Towards a Semantic Web Toolkit in Haskell

Querying RDF graphs & SPARQL construction

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18th April, 2012

Preamble

- Who I am...
  - Work @ Heriot Watt University
    - ★ **PhD** Fault tolerant, distributed-memory Haskell computing
    - ★ **Researcher** SerenA project *(more on that later)*.
  - I'm on Twitter: `@robstewartUK`
  - I'm also on Google+: `http://goo.gl/eL8zg`

- What I'll talk about
  - The *semantic web*
  - Linked Open Data
  - Available Haskell libraries to poke at both

- LaTeX, Haskell & Java source code on GitHub:
  `https://github.com/robstewart57/edlambda-semanticweb-haskell`

The Semantic Web

The Semantic Web

What is it?

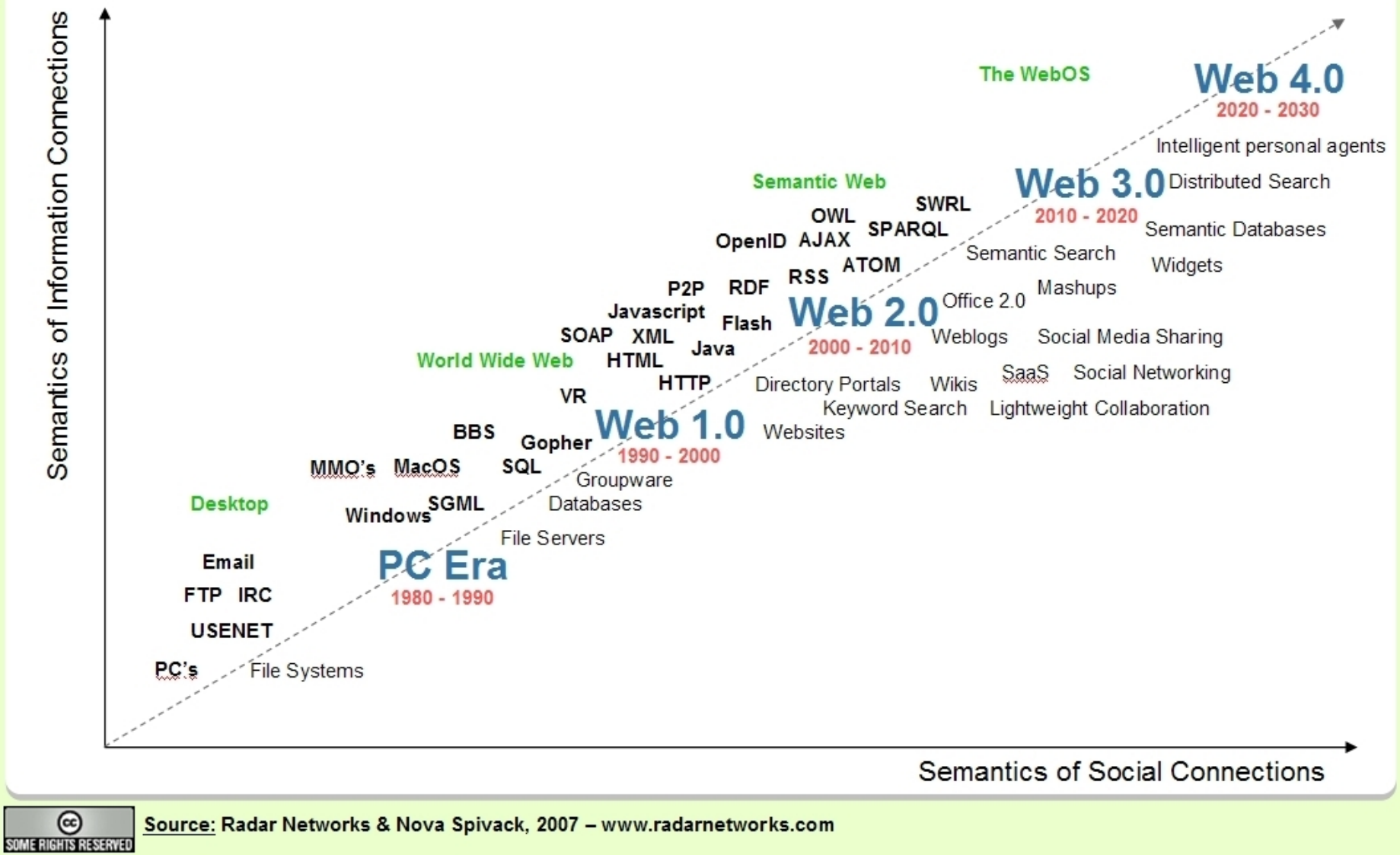
- A collaborative movement led by W3C
- Promotes common data formats
- Moving from *unstructured documents* into a **web of data**.
- *"Web 3.0"* is sometimes used as a synonym for the semantic web.

> *The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries* [1].

[1] "W3C Semantic Web Activity". World Wide Web Consortium (W3C). November 7, 2011

Future of the Web

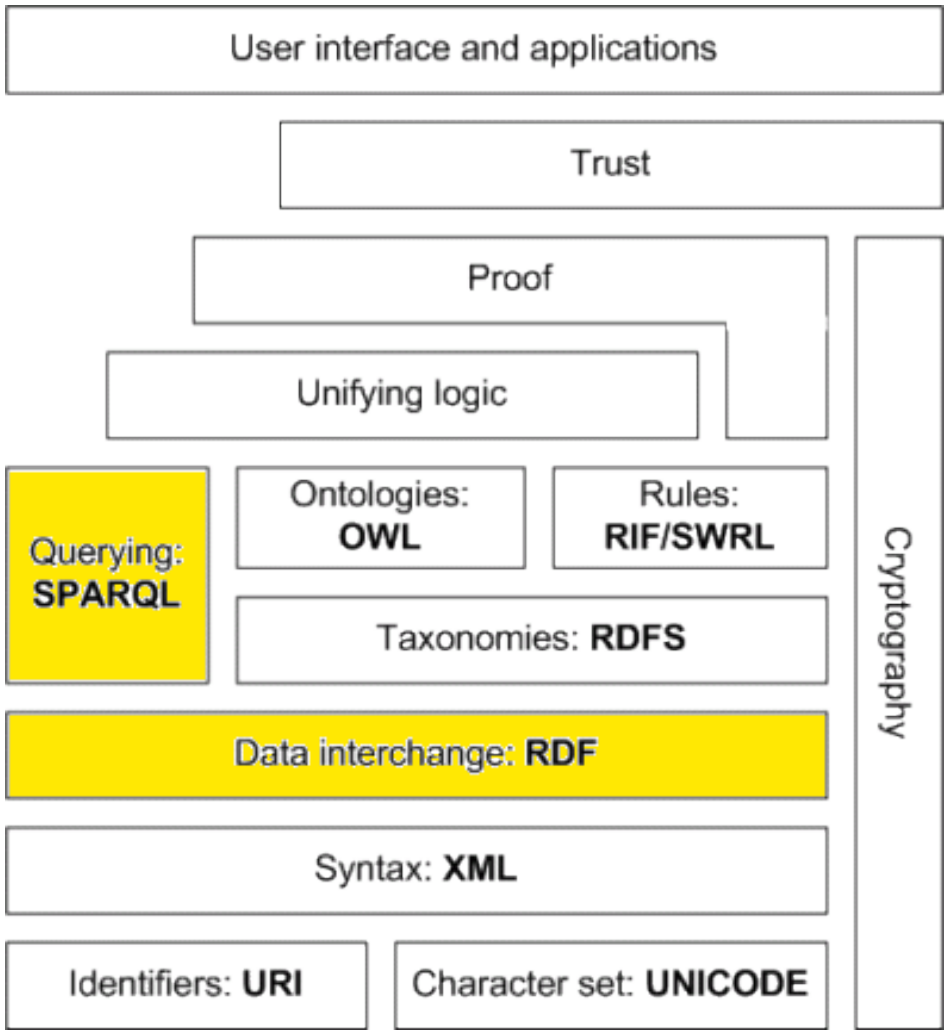
Web connectivity



Source: Radar Networks & Nova Spivack, 2007 – www.radarnetworks.com

The Semantic Web

Semantic Web Stack



The Semantic Web

Principles

- **URI** is simply a Web identifier
  - A disambiguation mechanism for distributed data
  - Start with *http://* or *ftp://* ...
  - Anyone can create a URI! e.g.
    - ★ `https://twitter.com/#!/robstewartUK`
    - ★ `http://dblp.l3s.de/d2r/page/authors/Tim_Berners-Lee`

[2] though not yet standardised

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    - `http://dblp.l3s.de/d2r/page/authors/Tim_Berners-Lee`
- **RDF** statements consist of three parts:

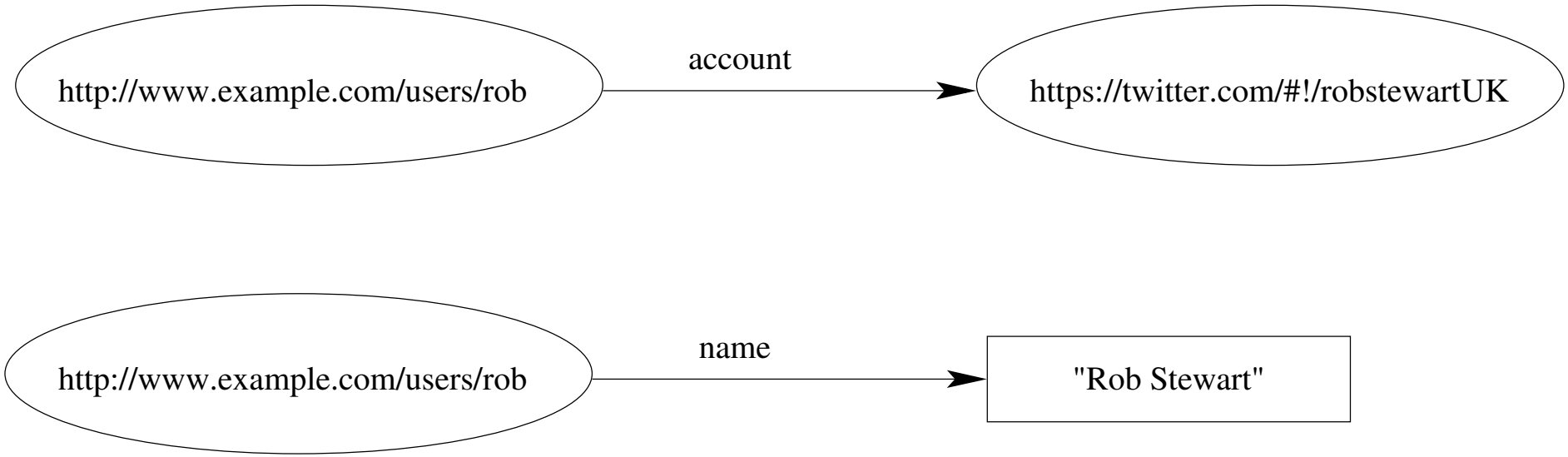
Subject	is the *resource* being described
Predicate	indicates a relationship with...
Object	is either a resource or a *literal*

  - RDF can be serialised in XML, N3, Turtle and JSON[2].

[2] though not yet standardised

The Semantic Web

Two RDF triples



The Semantic Web

Resource Description Framework serialised in XML

```
<?xml version="1.0"?>
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:foaf="http://xmlns.com/foaf/0.1/">
<rdf:RDF>
  <rdf:Description about="http://www.example.com/users/rob">
    <foaf:name>Rob Stewart</foaf:name>
    <foaf:account
       rdf:resource="https://twitter.com/#!/robstewartUK" />
  </rdf:Description>
</rdf:RDF>
```

The Semantic Web

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<?xml version="1.0"?>
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   </rdf:Description>
</rdf:RDF>
```

Key

Prefixes | Subject | Predicate | Object

The Semantic Web

SPARQL

SPARQL **P**rotocol **a**nd **R**DF **Q**uery **L**anguage

- And RDF query language to retrieve and manipulate persisted RDF
- On 15th January 2008, SPARQL 1.0 became W3C recommendation

- Four query forms
  - `SELECT` Extracts raw values to a table format
  - `CONSTRUCT` Extracts raw values into RDF
  - `ASK` Queries for the existence of a triple
  - `DESCRIBE` Extracts triples where specified URI is subject

The Semantic Web

SPARQL SELECT

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?account
WHERE {
 ?person foaf:name ?name
 ?person foaf:account ?account
}
```

name	account
“Rob Stewart”	<https://twitter.com/#!/robstewartUK>

The Semantic Web

SPARQL DESCRIBE

```
DESCRIBE <http://www.example.com/users/rob>
```

```
<?xml version="1.0"?>
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:foaf="http://xmlns.com/foaf/0.1/">
<rdf:RDF>
  <rdf:Description about="http://www.example.com/users/rob">
    <foaf:name>Rob Stewart</foaf:name>
    <foaf:account
       rdf:resource="https://twitter.com/#!/robstewartUK" />
  </rdf:Description>
</rdf:RDF>
```

The Semantic Web

SPARQL CONSTRUCT

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX example: <http://www.example.org/onto/>
CONSTRUCT { ?person example:hasName ?name }
WHERE {
  ?person foaf:name ?name
}
```

name	account
“Rob Stewart”	<https://twitter.com/#!/robstewartUK>

The Semantic Web

SPARQL ASK

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
ASK { ?x foaf:name "Rob Stewart" }
```

Yes.

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
ASK {?x foaf:topic_interest
        <http://www.dbpedia.org/resource/Closed_source_software>}
```

No.

Linked Open Data

Linked Open Data

What is it?

- Linked Data
  - Semantic structured data...
  - Using semantic web principles (e.g. RDF)
  - Referencing disambiguated URIs means data is interlinked

Linked Open Data

What is it?

- Linked Data
  - Semantic structured data...
  - Using semantic web principles (e.g. RDF)
  - Referencing disambiguated URIs means data is interlinked
- Open Data
  - Certain data should be freely available to use and republish
  - Without copyright, patents, or imposed control
  - Philosophy correlates to *open source code & open access*.

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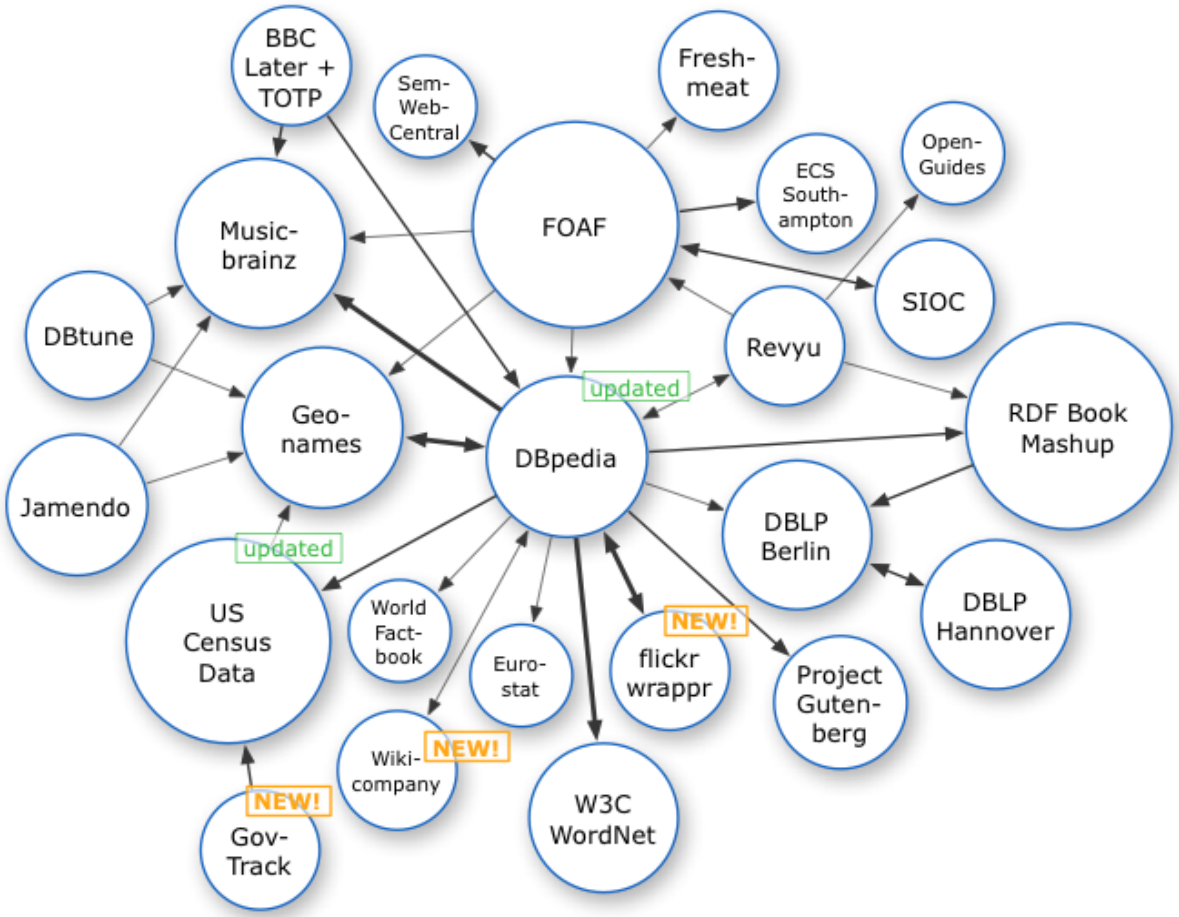
  - Philosophy correlates to *open source code & open access*.
- Linked Open Data!
  - LOD project aims to publish open data sets as RDF. Data sources include:
    - ★ DBpedia
    - ★ Geonames
    - ★ MusicBrainz
    - ★ DBLP

Linked Open Data

In September 2007



Linked Open Data

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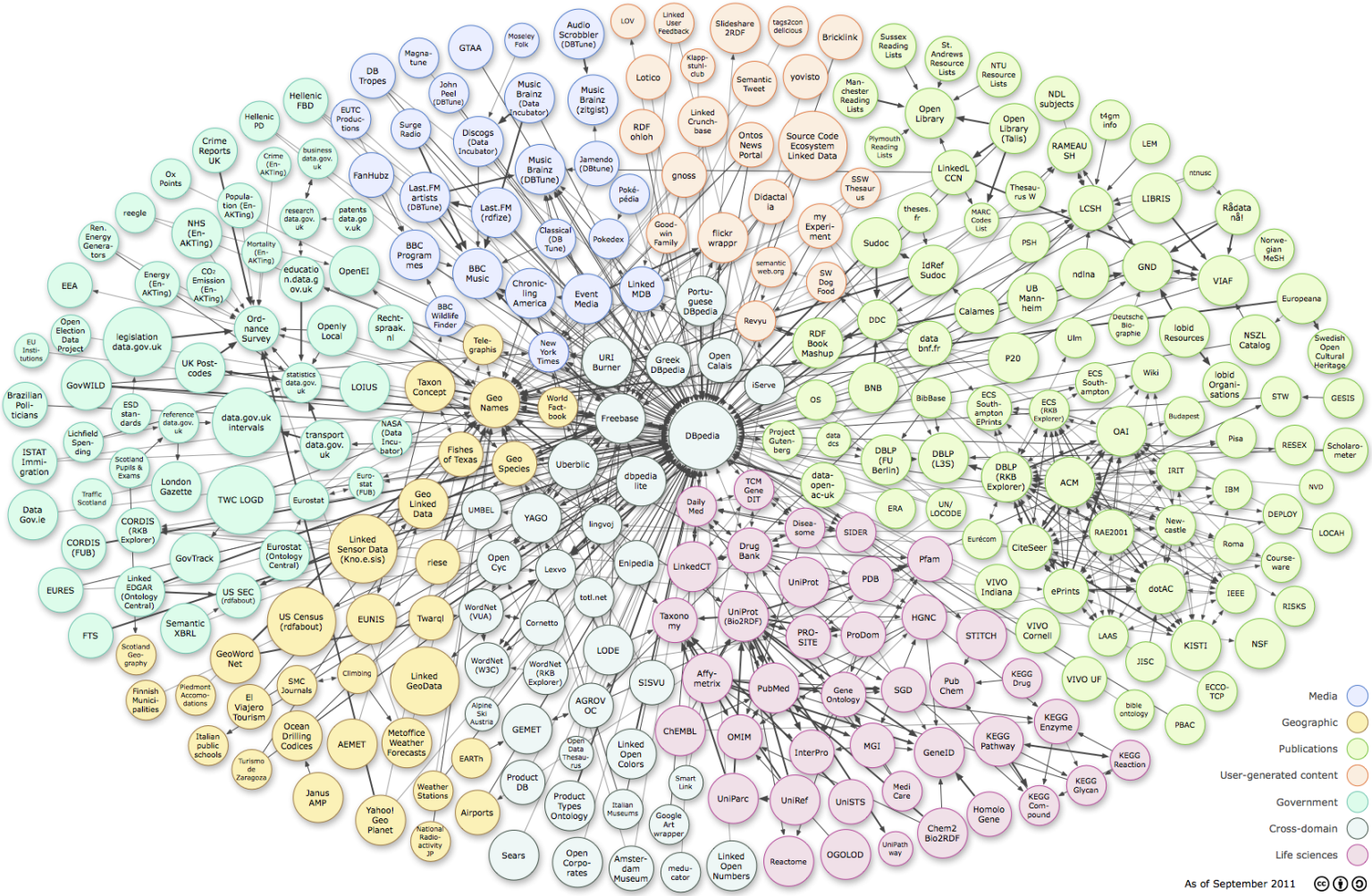
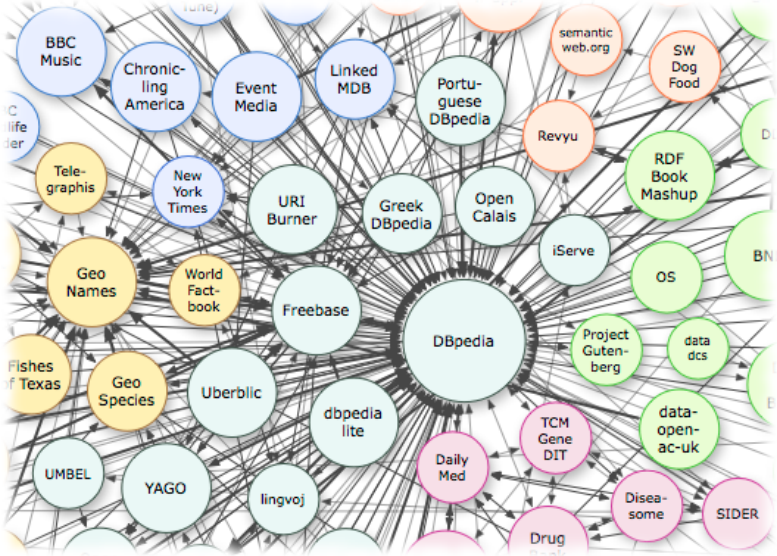


Linked Open Data

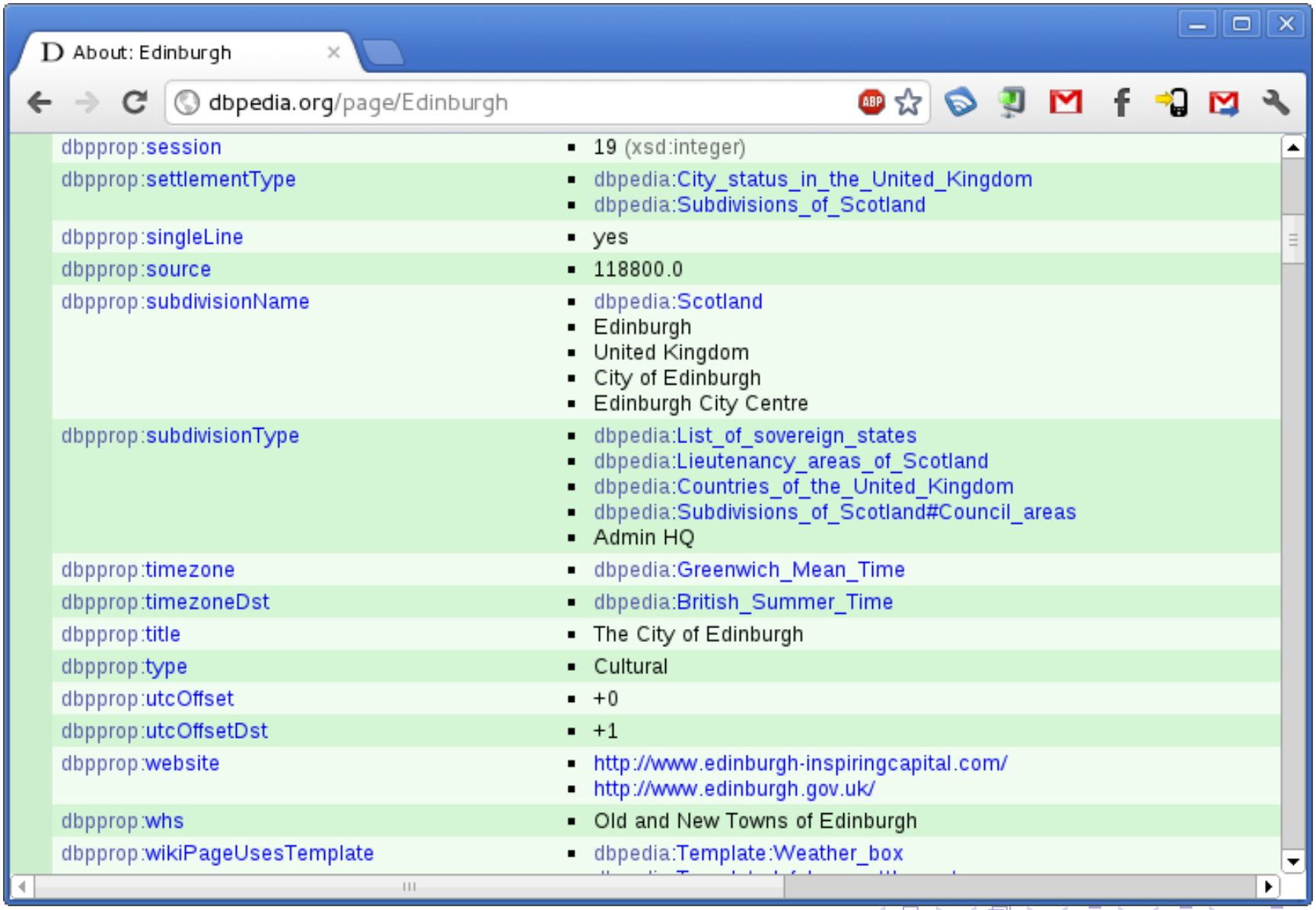
What is DBpedia?



- Extracts structured content from *Wikipedia* pages.
- Query relationships associated with Wikipedia resources...
- Including links to other semantic datasets (which is cool!).
- Describes *3.64 million* things, including...
  - *416,000* persons
  - *526,000* places
  - and *169,000* organisations

Linked Open Data

Resource Example - `http://dbpedia.org/resource/Edinburgh`



dbpprop:session	19 (xsd:integer)
dbpprop:settlementType	dbpedia:City_status_in_the_United_Kingdom dbpedia:Subdivisions_of_Scotland
dbpprop:singleLine	yes
dbpprop:source	118800.0
dbpprop:subdivisionName	dbpedia:Scotland Edinburgh United Kingdom City of Edinburgh Edinburgh City Centre
dbpprop:subdivisionType	dbpedia:List_of_sovereign_states dbpedia:Lieutenancy_areas_of_Scotland dbpedia:Countries_of_the_United_Kingdom dbpedia:Subdivisions_of_Scotland#Council_areas Admin HQ
dbpprop:timezone	dbpedia:Greenwich_Mean_Time
dbpprop:timezoneDst	dbpedia:British_Summer_Time
dbpprop:title	The City of Edinburgh
dbpprop:type	Cultural
dbpprop:utcOffset	+0
dbpprop:utcOffsetDst	+1
dbpprop:website	http://www.edinburgh-inspiringcapital.com/ http://www.edinburgh.gov.uk/
dbpprop:whs	Old and New Towns of Edinburgh
dbpprop:wikiPageUsesTemplate	dbpedia:Template:Weather_box

Linked Open Data

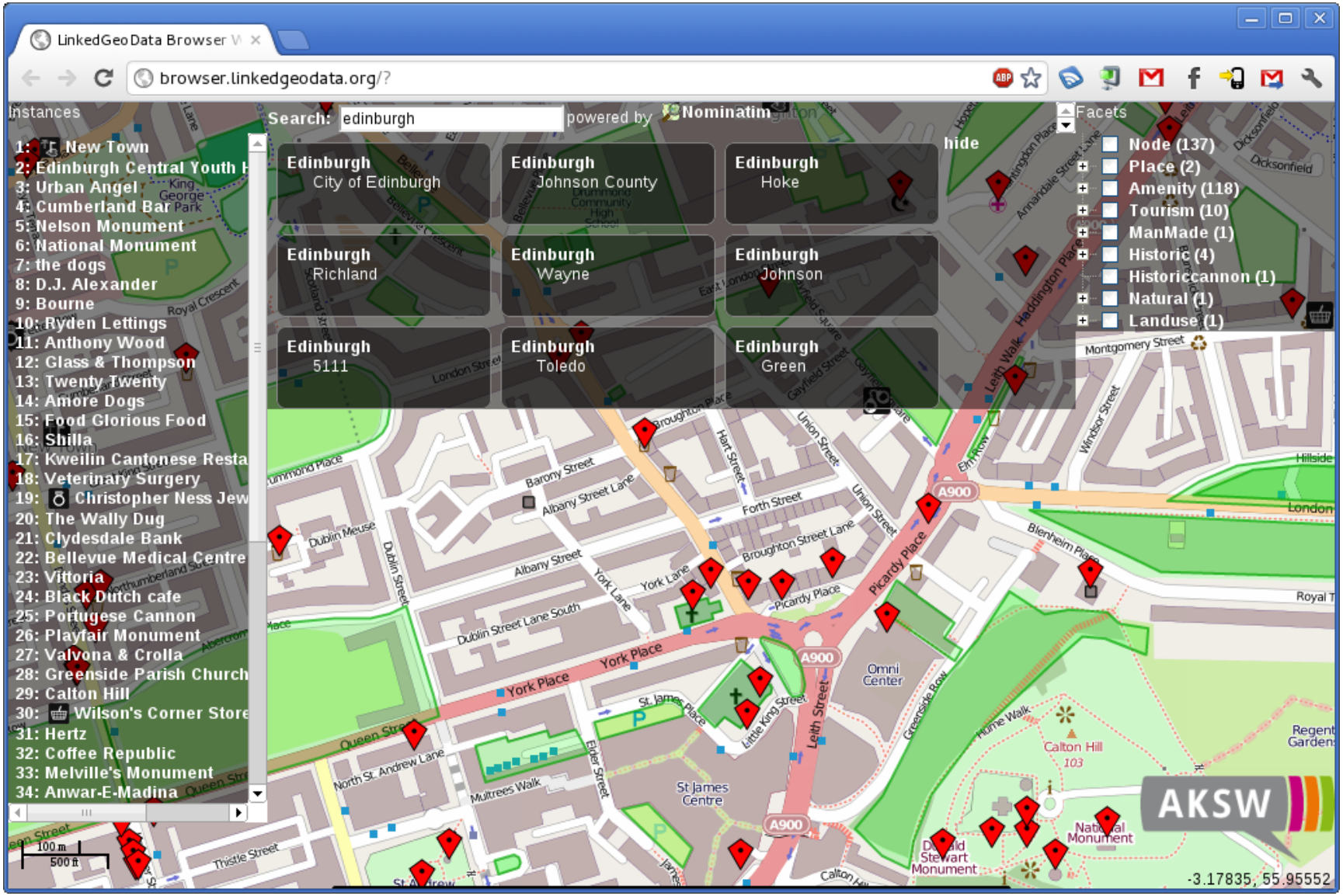
Linked Geo Data Project

- Effort to add spatial dimension to *web of data*
- Uses *crowd sourced* information from OpenStreetMap
- Interlinked resources with other knowledge bases on LOD network

- Information of 350 million nodes and 30 million ways...
- Resulting in over 2 billion triples!

Linked Open Data

Linked Geo Data Project



Linked Open Data - Project case study

SerenA - *Chance Encounters in the Space of Ideas*

- Homepage: `http://www.serena.ac.uk`
- Aims to bring closer people with *ideas*, *places*, *relevant documents*, *people*. . . resources!
- Presentation of ideas and resources, plus explanation of chain reasoning is *really* important for perceived **serendipity**.
- Implementation efforts are in progress. . .
  - Information seeking on cloud of *Linked Open Data*
  - *Agent framework* used for autonomous search and interface scheduling

For more implementation info: `http://goo.gl/ZGsfJ`

Semantic Web

Real World Applications

- **Web search**
  - `schema.org` used by Microsoft, Google and Yahoo.

    "A shared markup vocabulary makes easier for webmasters to decide on a markup schema and get the maximum benefit for their efforts" [3].

- **Retail**
  - `http://www.bestbuy.com`
    - ★ Exposes RDF describing their products
    - ★ 450,000 items, 60 triples per item... 27 million triples!

    "Its easy to sell the top 20 products using keywords, but surfacing the long tail is where the data makes the difference." - *Jay Myers, Best Buy* [4]

[3] http://schema.org/

[4] Best Buy Adopts RDF and the Open Web http://goo.gl/EWar

Semantic Web

JISC Monitoring Unit Data as RDF

- Project leader: Wilbert Kraan (`@wilm` on Twitter)
- JISCMU...

> *supports JISC policy and planning by providing a quality assurance role in monitoring the performance and use of JISC services.* [5]

- Example - full *institute* data as RDF/XML
  - `http://data.jiscmu.ac.uk/rest/organisations/`

```
SELECT ?Institution ?p ?o
WHERE{
?Institution a mu:Organisation .
?Institution mu:OfficialName "University of Edinburgh" .
?Institution ?p ?o . }
```

[5] http://www.jiscmu.ac.uk/about/

Semantic Web

Linked Data: JISC Institute data

Institution	p	o
http://data.jiscmu.ac.uk/rest/organisations/id/83	http://purl.org/dc/dcam/memberOf	SUNCAT Contributing Library
http://data.jiscmu.ac.uk/rest/organisations/id/83	http://purl.org/dc/dcam/memberOf	universitas 21
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:AlphabetisedName	Edinburgh, University of
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:Country	Scotland
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:Fax	0131 650 2147
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:JiscBanding	A
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:JiscFundedJanetConnection	true
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:LastChange	Join Organisation To
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:MailPoint	Old College
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:NetworkRegion	EaStMAN
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:OfficialName	University of Edinburgh
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:PostCode	EH8 9YL
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:Sector	Higher Education
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:Street	South Bridge
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:Telephone	0131 650 1000
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:Territory	Edinburgh & Lothian
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:Town	Edinburgh
http://data.jiscmu.ac.uk/rest/organisations/id/83	mu:Website	http://www.ed.ac.uk/

Semantic Web Toolkits

Semantic Web Toolkits

Popular Toolkits

Functional languages

- scardf (Scala)
- Wilbur (Common Lisp)
- Clojure-rdf (Clojure)
- *(Nothing for Erlang?)*

(Other languages)

- Jena (Java)
- Sesame (Java)
- Redland (C)
- rdfquery (Javascript)
- RAP (php)
- SWI-Prolog (prolog)
- Many more...

Jena

A very popular semantic web framework in Java

> *"Semantic Web applications. Jena provides a collection of tools and Java libraries to help you to develop semantic web and linked-data apps, tools and servers."*

- Support for serialisation of RDF in XML, N-triples and Turtle formats
- Ontology API for handling OWL and RDFS ontologies
- Rule-based inference engine for reasoning with RDF and OWL
- Query engine compliant with the latest SPARQL specification
- Lots more...

We'll be comparing RDF4H with Jena for RDF querying and manipulation.

Semantic Web Toolkits

Haskell packages

rdf4h is a library for working with RDF in Haskell.

hsparql includes a DSL to easily create queries, as well as methods to submit those queries to a SPARQL server, returning the results as simple Haskell data structures

swish is another library for working with RDF in Haskell. It explores Haskell as "a scripting language for the Semantic Web".

Haskell libraries

Looking at rdf4h

- **Author** Calvin Smith
- **Maintainers** Alex McCausland; Calvin Smith
- **Source code**
  - Calvin (upstream)
    - `darcs get http://protempore.net/rdf4h/`
  - Alex's fork
    - `git clone git://github.com/amccausl/RDF4H.git`

Semantic Web Toolkits

RDF4H

rdf4h is a library for working with RDF in Haskell.

- Supports parsing and serialisation of file formats:
  - N-Triples
  - Turtle
  - XML
- Provides type representation of:
  - RDF triples
  - Prefix mappings; namespaces ...
- Querying over data:
  - Sorting triples
  - Finding resources
  - Isomorphic graph equality
  - And other stuff...

RDF4H

Types

```
data Triple =
      Triple {-# UNPACK #-} !Node {-# UNPACK #-} !Node {-# UNPACK #-} !Node

type Triples = [Triple]
type Subject = Node
type Predicate = Node
type Object = Node

data Node =
  -- |An RDF URI reference
  UNode {-# UNPACK #-} !FastString

  -- |An RDF blank node
  | BNode {-# UNPACK #-} !FastString

  -- |An RDF blank node with an auto-generated identifier,
  --  as used in Turtle.
  | BNodeGen  {-# UNPACK #-} !Int

  -- |An RDF literal.
  | LNode {-# UNPACK #-} !LValue
```

RDF4H

RDF type class

```
class RDF rdf where
  -- |Return the base URL of this graph, if any.
  baseUrl :: rdf → Maybe BaseUrl

  -- |Return the prefix mappings defined for this graph, if any.
  prefixMappings :: rdf → PrefixMappings

  -- |Merges specified prefix mappings with the existing mappings
  addPrefixMappings :: rdf → PrefixMappings → Bool → rdf

  -- |Return an empty RDF graph.
  empty :: rdf

  -- |Return a graph containing all the given triples.
  mkRdf :: Triples → Maybe BaseUrl → PrefixMappings → rdf

  -- |Return all triples in the graph, as a list.
  triplesOf :: rdf → Triples

  -- |Return the triples in the graph that match the given pattern.
  query :: rdf → Maybe Subject → Maybe Predicate → Maybe Object → Triples
```

RDF4H

RDF instances

TriplesGraph contains a list-backed graph implementation suitable for smallish graphs or for temporary graphs that will not be queried. If you might have duplicate triples, use `MGraph` instead, which is also more efficient.

MGraph A simple graph implementation backed by `Data.Map`.

RDF4H

Useful functions

```
-- |Return a URIRef node for the given bytestring URI.
unode :: ByteString → Node

-- |Return a blank node using the given string identifier.
bnode :: ByteString →  Node

-- |Return a literal node using the given LValue.
lnode :: LValue →  Node

-- |Constructor functions for LValue
plainL :: ByteString → LValue
plainLL :: ByteString → ByteString → LValue
typedL :: ByteString → FastString → LValue

-- |A constructor function for 'Triple'
triple :: Subject → Predicate → Object → Triple

subjectOf :: Triple → Node
predicateOf :: Triple → Node
objectOf :: Triple → Node

isIsomorphic :: forall rdf1 rdf2. (RDF rdf1, RDF rdf2) ⇒ rdf1 → rdf2 → Bool
```

Comparing RDF4H and Jena

Reading an RDF file

Java

```
final public void readFile(String filename) throws FileNotFoundException {
        Model model = ModelFactory.createDefaultModel();
        String str = new Scanner(new File("file.rdf")).useDelimiter("Z").next();
        InputStream is = new ByteArrayInputStream(str.getBytes());
        BufferedReader br = new BufferedReader(new InputStreamReader(is));
        model.read(br, null);
    }
```

Haskell

```
readRDFFile :: IO TriplesGraph
readRDFFile = do
  contents ← readFile "file.rdf"
  let (Right rdf) = parseXmlRDF Nothing Nothing (B.pack contents)
  return rdf
```

Comparing RDF4H and Jena

Extracting Triples from Graphs

Java

```
final public Collection<Triple> getTriples(Model model){
        Collection<Triple> triples = new LinkedList<Triple>();
        StmtIterator stmts = model.listStatements();
        Statement s;
        while (stmts.hasNext()){
            s = stmts.nextStatement();
            triples.add(s.asTriple());
        }
        return triples;
}
```

Haskell

```
getTriples :: TriplesGraph → Triples
getTriples graph = triplesOf graph
```

Comparing RDF4H and Jena

Checking node type

Java

```
final public String checkNodeType(Node node){
        String str = null;
        if (node.isURI())           str = node + " is URI";
        else if(node.isBlank())     str = node + " is blank";
        else if(node.isLiteral()) str = node + " is literal";
        return str;
    }
```

Haskell

```
checkNodeType :: Node → String
checkNodeType node
  | isUNode node = (show node) ++ " is URI"
  | isBNode node = (show node) ++ " is blank"
  | isLNode node = (show node) ++ " is literal"
```

Comparing RDF4H and Jena

Constructing triples with language literal

Java

```
final public Triple makeTriple(String s, String p, String oLangLiteral){
        Model model = ModelFactory.createDefaultModel();
        Node subj = model.createResource(s).asNode();
        Node pred = model.createResource(p).asNode();
        Node obj = model.createLiteral(oLangLiteral,"en").asNode();
        return new Triple(subj,pred,obj);
    }
```

Haskell

```
mkTriple :: String → String → String → Triple
mkTriple s p o =
  let subj = unode (s2b s)
      pred = unode (s2b p)
      obj =  lnode (plainLL (s2b o) (s2b "en"))
  in triple subj pred obj
```

Comparing RDF4H and Jena

Constructing RDF graphs in Java

```
final public Model mkModel(){
 Model model = ModelFactory.createDefaultModel();
 String foafNS = "http://xmlns.com/foaf/0.1/";
 model.setNsPrefix("foaf", foafNS);
 Property topic_interest = model.createProperty(foafNS, "topic_interest");
 Property account = model.createProperty(foafNS, "account");
 Resource me = model.createResource("http://example.org/users/robstewart");
 Resource twitter = model.createResource("https://twitter.com/#!/robstewartUK");
 Resource haskell = model.createResource(
    "http://dbpedia.org/resource/Haskell_(programming_language)");
 Statement stmt;
 stmt = model.createStatement(me, account, twitter);
 model.add(stmt);
 stmt = model.createStatement(me, topic_interest, haskell);
 model.add(stmt);
 return model;
    }
```

Comparing RDF4H and Jena

Constructing RDF graphs in Haskell

```
mkGraph :: TriplesGraph
mkGraph = mkRdf
  [Triple
    ((unode ∘ s2b) "http://example.org/users/robstewart")
    ((unode ∘ s2b) "foaf:topic_interest")
    ((unode ∘ s2b) "http://dbpedia.org/resource/Haskell_(programming_language)")
  ,Triple
    ((unode ∘ s2b) "http://example.org/users/robstewart")
    ((unode ∘ s2b) "foaf:account")
    ((unode ∘ s2b) "https://twitter.com/#!/robstewartUK")
  ]
  Nothing
  (PrefixMappings
    (Map.fromList [ (s2b "foaf", s2b "http://xmlns.com/foaf/0.1/") ]))
```

Haskell libraries

Looking at swish

- **Author** Graham Klyne
- **Maintainers** Doug Burke
- **Source code**
  - Doug
    - `hg clone https://bitbucket.org/doug_burke/swish`

Semantic Web Toolkits

A quick look at Swish

Homepage:
`http://www.ninebynine.org/RDFNotes/Swish/Intro.html`

- Haskell framework for performing deductions on RDF data
- Graph isomorphism equality and differences
- Inference engine
  - Forward chain reasoning
  - Backward chain reasoning
  - Proof checking module
- Horn-style rule implementations
- RDF formal semantics entailment rule implementation
- Ready-to-run command line and script-driven programs

Haskell libraries

Looking at hsparql

- **Author** Jeff Wheeler
- **Maintainer** Rob Stewart
- **Source code**
  - `git clone git://github.com/robstewart57/hsparql.git`

Hsparql

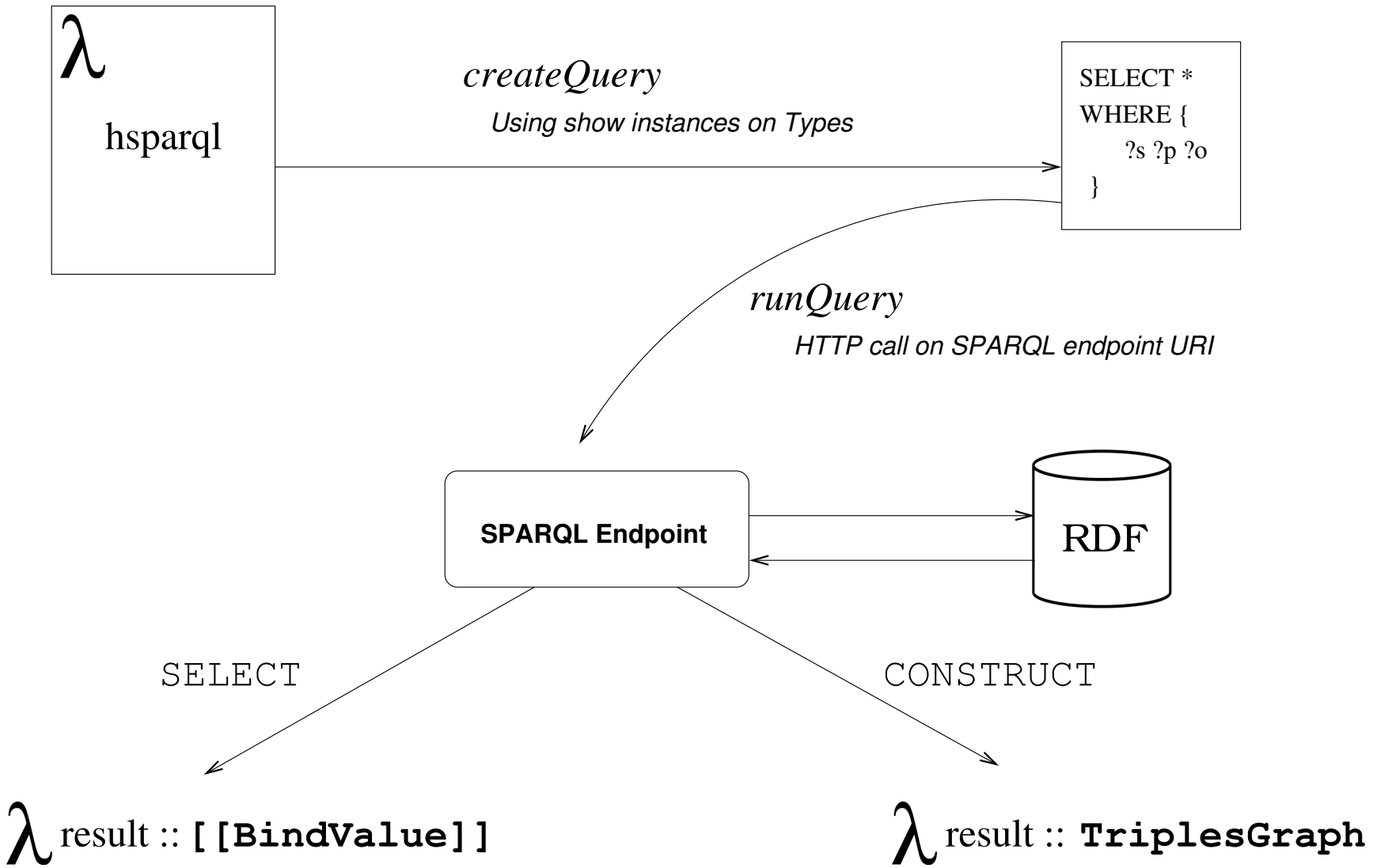
hsparql

hsparql includes a SPARQL domain specific language...

- To easily create SPARQL queries
- Includes functions for submitting SPARQL queries
  - For `CONSTRUCT` and `SELECT` queries
- Includes SPARQL response data structures
  - SPARQL Query Solutions (for `select` queries)
  - RDF graphs (for `construct` queries)

Hsparql

Flow



Hsparql

Generating SPARQL Queries - Types

```
data Duplicates = NoLimits | Distinct | Reduced

data Prefix = Prefix String IRIRef

data IRIRef = IRIRef String
            | PrefixedName Prefix String

data RDFLiteral = RDFLiteral String
                | RDFLiteralLang String String
                | RDFLiteralIRIRef String IRIRef

data Relation = Equal | NotEqual | LessThan | GreaterThan
       | LessThanOrEqual | GreaterThanOrEqual

data Operation = Add | Subtract | Multiply | Divide

data OrderBy = Asc Expr
             | Desc Expr
```

Hsparql

Generating SPARQL Queries - Types

```
-- |Permit variables and values to seamlessly be put into 'triple'
-- class TermLike a where

data QueryType = SelectType | ConstructType | TypeNotSet

data QueryForm = SelectForm QueryData | ConstructForm QueryData

-- |Local representations of incoming XML results.
data BindingValue =
   URI String                    -- ^Absolute reference to remote resource.
   | Literal String              -- ^Simple literal string.
   | TypedLiteral String String -- ^Literal element with type resource
   | LangLiteral String String  -- ^Literal element with language resource
   | Unbound                     -- ^Unbound result value
  deriving (Show, Eq)

data ConstructQuery = ConstructQuery
    { queryConstructs :: [Pattern] }

data SelectQuery = SelectQuery
    { queryVars :: [Variable] }
```

Hsparql

Examples of show instances

```
instance QueryShow Relation where
  qshow Equal                = "="
  qshow NotEqual             = "!="
  qshow LessThan             = "<"
  qshow GreaterThan          = ">"
  qshow LessThanOrEqual      = "≤"
  qshow GreaterThanOrEqual = "≥"

instance QueryShow OrderBy where
  qshow (Asc e)  = "ASC(" ++ qshow e ++ ")"
  qshow (Desc e) = "DESC(" ++ qshow e ++ ")"

instance QueryShow QueryForm where
  qshow (SelectForm qd) =  unwords
                         [ "SELECT"
                          , qshow (duplicates qd)
                          , qshow (vars qd)
                         ]

  qshow (ConstructForm qd) = "CONSTRUCT { " ++ qshow (constructTriples qd) ++ " }"
```

Hsparql

Generating a simple SELECT query

```
PREFIX resource: <http://dbpedia.org/resource/>
PREFIX dbprop: <http://dbpedia.org/property/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?page
WHERE {
  ?x dbprop:genre resource:Web_browser .
  ?x foaf:name ?name .
  ?x foaf:page ?page .
}
```

Hsparql

Generating a simple SELECT query

```
simpleSelect :: Query SelectQuery
simpleSelect = do
    resource <- prefix "dbprop" (iriRef "http://dbpedia.org/resource/")
    dbpprop  <- prefix "dbpedia" (iriRef "http://dbpedia.org/property/")
    foaf     <- prefix "foaf" (iriRef "http://xmlns.com/foaf/0.1/")

    x    <- var
    name <- var
    page <- var

    triple x (dbpprop .:. "genre") (resource .:. "Web_browser")

    triple x (foaf .:. "name") name
    triple x (foaf .:. "page") page

    return SelectQuery { queryVars = [name, page] }
```

Hsparql

Generating a simple CONSTRUCT query

```
simpleConstruct :: Query ConstructQuery
simpleConstruct = do
    resource <- prefix "dbpedia" (iriRef "http://dbpedia.org/resource/")
    dbpprop  <- prefix "dbprop" (iriRef "http://dbpedia.org/property/")
    foaf     <- prefix "foaf" (iriRef "http://xmlns.com/foaf/0.1/")
    example  <- prefix "example" (iriRef "http://www.example.com/")

    x    <- var
    name <- var
    page <- var

    construct <- constructTriple x (example .:. "hasName") name

    triple x (dbpprop .:. "genre") (resource .:. "Web_browser")
    triple x (foaf .:. "name") name
    triple x (foaf .:. "page") page

    return ConstructQuery { queryConstructs = [construct] }
```

Hsparql Under The Hood

Submitting SPARQL SELECT query

```
-- |Transform the 'String' result from the HTTP request into a two-dimensional
--  table storing the bindings for each variable in each row.
structureContent :: String -> Maybe [[BindingValue]]

-- |Connect to remote 'EndPoint' and find all possible bindings for the
--  'Variable's in the 'SelectQuery' action.
selectQuery :: EndPoint -> Query SelectQuery -> IO (Maybe [[BindingValue]])
selectQuery ep q = do
    let uri      = ep ++ "?" ++ urlEncodeVars [("query", createSelectQuery q)]
        request  = replaceHeader HdrUserAgent "hsparql-client" (getRequest uri)
    response <- simpleHTTP request >>= getResponseBody
    return ( structureContent response )
```

Hsparql Under The Hood

Submitting SPARQL CONSTRUCT query

```
-- |Connect to remote 'EndPoint' and construct 'TriplesGraph' from given
--  'ConstructQuery' action. /Provisional implementation/.
constructQuery :: EndPoint -> Query ConstructQuery -> IO TriplesGraph
constructQuery ep q = do
    let uri      = ep ++ "?" ++ urlEncodeVars [("query", createConstructQuery q )]
        h1 = mkHeader HdrUserAgent "hsparql-client"
        h2 = mkHeader HdrAccept "text/rdf+n3"
        request = Request { rqURI = fromJust (parseURI uri)
                          , rqHeaders = [h1,h2]
                          , rqMethod = GET
                          , rqBody = ""
                          }
    response <- simpleHTTP request >>= getResponseBody
    let rdfGraph = parseString (TurtleParser Nothing Nothing) (B.pack response)
    case rdfGraph of
     Left e -> error (show e)
     Right graph -> return graph
```

Hsparql

Hsparql in use

```
-- Here's a SELECT query example
selectExample :: IO ()
selectExample = do
  (Just s) <- selectQuery "http://dbpedia.org/sparql" simpleSelect
  putStrLn . take 500 . show $ s


-- Here's a CONSTRUCT query example
constructExample :: IO ()
constructExample = do
  rdfGraph <- constructQuery "http://dbpedia.org/sparql" simpleConstruct
  mapM_ print (triplesOf rdfGraph)
```

Hsparql

A more interesting SELECT example...

```
berliners :: Query SelectQuery
berliners = do
    xsd  <- prefix "xsd" (iriRef "http://www.w3.org/2001/XMLSchema#")
    prop <- prefix "prop" (iriRef "http://dbpedia.org/property/")
    dbo  <- prefix "dbo" (iriRef "http://dbpedia.org/ontology/")
    foaf <- prefix "foaf" (iriRef "http://xmlns.com/foaf/0.1/")
    resc <- prefix "resc" (iriRef "http://dbpedia.org/resource/")

    name     <- var
    birth    <- var
    death    <- var
    person   <- var
    knownfor <- var

    triple person (prop .:. "birthPlace") (resc .:. "Berlin")
    triple person (dbo  .:. "birthdate")  birth
    triple person (foaf .:. "name")       name
    triple person (dbo  .:. "deathdate")  death

    filterExpr $ birth .<. ("1900-01-01", xsd .:. "date")

    optional $ triple person (prop .:. "KnownFor") knownfor

    return SelectQuery { queryVars = [name, birth, death, person, knownfor] }
```

Hsparql

A more interesting SELECT example *result*

```
[
 [LangLiteral "Wilhelm II" "en",
  TypedLiteral "1859-01-27" "http://www.w3.org/2001/XMLSchema#date",
  TypedLiteral "1941-06-04" "http://www.w3.org/2001/XMLSchema#date",
  URI "http://dbpedia.org/resource/Wilhelm_II,_German_Emperor",
  Unbound]
,[LangLiteral "German Emperor Wilhelm II" "en",
  TypedLiteral "1859-01-27" "http://www.w3.org/2001/XMLSchema#date",
  TypedLiteral "1941-06-04" "http://www.w3.org/2001/XMLSchema#date",
  URI "http://dbpedia.org/resource/Wilhelm_II,_German_Emperor",
  Unbound]
,[LangLiteral "Edmund Landau" "en",
  TypedLiteral "1877-02-14" "http://www.w3.org/2001/XMLSchema#date",
  TypedLiteral "1938-02-19" "http://www.w3.org/2001/XMLSchema#date",
  URI "http://dbpedia.org/resource/Edmund_Landau",
  Unbound]
]
```

Hsparql

Another interesting SELECT example...

```
selectExample :: IO ()
selectExample = do
  (Just s) <- selectQuery "http://api.talis.com/stores/bbc-backstage/services/sparql" drWhoQuery
  putStrLn . show $ s

drWhoQuery :: Query SelectQuery
drWhoQuery = do
  rdfs <- prefix "rdfs" (iriRef "http://www.w3.org/2000/01/rdf-schema#")
  po  <- prefix "po" (iriRef "http://purl.org/ontology/po/")
  dc    <- prefix "dc" (iriRef "http://purl.org/dc/elements/1.1/")

  position <- var
  title    <- var
  syn      <- var
  series   <- var
  episode  <- var

  triple (iriRef "http://www.bbc.co.uk/programmes/b006q2x0#programme") (po .:. "series") series
  triple series (dc .:. "title") "Series 3"
  triple series (po .:. "episode") episode

  triple episode (dc .:. "title") title
  triple episode (po .:. "position") position
  triple episode (po .:. "short_synopsis") syn

  return SelectQuery { queryVars = [position, title, syn] }
```

Hsparql

Dr Who results

Position	Title	Syn
6	The Lazarus Experiment	Martha has to save her family from the schemes of the monstrous Professor Lazarus.
13	Last of the Time Lords	Earth has been conquered and the Master rules supreme. Can Martha Jones save the world?
2	The Shakespeare Code	In Elizabethan England, William Shakespeare is under the control of witch-like creatures.
10	Blink	Only the Doctor can stop the Weeping Angels, but he's lost in time.
5	Evolution of the Daleks	As a new Dalek Empire rises in 1930s New York, the Doctor must enter an unholy alliance.
4	Daleks in Manhattan	The Doctor finds his oldest enemies at work on top of the Empire State Building.
7	42	The Doctor and Martha have to stop a spaceship from hurtling into the sun.
8	Human Nature	A schoolteacher called John Smith dreams of adventures in time and space.
11	Utopia	Captain Jack Harkness storms back into the Doctor's life.
12	The Sound of Drums	Harry Saxon becomes Prime Minister, but his dark ambitions reach beyond the stars.
1	Smith and Jones	When Martha Jones finds herself on the moon, she meets a stranger called the Doctor.
3	Gridlock	The Doctor takes Martha to New Earth, only to find that the city has become a deadly trap.
9	The Family of Blood	It's 1913 and war comes to England early, as the terrifying Family hunt for the Doctor.

A Plan?

Towards a Semantic Web Toolkit for Haskell

Future Work

- rdf4h
  - Move towards feature parity with Jena Models
- swish
  - Complete UTF-8 handling
  - Internals: move to *polyparse*, *LookupMap*...
- hsparql

```
askQuery      :: EndPoint -> Query AskQuery -> IO Bool
describeQuery :: EndPoint -> Query DescribeQuery -> IO TriplesGraph
```

- A unified semantic web Type representation!
  - Have all 3 packages use the same representations
    - ★ *prefix mappings, URIs, typed literals...*
  - Unified serialisation of XML, N3, Turtle

Towards a Semantic Web Toolkit

A place for Haskell in the Semantic Web

- A feature rich RDF library
  - Providing an array of high level APIs working with RDF

and

- SPARQL construction & execution
  - *Programmatically* generate and execute SPARQL queries...
  - Living within the Haskell type system along the way

and

- A scripting interface to IO with RDF
  - To read, write & merge RDF graphs
  - Apply forward and backward chain reasoning rule inference
  - Compare graphs for equality

The end.

Next Ed Lambda meetup

- Title: **Haskell vs. F# vs. Scala: High-level Language Features and Parallelism Support**
- Speakers: *Prabhat Totoo, Pantazis Deligiannis & Hans-Wolfgang Loidl*
- When: 7pm - Tuesday 8th May, 2012

Abstract

This paper provides a performance and programmability comparison of parallel programming support in Haskell, F# and Scala. Emphasis is given on advanced language features such as purity, evaluation order, and integration of functional aspects into imperative and object-oriented languages. The expressive power of each language is analysed, especially regarding their support for parallelism. We quantify parallel performance and assess succinctness and modularity of the code.