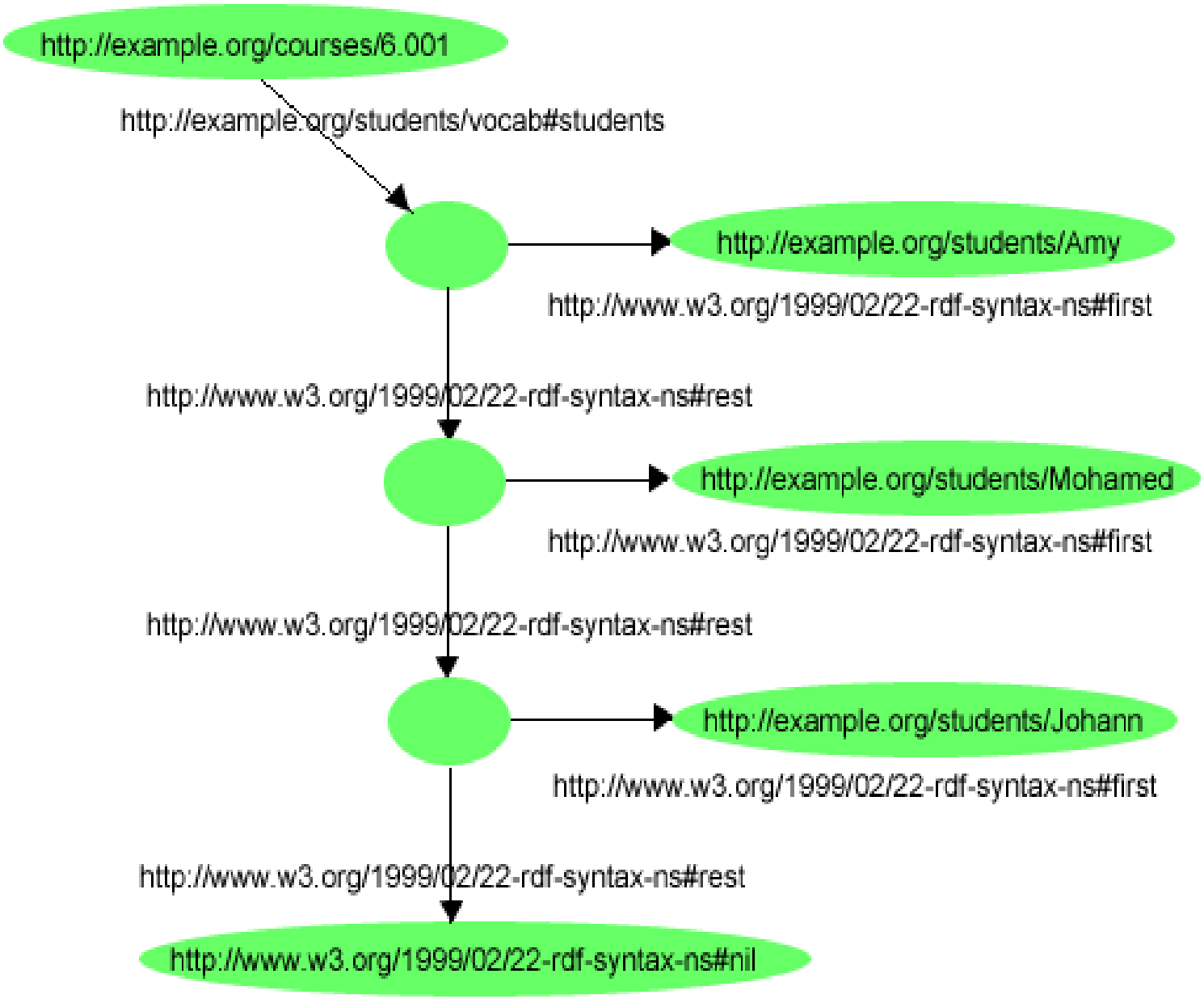
- Using rdf:value:

```
exproduct:item10245    exterms:weight  _:weight10245 .
_:weight10245          rdf:value       "2.4"^^xsd:decimal .
_:weight10245          exterms:units   exunits:kilograms .
```

- Vocabularies for units of measure: QUDT, OM...

Collections (rdf:List)

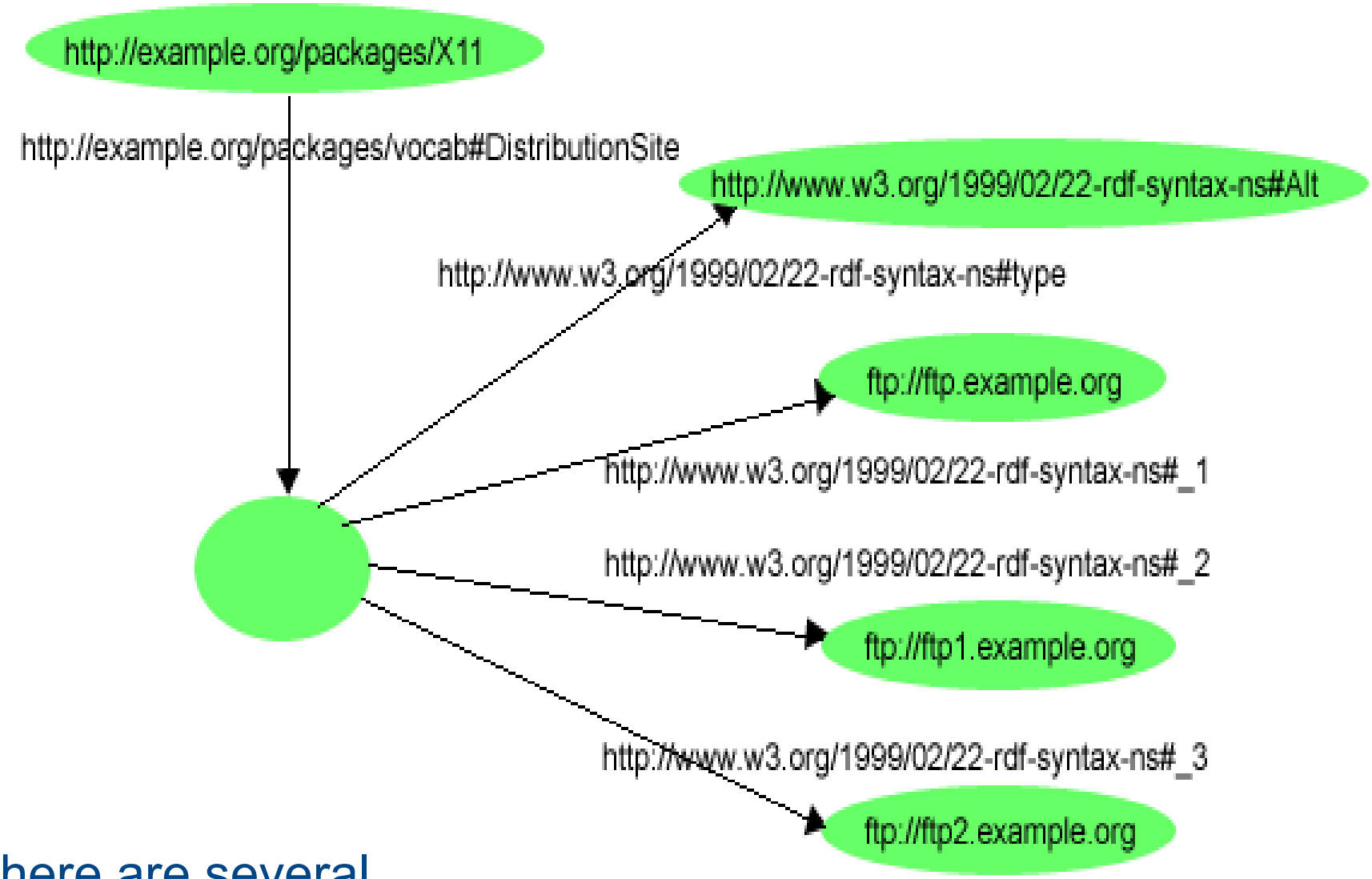
- Containers are not closed
  - we *cannot assume it only has the members we know of*
  - others can add more members to the list *without deleting triples* (i.e., *monotonically*)
- Collections (rdf:List-s):
  - can only have the listed members
  - rdf:first gives the first RDF node in the list
  - rdf:rest gives the rest of the list
  - rdf:nil is an empty list



From http://www.w3.org/TR/rdf-primer/

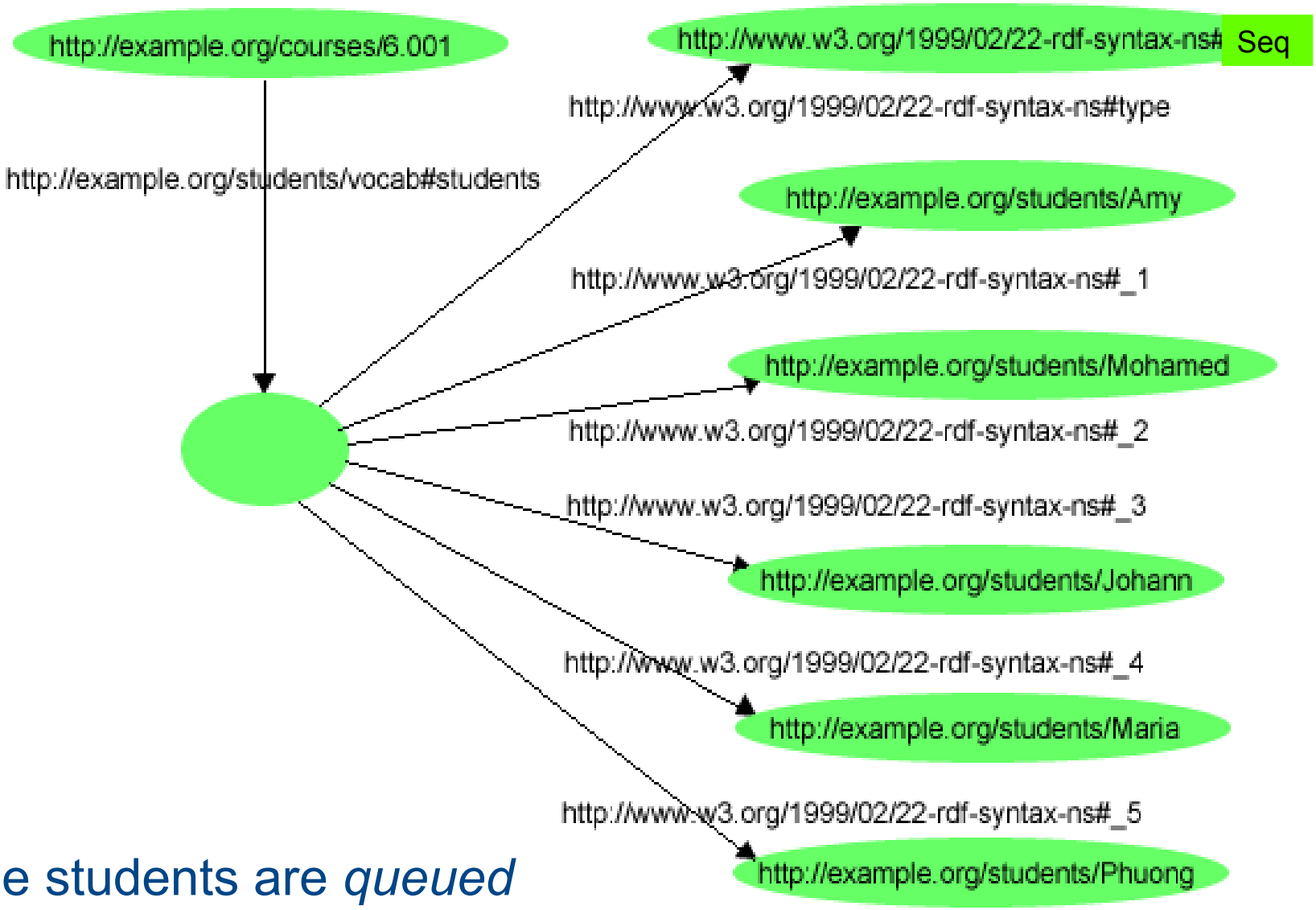
Containers (rdfs:Container)

- Containers can be used when a subject is related in the same way to many RDF nodes that are
  - ordered and/or duplicated
  - (*regular properties* suffice when the RDF nodes are unordered and there are no duplicates)
- Container nodes are often anonymous (can have an URI)
  - have RDF nodes as members (rdfs:member)
  - have special properties rdf:_1, rdf:_2 etc. to pick out particular members
- rdf:Alt – several alternative resources
- rdf:Seq – lists of RDF nodes, can have duplicates
- rdf:Bag – orderless RDF nodes, can have duplicates



There are several
alternative distribution sites.

From http://www.w3.org/TR/rdf-primer/



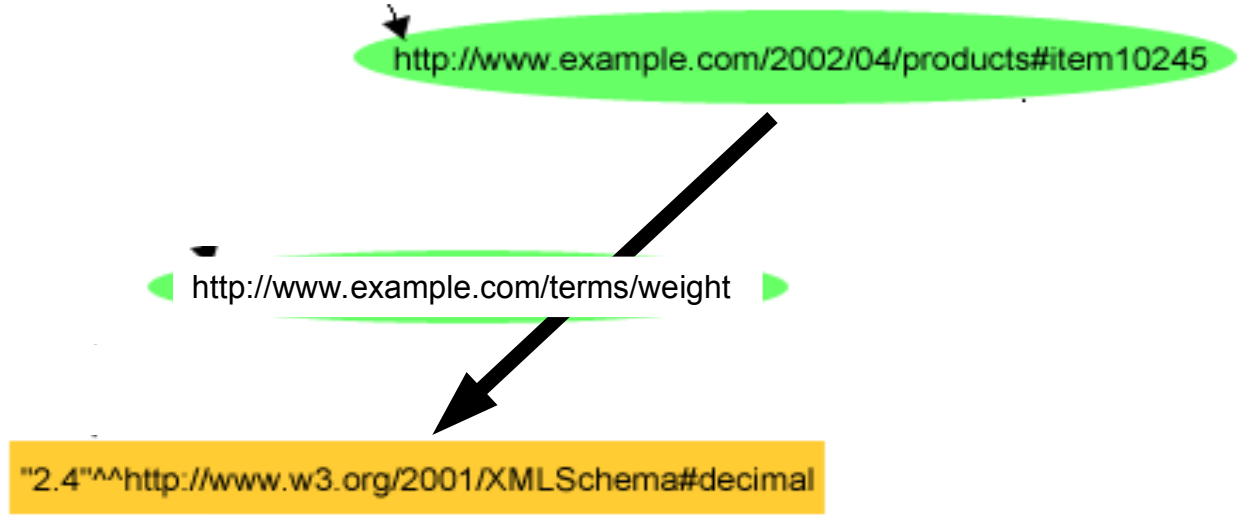
The students are *queued up* in order for the course.

From http://www.w3.org/TR/rdf-primer/

Reified statements (triples)

- Regular statement:
  exproducts:item10245 exterms:weight "2.4"^^xsd:decimal .
- Reified statement (*reification quad*):
  exproducts:triple12345 rdf:type rdf:Statement .
  exproducts:triple12345 rdf:subject exproducts:item10245 .
  exproducts:triple12345 rdf:predicate exterms:weight .
  exproducts:triple12345 rdf:object "2.4"^^xsd:decimal .
- Reification *gives the triple an identifier (URI)*
- Reification "unpacks" a triple into four new ones:
  - new type: rdf:Statement
  - new properties: rdf:subject, rdf:predicate, rdf:object
- We can now make *statements about statements*:
  - *"<Trippel-X> is valid from <dato> until <dato>."*
  - *"<dbpedia:Wikipedia> claims that <trippel-Y>."*

Non-reified:



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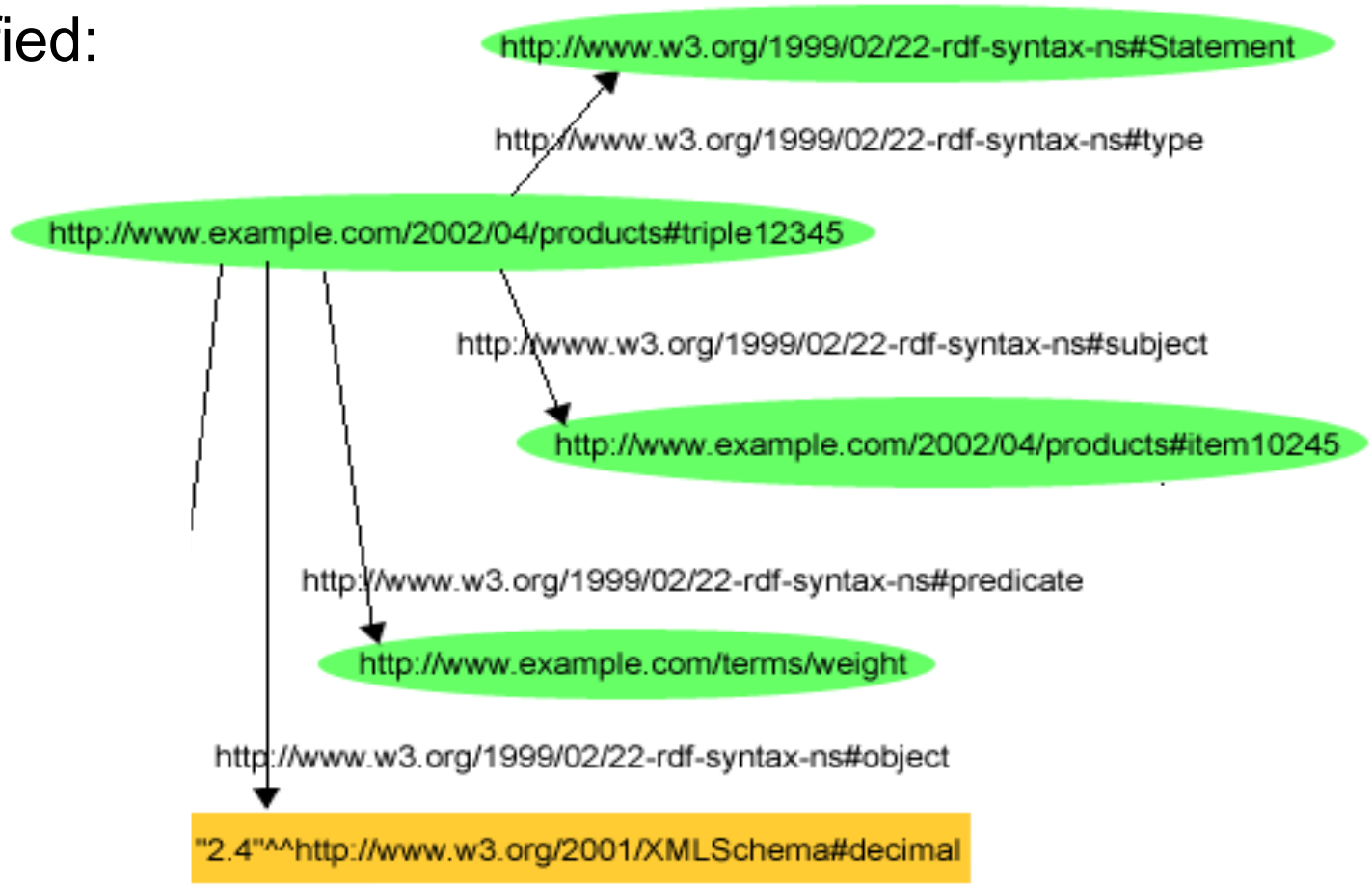
Reified:



From http://www.w3.org/TR/rdf-primer/

With other triples:

From http://www.w3.org/TR/rdf-primer/

RDFLib's Basic API

Creating models and statements

- import rdflib
- Creation:
  - Graph: g = rdflib.Graph()
  - Resource: res = rdflib.URIRef(*resURIstr*)
  - Property: prop = rdflib.URIRef(*propURIstr*)
  - Literal: lit = rdflib.Literal*(pythonValue)*
- Add/remove triple:
  - g.add((res, prop, lit))
  - g.remove((res, prop, lit))
- Close persisted model:
  - g.close()

Serialising and parsing

- Serialising:
  - g.serialize(destination=*fileNameStr*, format='ttl')
  - ttl_str = g.serialize(format='ttl').decode()
  - ttl_str = g.serialize(format='json-ld').decode()
    - requires: pip install rdflib_jsonld
- Parsing:
  - g.parse(location=*fileNameStr*, format='ttl')
  - g.parse(source=*webIRLStr*, format='ttl')
  - g.parse(data=*pythonStr*, format='ttl')

Listing statements

- Retrieving statements (triples):
  - for triple in g:
    do_something(triple)
    - s = triple[0], p = triple[1], o = triple[2]
  - for s, p, o in g:
    do_something(s, p, o)
  - for s, p, o in g.triples((sub, pred, obj)):
    do_something(s, p, o)
    - sub, pred, obj can be None
  - for s, p, o in g[sub : pred : obj]:
    do_something(s, p, o)
    - sub, pred, obj can be empty: s, p, o must match

Selecting statements

- Convenience methods:
  - for s in g.subjects(p, o):
    do_something(s)
  - for p, o in g.predicates_objects(s):
    do_something(p, o)
  - if unique:
    - o1 = g.value(s, p)
    - g.set((s, p, o2))

RDFLib interfaces

- Namespaces:
  - predefined:
    - RDF, RDFS, OWL, XSD, FOAF, SKOS, DC, DCTERMS
    - rdflib.namespace.RDF.type
    - or… from rdflib.namespace import RDF
  - user-defined:
    - >>> i2s = rdflib.Namespace('http://i2s.uib.no/')
      >>> i2s.MainAuthor
      rdflib.term.URIRef(u'http://i2s.uib.no/MainAuthor')
  - add prefix to graph:
    - >>> g.bind('i2s', i2s)

Group project

Group project

- The group project shall develop a *semantic KG-based (RDF, SPARQL, OWL...) dataset, application, or service*
- Programming language, development and run-time platform is free of choice
- The project should be carried out in groups of three and not more
- Working individually / in pairs is possible, but not optimal
- Groups of more than three will never be accepted
- The application will be presented in the seminar groups, and each group member will describe their contribution to the finished product
- The assignment must be done in the teaching semester

Choosing a task

- Example projects:
  - *municipality maker*
  - *map of party financing*
  - *toll road reasoner*
  - *tracking IT infrastructure*
  - *music concert assistant*
  - *live semantic flight data*
  - *semantic security service*

- Given assignment:
  - the News Angler project has several challenging tasks!

- More in the wiki: wiki.uib.no/info216

Success factors

- Show that you can program with semantic technologies
  - *at least* RDF, *preferred* RDFS, SPARQL, ...
  - ...JSON-LD is an *emerging alternative*
- Use existing data sets (open semantic resources)
- Use existing vocabularies (and perhaps extend them)
- *Simple* presentation interface / dashboard
- Make the program run :-)
- *Shortcuts can be ok* (some manual steps, artificial data)
- *Try to have an original idea*

Example: combination projects

- Take two or more (semantic?) data sets
- Read them
- If necessary: lift them (i.e.: add semantic tags)
- Combine the data sets semantically
- Use them to derive new data/answer new queries
  - impossible to answer before
  - harder to answer before
- Mantainability:
  - what happens when the data sets change?
- *Dynamic data sets are more interesting that static ones!*

Example: lifting projects

- Take a data set or a Web API (web service)
- Read it / access it over the net
- Lift it (i.e.: add semantic tags)
  - using existing vocabularies as far as possible
- Show and implement use cases
  - that were impossible before
  - that were harder before
  - that were less flexible before
- *Focus on maintainability – making it easy run over time!*

Other projects are very possible!

- Combination and lifting projects are the most common
- Other types are very possible, e.g.:
  - semantic crawlers and spiders
  - presentation / visualisation of graphs
- *You are free to propose (almost) anything!*

- How big should my project be?
  - usually not a problem
  - always possible to narrow the scope
  - usually possible to expand the scope
  - a bit easier to start “too big” than “too small”

Semantic data sets and vocabularies

(quick overview to help you find project ideas!)

Places to start

- Open and semantic:
  - open semantic data sets: *http://lod-cloud.net*
  - vocabularies: *https://lov.linkeddata.es/dataset/lov/*
- Open data in general:
  - internationally: *http://datahub.io* or *http://ckan.org*
  - Norge: *http://data.norge.no*
  - EU: *https://open-data.europa.eu*
  - UK: *http://data.gov.uk*
  - USA: *http://data.gov*

The LOD cloud...

- *http://www.lod-cloud.net/*
  - statistics at www.lod-cloud/net/state
  - ca 1250 data sources (LOD-cloud, 2019)
  - based on data from DataHub (+ some crawling)
    - datahub.io or ckan.org
    - an open data portal
    - not necessarily semantic
  - ...also based on LOD crawling