Web Data Integration

Data Exchange Formats

- Part 2 -
1. Data Exchange Formats - Part I
   1. Character Encoding
   2. CSV
   3. XML

2. Data Exchange Formats - Part II
   1. JSON
      1. Basic Syntax
      2. JSON in Java
   2. RDF
      1. RDF Data Model
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      3. RDF Schema
      4. SPARQL Query Language
      5. RDF in Java
2.1 JavaScript Object Notation (JSON)

- JavaScript
  - a popular programming language on the Web
  - understood by all Web browsers
  - originally:
    - used for simple interactions (e.g., change image on mouse over)
  - nowadays:
    - also used for complex applications, Ajax (Asynchronous JavaScript and XML)
    - for instance used to implement Google Docs

- JSON
  - is a lightweight data exchange format that uses JavaScript syntax
  - easy to read and write for humans and machines
  - less verbose alternative to XML
JavaScript Object Notation (JSON)

- **Basics:**
  - objects are noted as in JavaScript
  - objects are enclosed in curly brackets `{ … }`
  - data is organized in key value pairs separated by colons `{ key : value }`

- **Example:**
  ```json
  { "firstname" : "John" ,
    "lastname" : "Smith" ,
    "age" : 46 }
  ```

- **Simple processing with JavaScript:**
  ```javascript
  var obj = JSON.parse(jsonString) ;
  var name = obj.firstname + " " + obj.lastname ;
  ```
The JSON Syntax

Arrays in JSON

```json
{
  "id" : 1,
  "name" : "Good book",
  "tags" : [
    "Novel",
    "Fiction"
  ],
  "stock" : {
    "warehouse" : 300,
    "retail" : 20
  }
}
```

Source: json.org
Nested Objects in JSON

JSON

```json
{  "firstname" : "John",
  "lastname" : "Smith",
  "age" : 46,
  "employer" : {
    "name" : "Tech Inc.",
    "address" : {
      "street" : "Main St.",
      "number" : 14,
      "city" : "Smalltown"
    }
  }
}
```

XML

```xml
<firstname>John</firstname>
<lastname>Smith</lastname>
<age>46</age>
<employer>
  <name>Tech Inc.</name>
  <address>
    <street>Main St.</street>
    <number>14</number>
    <city>Smalltown</city>
  </address>
</employer>
```
JSON versus XML

• JSON is a lot like XML
  – Data Model: Tree
  – Opening/closing tags/brackets

• Differences
  – More compact notation than XML
  – No id/idref – JSON data is \textit{strictly} tree shaped
  – Less data types (only strings and numbers)
  – No schema language*
  – No query language*

*although people are working on that and there are various proposals.
Processing JSON with Java

- **GSON**
  - Library for parsing and serializing JSON in Java
  - https://github.com/google/gson

- **Class Definition**

  ```java
  public class Person {
    private String firstname;
    private String lastname;
    private int age;
  }
  ```

- **Object Deserialization**

  ```java
  Person obj = gson.fromJson(jsonObject, Person.class);
  ```

- **Object Serialization**

  ```java
  String json = gson.toJson(obj);
  ```
2.2 Resource Description Framework (RDF)

Graph data model designed for sharing data on the Web.

- Applications:
  - annotation of Web pages (RDFa)
  - publication of data on the Web (Linked Data)
  - exchange of graph data between applications

- View 1: Sentences in form Subject-Predicate-Object (called Triples)
  - „Chris works at University of Mannheim.“

- View 2: Labeled directed graph
  - A set of RDF triples forms a labeled directed graph
RDF Basic Concepts

- **Resources**
  - everything (a person, a place, a web site…) is a resource
  - are identified by URI references
  - may have one or more types (e.g. foaf:Person)

- **Literals**
  - are data values, e.g., strings or integers
  - may only be objects, not subjects of triples
  - may have a data type or a language tag

- **Predicates (Properties)**
  - Connect resources to other resources
  - Connect resources to literals
RDF as a Labeled Directed Graph

http://dws.uni-mannheim.de/person1

http://dws.uni-mannheim.de/papers/paper1

"Christian Bizer"

http://dbpedia.org/resource/RDFa

“The WebDataCommons Dataset Series”

dc:creator

dc:title

dc:subject

rdfs:label

Resource

Literal

predicate
The Role of URIs in RDF

- In a typical database or XML document, identifiers are unique only with respect to the database or XML document.
  - they have no meaning outside the database/document

- RDF uses URI’s as global identifiers for resources
  - hence, multiple data sets can refer to the same entity
  - key benefit for data integration!

- Advantage
  - global references between data items are possible (Linked Data)

- Disadvantage
  - RDF is rather verbose.
  - most syntaxes use QNames (e.g. dc:subject).

http://dws.uni-mannheim.de/papers/paper1
http://dbpedia.org/resource/RDFa
dc:subject
Language Tags and Data Types

• RDF literals may have language tags or data types (but not both)

• Examples:

  ex:Muenchen ex:hasName "München"@de .
  ex:Muenchen ex:hasName "Munich"@en .
  ex:Muenchen ex:hasPopulation "1356594 "^^xsd:integer .
  ex:Muenchen ex:hasFoundingYear "1158-01-01"^^xsd:date .

• RDF uses the XML Schema data types

• Be careful, the following three literals are different:
  – "München"
  – "München"@de
  – "München"^^xsd:string
RDF Syntaxes

There are various syntaxes for serializing RDF graphs.

1. N-Triples and Turtle: Plain text syntaxes
2. RDF/XML: RDF serialization in XML
3. RDFa: Syntax for embedding RDF into HTML pages
4. JSON-LD: RDF serialization in JSON
N-Triples and Turtle

- **N-Triples** is a line-based, plain text serialization format for RDF graphs
  
  ```
  <http://www.dws.uni-mannheim.de/teaching/wdi>
  <http://purl.org/dc/elements/1.1/subject>
  <http://www.dws.uni-mannheim.de/teaching/wdi>
  
  - Turtle extends N-Triples with QNames
    
    ```
    @BASE <http://www.dws.uni-mannheim.de/teaching/>
    @PREFIX dc: <http://purl.org/dc/elements/1.1/>
    @PREFIX dbpedia: <http://dbpedia.org/resource/>
    :wdi dc:title "Web Data Integration"@en .
    ```
    - Point marks end of triple
    - URIs are enclosed by `<>`
    - Literals enclosed by " "
    - Empty prefix refers to BASE namespace
RDF/XML

• XML-based serialization format for RDF

• Defining resources:

```
<rdf:Description rdf:about="http://www.dws.uni-mannheim.de/teaching/wdi">
    <dc:creator>Christian Bizer</dc:creator>
</rdf:Description>
```

• Resource with a type:

```
<rdf:Description rdf:about="http://www.dws.uni-mannheim.de/teaching/wdi">
    <rdf:type rdf:resource="http://www.dws.uni-mannheim.de/teaching/Lecture"/>
    <dc:creator>Christian Bizer</dc:creator>
</rdf:Description>
```

• Alternative notation:

```
<dws:Lecture rdf:about="http://www.dws.uni-mannheim.de/teaching/wdi" />
```
JSON-LD

- JSON syntax for embedding data into HTML pages
- Similar to Microdata and RDFa

```html
<script type="application/ld+json">
{
    "@context": "http://schema.org",
    "@type": "Organization",
    "url": "http://www.example.com",
    "name": "Unlimited Ball Bearings Corp.",
    "contactPoint": {
        "@type": "ContactPoint",
        "telephone": "+1-401-555-1212",
        "contactType": "Customer service"
    }
}
</script>
```

https://json-ld.org/
https://developers.google.com/search/docs/guides/intro-structured-data
2.3 RDF Schema

**Language for defining RDF vocabularies.**

- RDF schema provides for defining:
  - classes (that are used as types) and
  - properties (that are used as predicates)

- Example of an RDF schema vocabulary definition:
  
  ```
  dws:Teacher rdf:type rdfs:Class .
  dws:Course rdf:type rdfs:Class .
  dws:teaches rdf:type rdf:Property .
  ```

- Example of using the vocabulary:
  
  ```
  dws:ChrisBizer rdf:type dws:Teacher .
  dws:WebDataIntegration rdf:type dws:Course .
  dws:ChrisBizer dws:teaches dws:WebDataIntegration .
  ```
Classes and Properties may form Hierarchies

• Sub-class Definition
  \[
  \text{dws:UniversityTeacher} \ rdfs:subClassOf \ dws:Teacher .
  \]

• Sub-property Definition
  \[
  \text{dws:CourseName} \ rdfs:subPropertyOf \ dc:title .
  \]

• Implication: All dws:UniversityTeachers are also dws:Teachers

• Multiple inheritance is allowed
Domain and Range Definitions

• RDF Schema provides for defining domains and ranges of properties:

\[
\text{dws:teaches \ rdf:type \ rdf:Property .} \\
\text{dws:teaches \ rdfs:domain \ dws:Teacher .} \\
\text{dws:teaches \ rdfs:range \ dws:Lecture .}
\]

• Implications:
  1. All resources that have a \text{dws:teaches} property are of \text{rdf:type dws:Teacher}.
  2. All objects of \text{dws:teaches} triples are of \text{rdf:type dws:Lecture}.

• Domains and ranges are inherited to sub-properties
RDF Schema Reasoning

- Given the RDF schema
  
  dws:Teacher rdfs:subClassOf foaf:Person .
  dws:teaches rdfs:domain dws:Teacher .
  dws:teaches rdfs:range dws:Lecture .

- and the single triple
  
  dws:ChrisBizer dws:teaches dws:WebDataIntegration .

- A machine (reasoning engine) can infer (conclude) that
  
  dws:ChrisBizer rdf:type dws:Teacher .
  dws:ChrisBizer rdf:type foaf:Person .
  dws:WebDataIntegration rdf:type dws:Lecture .

- OWL (Web Ontology Language)
  - provides for more expressive definitions and inferences
  - see lecture: Semantic Web Technologies
Purpose of RDF Schema

• Recap: XML Schema defines *allowed* structures
• In contrast: RDF Schema *does not* constrain anything

• Purpose of XML Schema
  – validation of XML documents

• Purpose of RDF Schema
  – machine interpretability of RDF data
    – by URI references between different RDF schemata
      e.g. `dws:Teacher rdfs:subClassOf foaf:Person`
    – by inference of additional triples
    – *NOT* validation
  – *W3C RDF Data Shapes* provide for RDF validation
2.4 SPARQL

Language for querying RDF graphs.

- Queries are expressed in the form of triple patterns
- Query results are tabular and given as XML, JSON, or CSV
- The SPARQL Protocol is used to query remote endpoints
- Example query:

```sparql
PREFIX foaf: <http://xmlns.com/foaf/0.1/>  
SELECT ?name ?email  
WHERE {  
  ?person foaf:name ?name .  
}
```
**Triple Pattern Matching**

**RDF Graph**

- `dbpedia: The_Beatles`
  - `foaf:made`
  - `dc:title`
  - "Help!"
- `dbpedia: The_Beatles`
  - `foaf:made`
  - `dc:title`
  - "Abbey Road"
- `dbpedia: The_Beatles`
  - `foaf:made`
  - `dc:title`
  - "Let It Be"

**Triple Pattern**

- `dbpedia: The_Beatles`
  - `foaf:made`
  - `?album`
  - `dc:title`
  - `?title`

**Query Result**

<table>
<thead>
<tr>
<th>?album</th>
<th>?title</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://...">http://...</a></td>
<td>&quot;Help!&quot;</td>
</tr>
<tr>
<td><a href="http://...">http://...</a></td>
<td>&quot;Abbey Road&quot;</td>
</tr>
<tr>
<td><a href="http://...">http://...</a></td>
<td>&quot;Let It Be&quot;</td>
</tr>
</tbody>
</table>

Source: EUCLID - Querying Linked Data
Optional Triple Patterns

- Declaring triple patterns as OPTIONAL allows you to get query results even if only a subset of the patterns matches
  
  \[
  \text{WHERE \{ A OPTIONAL \{ B \} \}}
  \]

- Keep all solutions from A whether or not there is a matching solution for B

- Important for querying endpoints with a lot of missing values

- Example:

```sparql
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?name ?birth ?death
WHERE {
    ?person foaf:name ?name .
    OPTIONAL { ?person dbo:deathDate ?death . }
}
```
FILTER Clauses

- FILTER clauses keep only solutions that fulfil a condition (expression must evaluate to true)

- Example

```sql
PREFIX : <http://dbpedia.org/resource/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?name ?birth
WHERE {
  ?person foaf:name ?name .
  FILTER (?birth < "1900-01-01"^^xsd:date) .
}
```

- Comparators: = != < > <= >=

- Logical Operators: && || !

- Functions: SUBSTR(), regex(), month(now()), isURI(), …
  - more functions: http://www.w3.org/TR/sparql11-query/#SparqlOps
Solution Modifiers

- Sort results
  
  ORDER BY ?name

- Restrict number of results
  
  LIMIT 100

- Page over result list
  
  LIMIT 100
  OFFSET 0
  LIMIT 100
  OFFSET 100

PREFIX : <http://dbpedia.org/resource/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?name ?birth
WHERE {
    ?person foaf:name ?name .
}
ORDER BY ?name
LIMIT 10
OFFSET 100
2.5 Processing RDF in Java: Jena

• Jena is a popular framework for processing RDF in Java

• Download: https://jena.apache.org/

• Capabilities
  – supports various RDF syntaxes
  – SPARQL query language
  – RDF Schema and OWL reasoning
  – various storage back ends

• Central concepts
  – model (i.e., RDF graphs): class Model
  – resource: class Resource
• Read a graph from a URL (or local file):
  ```java
  model.read("http://dbpedia.org/resource/Mannheim");
  ```

• Navigating through a model
  ```java
  Resource mannheim =
      model.getResource("http://dbpedia.org/resource/Mannheim");

  Literal areaCode = mannheim.getProperty(
      "http://dbpedia.org/ontology/areaCode")
      .getLiteral();
  ```
String queryString = "SELECT ?x ...";
Query query = QueryFactory.create(queryString);
QueryExecution qe = QueryExecutionFactory.create(query, model);
ResultSet results = qe.execSelect();
while(results.hasNext()) {
    QuerySolution sol = results.next();
    String s = sol.get("x").toString();
    ...
}
Querying a Public SPARQL Endpoint

- Many RDF data sources provide SPARQL endpoints
  - e.g. DBpedia, Linked Movies Database, data.gov.uk, …
  - List of public endpoints: https://www.w3.org/wiki/SparqlEndpoints

- Access with Jena

```java
String query = "SELECT ...";
String endpoint = "http://dbpedia.org/sparql";
Query q = QueryFactory.create(strQuery);
QueryExecution qexec =
    QueryExecutionFactory.sparqlService(endpoint, q);
ResultSet RS = qexec.executeSelect();
```
Wrap-up: Data Exchange Formats

- Data is provided on the Web using various exchange formats
  - CSV
  - XML
  - JSON
  - RDF
  - ...
- Data exchange formats provide us with syntaxes for transferring data
- They do not solve the actual data integration challenges:
  1. Do two records describe the same real-world entity?
  2. Which elements in different schemata have the same meaning?
  3. Which data values from different sources should I trust?
- These challenges will be the topic of the upcoming lectures
3. References

- Standards and specifications
  - JSON: http://www.json.org/
  - RDF: http://www.w3.org/TR/rdf11-concepts/
  - RDF Schema: http://www.w3.org/TR/rdf-schema/
  - SPARQL: http://www.w3.org/TR/sparql11-overview/

- Tutorials
  - GSON: http://code.google.com/p/google-gson/
  - RDF: https://www.w3.org/TR/rdf-primer/
  - JENA: http://jena.apache.org/documentation/
  - Euclid Curriculum covering SPARQL: http://www.euclid-project.eu/

- Lecture
  - Semantic Web Technologies
Exercise: Querying DBpedia 1

- Query tool
  - http://dbpedia.org/snorql/
- Query 1: What is the population and the area code of Mannheim?
  - http://dbpedia.org/resource/Mannheim

```
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?name ?birth WHERE {
  ?person foaf:name ?name .
  FILTER (?birth < "1900-01-01"^^xsd:date) .
}
ORDER BY ?name
```

Results: Browse ▼ Go! Reset
Exercise: Querying DBpedia 2

- Query tool
  - http://dbpedia.org/snorql/

- Query 2: Find all German cities that have a population of more than 100,000 people?
Solution: Querying DBpedia

- Query 1

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?population ?areacode
WHERE {
:Mannheim dbo:populationTotal ?population .
}
```

- Query 2

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?city ?population
WHERE {
?city rdf:type dbo:City .
?city dbo:country :Germany .
FILTER (?population > "100000"^^xsd:integer)
}
```