Web Data Integration

Data Exchange Formats

- Part 2 -
Outline

1. Data Exchange Formats - Part I
   1. Character Encoding
   2. Comma Separated Values (CSV)
   3. Extensible Markup Language (XML)

2. Data Exchange Formats - Part II
   1. JavaScript Object Notation (JSON)
      1. Basic Syntax
      2. JSON in Java
   2. Resource Description Framework (RDF)
      1. RDF Data Model
      2. RDF Syntaxes
      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:

```
{
  "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

Source: json.org

Arrays in JSON

```json
{
  "id" : 1,
  "name" : "Good book",
  "tags" : [
    "Novel",
    "Fiction"
  ],
  "stock" : {
    "warehouse" : 300,
    "retail" : 20
  }
}
```
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 compared to XML
  – no id/idref – JSON data is *strictly* tree shaped
  – less data types (only string, number, and Boolean)

• 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](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
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

  <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

  @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:

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

- RDF triples using the vocabulary:

```reason
{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**
  \[ \text{dws:UniversityTeacher} \text{ rdfs:subClassOf } \text{dws:Teacher} . \]

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

- **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:
  
  \[ \text{dws:teaches} \quad \text{rdf:type} \quad \text{rdf:Property} . \]
  
  \[ \text{dws:teaches} \quad \text{rdfs:domain} \quad \text{dws:Teacher} . \]
  
  \[ \text{dws:teaches} \quad \text{rdfs:range} \quad \text{dws:Course} . \]

- Implications:
  
  1. All resources that have a \text{dws:teaches} property are of \text{rdf:type} \text{dws:Teacher}.

  2. All objects of \text{dws:teaches} triples are of \text{rdf:type} \text{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: IE650 Knowledge Graphs
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:

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

**RDF Graph**

```
foaf:made
```

```
dbpedia: The_Beatles


dc:title

"Help!"
"Abbey Road"
"Let It Be"
```

**Triple Pattern**

```
dbpedia: The_Beatles

?album

foaf:made

?title

dc: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
  
  \[
  \text{WHERE } \{ \text{ A OPTIONAL } \{ \text{ B } \} \} \]

- 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 fulfill 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**
  
  ```sparql
  ORDER BY ?name
  ```

- **Restrict number of results**
  
  ```sparql
  LIMIT 100
  ```

- **Page over result list**
  
  ```sparql
  LIMIT 100
  OFFSET 0
  LIMIT 100
  OFFSET 100
  ```

```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 .
}
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/

SPARQL Explorer for http://dbpedia.org/sparql

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

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

About: Mannheim
An Entity of Type: place, from Named Graph: http://dbpedia.org/

Die Quadrat- und Universitätsstadt Mannheim (kurz: Mannheim [mæmːəm], Kurpfalz mit ihrem stadträtenden Barockschloss, einer der größten Schlossanlagen.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>dbo:PopulatesPlace</td>
<td><a href="http://dbpedia.org/resource/Mannheim">http://dbpedia.org/resource/Mannheim</a></td>
</tr>
<tr>
<td>dbo:abstract</td>
<td>14496000.000000 (xsd:double)</td>
</tr>
<tr>
<td>dbo:abstract</td>
<td>Mannheim (kurz: Mannheim [mæmːəm], Kurpfalz mit ihrem stadträtenden Barockschloss, einer der größten Schlossanlagen)</td>
</tr>
<tr>
<td>dbo:administrator</td>
<td>dbr:Karlsruhe</td>
</tr>
<tr>
<td>dbo:areaCode</td>
<td>0621</td>
</tr>
<tr>
<td>dbo:areaTotal</td>
<td>14496000.000000 (xsd:double)</td>
</tr>
<tr>
<td>dbo:country</td>
<td>dbr:Germany</td>
</tr>
<tr>
<td>dbo:elevation</td>
<td>97 000000 (xsd:double)</td>
</tr>
<tr>
<td>dbo:federalState</td>
<td>dbr:Ebaden-Württemberg</td>
</tr>
<tr>
<td>dbo:leaderTitle</td>
<td>Lord Mayor</td>
</tr>
<tr>
<td>dbo:populationAsOf</td>
<td>2008-12-31 (xsd:date)</td>
</tr>
<tr>
<td>dbo:populationMetro</td>
<td>2362384 (xsd:integer)</td>
</tr>
<tr>
<td>dbo:populationTotal</td>
<td>311142 (xsd:integer)</td>
</tr>
<tr>
<td>dbo:postalCode</td>
<td>68001-68309</td>
</tr>
<tr>
<td>dbo:thumbnail</td>
<td><a href="http://commons.wikimedia.org/wiki/Mannheim">http://commons.wikimedia.org/wiki/Mannheim</a></td>
</tr>
</tbody>
</table>
Solution: Querying DBpedia 1

- Question: What is the population and the area code of Mannheim?
- SPARQL Query:

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

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

- Result:

```
SPARQL results:
population  areacode
2362046    "0621"
```
Exercise: Querying DBpedia 2

- Question 2: Find all Settlements in Germany that have a population of more than 100,000 people?

- Query tool
  - [http://dbpedia.org/snorql/](http://dbpedia.org/snorql/)

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About: Mannheim

An Entity of Type: place, from Named Graph: [http://dbpedia.org](http://dbpedia.org)


<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>dbo:administrativeDistrict</td>
<td>db:Karlsruhe</td>
</tr>
<tr>
<td>dbo:areaCode</td>
<td>0521</td>
</tr>
<tr>
<td>dbo:areaTotal</td>
<td>144960000 000000 (xsd:double)</td>
</tr>
<tr>
<td>dbo:country</td>
<td>db:Germany</td>
</tr>
<tr>
<td>dbo:elevation</td>
<td>97 00000 (xsd:double)</td>
</tr>
<tr>
<td>dbo:federalState</td>
<td>db:Eaden-Württemberg</td>
</tr>
<tr>
<td>dbo:leaderTitle</td>
<td>Lord Mayor</td>
</tr>
<tr>
<td>dbo:populationAsOf</td>
<td>2008-12-31 (xsd:date)</td>
</tr>
<tr>
<td>dbo:populationMetro</td>
<td>23632046 (xsd:integer)</td>
</tr>
<tr>
<td>dbo:populationTotal</td>
<td>311142 (xsd:integer)</td>
</tr>
<tr>
<td>dbo:postalCode</td>
<td>68001-68309</td>
</tr>
<tr>
<td>dbo:thumbnail</td>
<td><a href="http://commons.wikimedia.org/wiki">http://commons.wikimedia.org/wiki</a></td>
</tr>
</tbody>
</table>
Solution: Querying DBpedia 2

- Question: Find all settlements in Germany that have a populationMetro of more than 100,000 people?
- SPARQL Query:

```
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 dbo:country :Germany .
    FILTER (?population > "100000"^^xsd:nonNegativeInteger)
}
```

- Result:

<table>
<thead>
<tr>
<th>city</th>
<th>population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Munich_Metropolitan_Region</td>
<td>5991144</td>
</tr>
<tr>
<td>Hamburg</td>
<td>5107429</td>
</tr>
<tr>
<td>Hamburg_Metropolitan_Region</td>
<td>6100000</td>
</tr>
<tr>
<td>Hannover-Braunschweig-Göttingen-Wolfsburg_Metropolitan_Region</td>
<td>3900000</td>
</tr>
<tr>
<td>Stuttgart_Metropolitan_Region</td>
<td>5300000</td>
</tr>
<tr>
<td>Central_German_Metropolitan_Region</td>
<td>2400000</td>
</tr>
<tr>
<td>Ruhr</td>
<td>1069783</td>
</tr>
<tr>
<td>Berlin</td>
<td>6148600</td>
</tr>
<tr>
<td>BerlinBrandenburg_Metropolitan_Region</td>
<td>6004057</td>
</tr>
<tr>
<td>Frankfurt_Rhine-Main_Regional_Authority</td>
<td>2295568</td>
</tr>
<tr>
<td>Frankfurt_Rhine-Main</td>
<td>6008516</td>
</tr>
<tr>
<td>Rhine-Neckar</td>
<td>2362000</td>
</tr>
<tr>
<td>Rhine-Rhine</td>
<td>1009783</td>
</tr>
</tbody>
</table>
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, …
  • List of public endpoints:

• Access with Jena

  String queryString = "SELECT ...";
  String endpoint = "http://dbpedia.org/sparql";
  Query query = QueryFactory.create(queryString);
  QueryExecution qexec =
    QueryExecutionFactory.sparqlService(endpoint, query);
  ResultSet RS = qexec.executeQuerySelect();
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