Web Data Integration

Data Exchange Formats

- Part 2 -
Outline

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   2. CSV
   3. XML

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      1. Basic Syntax
      2. JSON in Java
   2. RDF
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      2. RDF Syntaxes
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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 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(jsonString, 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
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).
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

\[
<\text{http://www.dws.uni-mannheim.de/teaching/wdi}>
<\text{http://purl.org/dc/elements/1.1/subject}>
<\text{http://dbpedia.org/resource/RDFa}>
<\text{http://www.dws.uni-mannheim.de/teaching/wdi}>
<\text{http://purl.org/dc/elements/1.1/title}>
"\text{Web Data Integration}@en\ .
\]

- Turtle extends N-Triples with QNames

\[
\text{@BASE} <\text{http://www.dws.uni-mannheim.de/teaching/>}
\text{@PREFIX dc:} <\text{http://purl.org/dc/elements/1.1/}>
\text{@PREFIX dbpedia:} <\text{http://dbpedia.org/resource/>}
:wdi \text{dc:subject dbpedia:RDFa} .
:wdi \text{dc:title "Web Data Integration"en} .
\]

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

- 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:
  
  dws:teaches rdf:type rdf:Property .
  dws:teaches rdfs:domain dws:Teacher .
  dws:teaches rdfs:range dws:Lecture .

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

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

Prefix definition
Result definition
Triple patterns (variables)
Triple Pattern Matching

RDF Graph

- `foaf:made` relation between `dbpedia: The_Beatles` and albums
- DC:title property for album titles

Triple Pattern

- `dbpedia: The_Beatles`
- `?album`
- `?title`
  - DC:title property for album titles

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>
Optional Triple Patterns

- Declaring triple patterns as OPTIONAL allows you to get query results even if only a subset of the patterns matches
  
  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:

```
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
  
  ```sql
  ORDER BY ?name
  ```

- Restrict number of results
  
  ```sql
  LIMIT 100
  ```

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

```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 .
}
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
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?