Web Data Integration

Data Exchange Formats

- Part 2 -
Outline

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   2. Comma Separated Values (CSV)
   3. Extensible Markup Language (XML)

2. Data Exchange Formats - Part II
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      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
  - less verbose alternative to XML
  - widely adopted
    - by Web APIs as data exchange format
    - for embedding structured data in the HEAD section of HTML pages
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 ;
  var backToString = JSON.stringify(obj)
  ```
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)

- **Adoption**
  - XML: Wider adoption in enterprise context
  - JSON: Wider adoption in Web context
  - Programmable Web 2019:
    - 2800 XML APIs vs. 5400 JSON APIs
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, JSON-LD)
  - 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 page, …) 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/person451

"Christian Bizer"

http://dws.uni-mannheim.de/papers/paper671

"The WebDataCommons Dataset Series"

http://dbpedia.org/resource/RDFa

Resource

Literal

predicates

dc:creator

rdfs:label

dc:title

dc:subject
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, all data is connected to its origin
  - multiple data sets can refer to each other
  - lays the foundation for a global data space

- 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
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

```html
<http://www.dws.uni-mannheim.de/teaching/wdi>
<http://purl.org/dc/elements/1.1/subject>

<http://www.dws.uni-mannheim.de/teaching/wdi>
<http://purl.org/dc/elements/1.1/title>
"Web Data Integration"@en .
```

- **Turtle** extends N-Triples with QNames

```html
@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

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

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

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

- JSON syntax for RDF used for embedding RDF into the HEAD section of HTML pages

```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 a RDF schema vocabulary definition:

```
dws:Teacher rdf:type rdfs:Class .
dws:Course rdf:type rdfs:Class .
dws:teaches rdf:type rdf:Property .
```

- RDF triples 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

• Subclass Definition
  
  \[ \text{dws:UniversityTeacher} \ rdfs:subClassOf \ \text{dws:Teacher} \ . \]

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

• 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:Course .`

- 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:Course`.

- Domains and ranges are inherited to subproperties
RDF Schema Reasoning

• Given the RDF schema

  dws:Teacher rdfs:subClassOf foaf:Person .
  dws:teaches rdfs:domain dws:Teacher .
  dws:teaches rdfs:range dws:Course .

• 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:Course .

• OWL (Web Ontology Language)
  – provides for more expressive definitions and inferences
  – see course: 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 inferring additional triples
    – by setting links (correspondences) between different RDF terms
      e.g. dws:Teacher rdfs:subClassOf foaf:Person
        – NOT validation
  – W3C SHACL Shapes Constraint Language provide for RDF validation
    https://www.w3.org/TR/shacl/
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 .
}
```

Prefix definition
Result definition
Triple patterns (?x = variables)
Triple Pattern Matching

**RDF Graph**

- dbpedia: The_Beatles
  - foaf:made
    - dc:title
      - "Help!"
    - dc:title
      - "Abbey Road"
    - 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

  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:

```sql
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

```sparql
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
```
Exercise: Querying DBpedia 1

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

- Query tool
  - http://dbpedia.org/snorql/
Exercise: Querying DBpedia 2

- Question 2: Find all German cities that have a population of more than 100,000 people?
- Query tool
  - http://dbpedia.org/snorql/

SPARQL Explorer for http://dbpedia.org/sparql
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`
Processing RDF in Java: Jena

• 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 qexec =
    QueryExecutionFactory.create(query, model);
ResultSet results = qexec.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 GeoData, EU Open Data Portal, ...

- Access with Jena

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

• Data is provided on the Web using various exchange formats
  – CSV, XML, JSON, RDF, ....

• Exchange formats provide us with syntaxes for transferring data

• Exchange formats 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 conflicting values from different sources should I trust?

• These challenges will be the topics of the upcoming lectures

• Still, which format should I use for my application?
  • Answer depends more on social than on technical factors:
    • What formats are already used by others in wider application domain?
    • What formats can the programming language of choice read and write out of the box?
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: https://github.com/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/

- Course
  - IE 650 Knowledge Graphs