TECHNISCHE UNIVERSITÄT DRESDEN

FOUNDATIONS OF SEMANTIC WEB TECHNOLOGIES

Introduction to RDF

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DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

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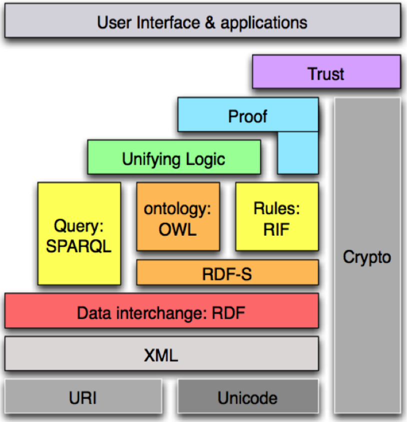
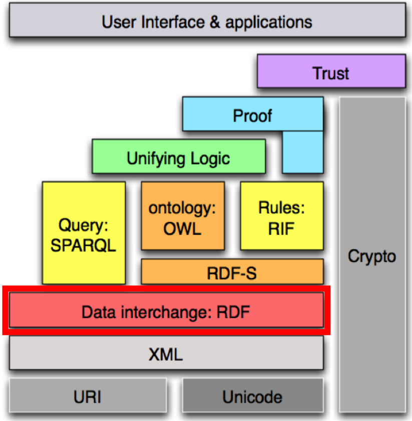
Content

Introduction to RDF



Introduction to RDF



Agenda

- XML – Motivation
- RDF data model
- Syntax for RDF: Turtle and XML
- Datatypes
- Multi-Valued Relationships
- Blank Nodes
- Lists
- Graph Definitions
- RDF in Practice

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Disadvantages of XML

- tag names ambiguous (can be tackled by name spaces and URIs)
- tree structure not optimal for
  - intuitive description of the data
  - information integration
- Example: how to encode in a tree the sentence:
  "The book 'Semantic Web – Grundlagen' was published by Springer-Verlag."

Modeling Problems in XML

"The book 'Semantic Web – Grundlagen' was published by Springer-Verlag."

Modeling Problems in XML

"The book 'Semantic Web – Grundlagen' was published by Springer-Verlag."

```
<Published>
 <Publisher>Springer-Verlag</Publisher>
 <Book>Semantic Web -- Grundlagen</Book>
</Published>
```

Modeling Problems in XML

"The book 'Semantic Web – Grundlagen' was published by Springer-Verlag."

```
<Published>
 <Publisher>Springer-Verlag</Publisher>
 <Book>Semantic Web -- Grundlagen</Book>
</Published>
```

```
<Publisher Name="Springer-Verlag">
 <Published Book="Semantic Web -- Grundlagen"/>
</Publisher>
```

Modeling Problems in XML

"The book 'Semantic Web – Grundlagen' was published by Springer-Verlag."

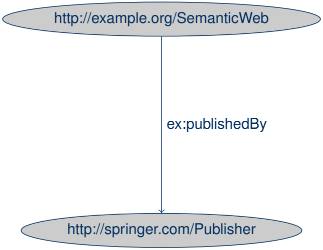
```
<Published>
 <Publisher>Springer-Verlag</Publisher>
 <Book>Semantic Web -- Grundlagen</Book>
</Published>

<Publisher Name="Springer-Verlag">
 <Published Book="Semantic Web -- Grundlagen"/>
</Publisher>

<Book Name="Semantic Web -- Grundlagen">
 <Publisher Publisher="Springer-Verlag"/>
</Book>
```

RDF: Graphs instead of Trees

Solution: Representation as (directed) Graphs



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General Remarks about RDF

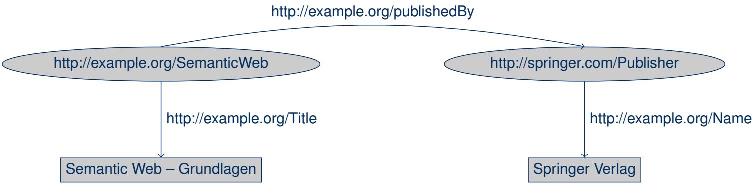
- “Resource Description Framework”
- W3C Recommendation (http://www.w3.org/RDF)
- currently being revised
- RDF is a data model
  - originally: assign metadata to Web resources, later more general usage
  - encodes structured information
  - universal, machine-readable exchange format

Constituents of RDF Graphs

- URIs
  - for uniquely referencing resources
  - (already discussed at XML lecture)
- literals
  - describe data values that do not have an independent existence
- blank nodes
  - allow for stating the existence of some individual (and describing its properties) without giving it a name

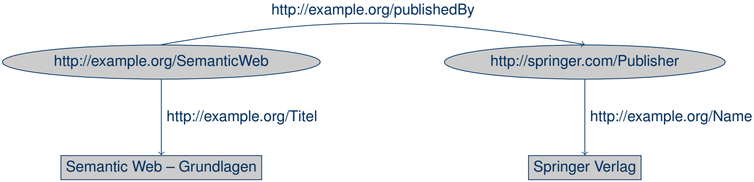
Literals

- for representing data values
- noted as strings
- interpreted by an associated datatype
- literals without datatype are treated like strings



Graph as a Set of Triples

- there are several different ways to represent graphs
- we use list of (node-edge-node) triples



RDF Triple

Constituents of an RDF triple

- inspired by linguistic but not always an exact match
- permitted occurrences of constituents:
  subject : URI or blank node
  predicate: URI (also called properties)
  object: URI or blank node or literal
- node and edge labels are unique, thus the original graph can be reconstructed from the list of triples

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Simple Syntax for RDF

- direct enumeration of triples:
  - N3: “Notation 3” – comprehensive formalism
  - N-Triples: fraction of N3
  - Turtle: extension of N-Triples (by abbreviations)
- Turtle syntax:
  - URIs in angular brackets
  - literals in quotes
  - tripels terminated by full stop
  - spaces and line breaks outside such delimiters are ignored

Turtle Syntax: Abbreviations

Example

```
<http://ex.org/SemanticWeb> <http://ex.org/publishedBy>
  <http://springer.com/Publisher> .
<http://ex.org/SemanticWeb> <http://ex.org/Titel>
  "Semantic Web -- Grundlagen" .
<http://springer.com/Verlag> <http://ex.org/Name>
  "Springer Verlag" .
```

In Turtle we can define prefix abbreviations:

```
@prefix ex:  <http://ex.org/> .
@prefix springer:  <http://springer.com/> .
ex:SemanticWeb ex:publishedBy springer:Publisher .
ex:SemanticWeb ex:Title "Semantic Web -- Grundlagen" .
springer:Publisher ex:Name "Springer Verlag" .
```

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Turtle Syntax: Abbreviations

Multiple triples with the same subject can be grouped:

```
@prefix ex:  <http://ex.org/> .
@prefix springer:  <http://springer.com/> .

ex:SemanticWeb     ex:publishedBy springer:Publisher ;
                   ex:Title       "Semantic Web -- Grundlagen" .
springer:Publisher ex:Name        "Springer Verlag" .
```

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Turtle Syntax: Abbreviations

Multiple triples with the same subject can be grouped:

```
@prefix ex:  <http://ex.org/> .
@prefix springer:  <http://springer.com/> .

ex:SemanticWeb     ex:publishedBy springer:Publisher ;
                   ex:Title       "Semantic Web -- Grundlagen" .
springer:Publisher ex:Name        "Springer Verlag" .
```

likewise triples with coinciding subject and predicate:

```
@prefix ex:  <http://ex.org/> .

ex:SemanticWeb ex:Author ex:Hitzler, ex:Krötzsch,
                         ex:Rudolph, ex:Sure ;
               ex:Titel  "Semantic Web -- Grundlagen" .
```

XML Syntax of RDF

- Turtle intuitively understandable, machine-processable
- yet, better tool support and available libraries for XML
- thus: XML syntax more wide-spread

XML Syntax of RDF

- like in XML, name spaces are used in order to disambiguate tag names
- RDF-specific tags have a predefined name space, by convention abbreviated with 'rdf'

```
<?xml version="1.0" encoding="utf-8"?>
<rdf:RDF
 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:ex="http://example.org/">

 <rdf:Description rdf:about="http://example.org/SemanticWeb">
  <ex:publishedBy>
   <rdf:Description rdf:about="http://springer.com/Publisher"/>
  </ex:publishedBy>
 </rdf:Description>

</rdf:RDF>
```

XML Syntax of RDF

- the rdf:Description element encodes the subject (the URI of which is stated as the value of the associated rdf:about attribute)
- every element directly nested into an rdf:Description element denotes a predicate (the URI of which is the element name),
- predicate elements in turn contain the triple's object as rdf:Description element

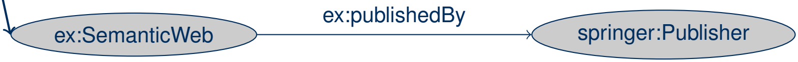
```
:
:
 <rdf:Description rdf:about="http://example.org/SemanticWeb">
  <ex:publishedBy>
   <rdf:Description rdf:about="http://springer.com/Publisher"/>
  </ex:publishedBy>
 </rdf:Description>
:
```

XML Syntax of RDF

```
<?xml version="1.0" encoding="utf-8"?>
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:ex="http://example.org/">
<rdf:Description rdf:about="http://example.org/SemanticWeb">
 <ex:publishedBy>
  <rdf:Description rdf:about="http://springer.com/Publisher"/>
 </ex:publishedBy>
</rdf:Description>
</rdf:RDF>
```

XML Syntax of RDF

```
<?xml version="1.0" encoding="utf-8"?>
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:ex="http://example.org/">
<rdf:Description rdf:about="http://example.org/SemanticWeb">
 <ex:publishedBy>
  <rdf:Description rdf:about="http://springer.com/Publisher"/>
 </ex:publishedBy>
</rdf:Description>
</rdf:RDF>
```



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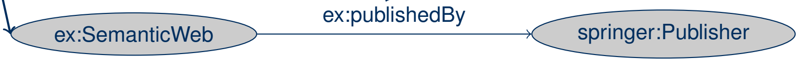
XML Syntax of RDF

```
<?xml version="1.0" encoding="utf-8"?>
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:ex="http://example.org/">
<rdf:Description rdf:about="http://example.org/SemanticWeb">
 <ex:publishedBy>
  <rdf:Description rdf:about="http://springer.com/Publisher"/>
 </ex:publishedBy>
</rdf:Description>
</rdf:RDF>
```



XML Syntax of RDF

```
<?xml version="1.0" encoding="utf-8"?>
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:ex="http://example.org/">
<rdf:Description rdf:about="http://example.org/SemanticWeb">
 <ex:publishedBy>
  <rdf:Description rdf:about="http://springer.com/Publisher"/>
 </ex:publishedBy>
</rdf:Description>
</rdf:RDF>
```

XML Syntax of RDF

- untyped literals can be included as free text into the predicate element
- condensed forms admissible:
  - one subject containing several property elements
  - one object description serves as subject for another triple

```
<rdf:Description rdf:about="http://example.org/SemanticWeb">
 <ex:Title>Semantic Web -- Grundlagen</ex:Title>
 <ex:publishedBy>
  <rdf:Description rdf:about="http://springer.com/Publisher"/>
   <ex:Name>Springer Verlag</ex>Name>
  </rdf:Description>
 </ex:publishedBy>
</rdf:Description>
```

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XML Syntax of RDF

- alternative (but semantically equivalent) representation of literals as XML attributes
- property URIs are then used as attribute names
- object URIs can be given as value of the rdf:resource attribute inside a property tags

```
<rdf:Description rdf:about="http://example.org/SemanticWeb"
              ex:Title="Semantic Web -- Grundlagen">
 <ex:publishedBy rdf:resource="http://springer.com/Publisher"/>
</rdf:Description>
<rdf:Description rdf:about="http://springer.com/Verlag"
              ex:Name="Springer Verlag"/>
```

RDF/XML Syntax: Complications

- name spaces are needed (not just for abbreviation reasons), because colons inside XML elements and attributes are always interpreted as name space delimiters
- problem: in XML, no name spaces in attribute values allowed (would be interpreted as URI schema), thus we cannot write:
  `rdf:about="ex:SemanticWeb"`
- “work around” via XML entities:
  Declaration:
  `<!ENTITY ex 'http://example.org/'>`
  Usage:
  `rdf:resource="&ex;SemanticWeb"`

RDF/XML Syntax: Base URIs

- usage of base URIs:

```
<rdf:RDF
 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:base="http://example.org/">

 <rdf:Description rdf:about="SemanticWeb">
  <ex:publishedBy rdf:resource="http://springer.com/Publisher"/
 </rdf:Description>

</rdf:RDF>
```

- relative URIs (i.e. those that are to be preceded by the given base URI) are recognized by the absence of a schema part

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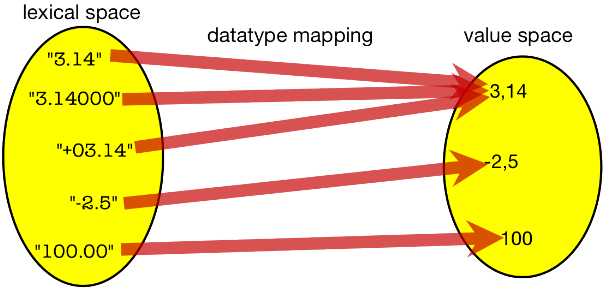
Datatypes

Example: `xsd:decimal`



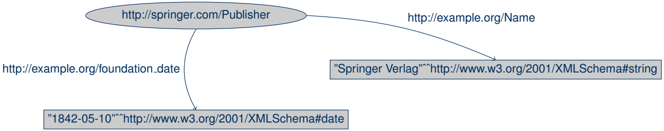
For xsd:decimal holds ”3.14”=”+03.14”
But not for xsd:string !

Datatypes in RDF

- by now: untyped literals, treated like strings (e.g.: ”02”<”100”<”11”<”2”)
- typing allows for a better (more semantic = meaning-adequate) handling of values
- datatypes are themselves denoted by URIs and can essentially be freely chosen
- common: usage of xsd datatypes
- syntax:
  ”datavalue”^^datatype_URI

Datatypes in RDF – Example

Graph:



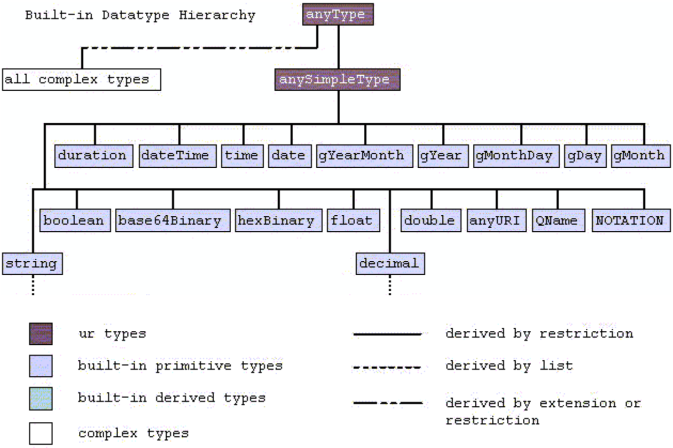
Turtle:

```
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
<http://springer.com/Publisher>
   <http://example.org/Name> "Springer Verlag"^^xsd:string ;
   <http://example.org/foundation\_date> "1842-05-10"^^xsd:date .
```

XML:

```
<rdf:Description rdf:about="http://springer.com/Publisher">
 <ex:Name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    Springer Verlag
 </ex:Name>
 <ex:foundation\_date rdf:datatype="http://www.w3.org/2001/XMLSchema#date">
    1842-05-10
 </ex:foundation\_date>
</rdf:Description>
```

XML Schema Datatypes



XML Schema – Facets

- facets are defining properties of a data range
- foundational facet:
  - abstract property for semantically characterizing the values of a value space
  - definition of equality, kind of order relation (total, partial), limits, cardinality, numerical vs. non-numerical
- constraining facet:
  - optional properties to restrict the value space (and thus the lexical space)
  - length (e.g. for strings), minLength, maxLength, pattern (regular expression), enumeration (restriction to explicitly given values), whiteSpace (possible values: preserve, replace (e.g. Tab by Space), collapse (extends replace), maxInclusive, maxExclusive, minExclusive, minInclusive, totalDigits, fractionDigits

XML Schema – duration

- `duration` represents a time span
- six-tuple having as entries Gregorian year, month, day, hour, minute and second, formatted as defined in ISO 8601 §5.5.3.2
- lex. form: PnYnMnDTnHnMnS
- Example: P1Y2M3DT10H30M: duration 1 year, 2 months, 3 days, 10 hours, and 30 minutes)
- admissible facets: pattern, enumeration, whiteSpace, maxInclusive, maxExclusive, minInclusive, minExclusive

XML Schema – dateTime

- `dateTime`: objects with year, month, day, hour and minute given as integer, second given as decimal, optional time zone information
- corresponding decimal value: timeOnTimeline
- lex. form: '-'? yyyy '-' mm '-' dd 'T' hh ':' mm ':' ss ('.' s+)? ((('+' | '-') hh ':' mm) | 'Z')?
- Z stands for UTC (Coordinated Universal Time = Greenwich Mean Time)
- Example: 2002-10-10T12:00:00-05:00: noon of October the 10th 2002, Central Daylight Savings Time/Eastern Standard Time in the US, corresponds to 2002-10-10T17:00:00Z
- admissible facets: pattern, enumeration, whiteSpace, maxInclusive, maxExclusive, minInclusive, minExclusive

XML Schema – time

- `time`: certain point in time, recurring every day
- like `dateTime` but without date
- lex. form: hh ':' mm ':' ss ('.' s+)? ((('+' | '-') hh ':' mm) | 'Z')?
- Example: 12:00:00-05:00: 12:00 Central Daylight Savings Time/Eastern Standard Time in the US, corresponds to 17:00:00 UTC
- admissible facets: pattern, enumeration, whiteSpace, maxInclusive, maxExclusive, minInclusive, minExclusive

XML Schema – date

- `date`: a certain day (interpreted as interval without upper bound)
- like `dateTime` but restricted to date (plus optional time zone information)
- lex. form: '-'? yyyy '-' mm '-' dd ((('+' | '-') hh ':' mm) | 'Z')?
- Example: 2002-10-10-05:00: 10th of October 2002, interval starts -5 hours compared to UTC

XML Schema – gXXX

- `gYearMonth`: a certain Gregorian month in a certain Gregorian year
- `gYear`: a certain Gregorian year
- `gMonthDay`: a (yearly recurring) day of a Gregorian year (like third of April)
- `gDay`: a (monthly recurring) day in the Gregorian calendar (like the third day of each month)
- `gMonth`: a (yearly recurring) month according to the Gregorianischen calendar (erster Monat/Januar)

XML Schema – boolean, base64 und hexBinary

- `boolean`: values of Boolean logic
  - lex. form: { true, false, 1, 0 }
  - admissible facets: pattern, whiteSpace
- `base64`: binary data with base64-encoding with alphabet: a-z, A-Z, 0-9, +, /, = and whitespace
  - admissible facets: length, minLength, maxLength, pattern, enumeration, whiteSpace
- `hexBinary`: binary data with hex encoding: ”0FB7” is hex encoding for 16-bit Integer 4023 (binary representation: 0000.1111.1011.0111)
  - admissible facets: length, minLength, maxLength, pattern, enumeration, whiteSpace

XML Schema – float and double

- `float`: like IEEE single-precision 32-bit floating point type, values $m \times 2^e$ with m, e integers, $|m| < 2^{24}$, $-149 \leq e \leq 104$ plus positive infinity (`INF`) and negative infinity (`-INF`) as well as not-a-number (`NaN`)
- `double`: like IEEE double-precision 64-bit floating point type, values $m \times 2^e$ with m, e integers, $|m| < 2^{53}$, $-1075 \leq e \leq 970$ plus positive infinity (`INF`) and negative infinity (`-INF`) as well as not-a-number

- Examples: -1E4, 1267.43233E12, 12.78e-2, 12 , -0, 0, INF
- not all decimal values within the defined range can be represented
- admissible facets: pattern, enumeration, whiteSpace, maxInclusive, maxExclusive, minInclusive, minExclusive

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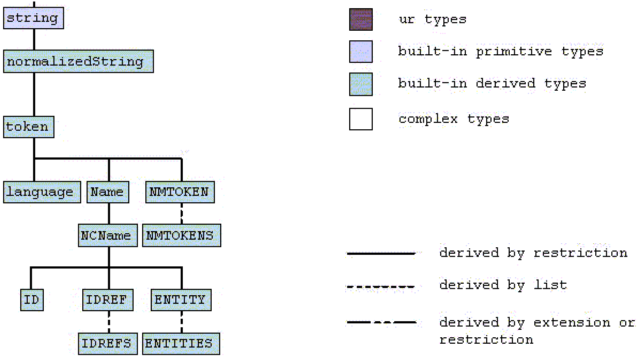
XML Schema – anyURI, QName, NOTATION

- `anyURI`: a Uniform Resource Identifier, absolut or relative, with or without fragment identifier
- `QName`: a qualified XML Name (name space plus local part, where name space is `anyURI` and local part is `NCName`
- `NOTATION`: like NOTATION attribute type in XML 1.0, cannot be used directly (only derived datatypes)

- admissible facets: length, minLength, maxLength, pattern, enumeration, whiteSpace

XML Schema Datatypes

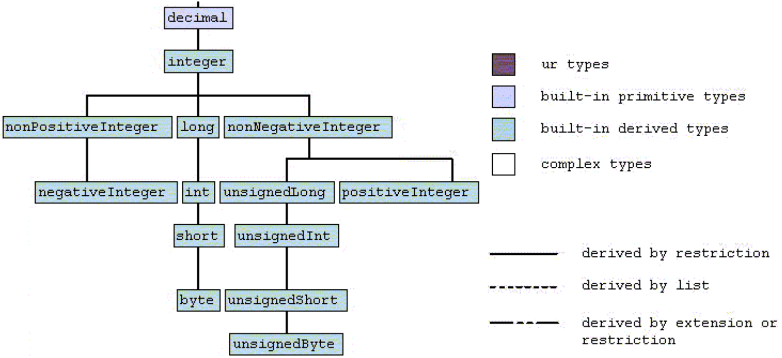


XML Schema – string

- `string`: sequence of characters, where a character is an atomic unit with corresponding code point (integer) in the Universal Character Set

- admissible facets: length, minLength, maxLength, pattern, enumeration, whiteSpace
- further specializations: see specs

XML Schema Datatypes



XML Schema – decimal and integer

- `decimal`: subset of the real numbers, that can be represented as decimal numbers. Value space: numbers representable as $i \times 10^{-n}$ with i, n integers and $n \geq 0$, precision irrelevant: 2.0 equals 2.00
- Examples: -1.23, 12678967.543233, +100000.00, 210
- admissible facets: totalDigits, fractionDigits, pattern, whiteSpace, enumeration, maxInclusive, maxExclusive, minInclusive, minExclusive
- `integer` restriction of `decimal`: `fractionDigits`=0, no decimal point

XML Schema – Types Derived from Integer

- `long` restriction of `integer`: `maxInclusive`=9223372036854775807, `minInclusive`=-9223372036854775808
- `int` restriction of `long`: `maxInclusive`=2147483647, `minInclusive`=-2147483648
- `short` restriction of `int`: `maxInclusive`=32767, `minInclusive`=-32768
- `byte` restriction of `short`: `maxInclusive`=127, `minInclusive`=-128

XML Schema – Types Derived from Integer

- `nonNegativeInteger` restriction of `integer`: `minInclusive`=0
- `positiveInteger` restriction of `nonNegativeInteger`: `minInclusive`=1
- `unsignedLong` restriction of `nonNegativeInteger`: `maxInclusive`=18446744073709551615
- `unsignedInt` restriction of `unsignedLong`: `maxInclusive`=4294967295
- `unsignedShort` restriction of `unsignedInt`: `maxInclusive`=65535
- `unsignedByte` restriction of `unsignedShort`: `maxInclusive`=255

XML Schema – Types Derived from Integer

- `nonPositiveInteger` restriction of `integer`: `maxInclusive`=0
- `negativeInteger` restriction of `nonPositiveInteger`: `minInclusive`=-1

XML Schema – Canonical Values

- there may be several lexical forms for one value
- one of these is picked as the value's canonical form
- useful to detect equivalence between different notations of the same values
- the following lexical forms of the datatype `decimal` represent the same value: 100.5, +100.5, 0100.5, 100.50, 100.500, 100.5000, the canonical variant is: 100.5

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The Predefined Datatype

- rdf:XMLLiteral is the only datatype that is pre-defined within the RDF standard
- denotes arbitrary balanced XML snippets
- in RDF/XML special syntax for unambiguous representation:

```
<rdf:Description rdf:about="http://example.org/SemanticWeb">
 <ex:Titel rdf:parseType="Literal">
    <b>Semantic Web</b><br />
    Grundlagen
 </ex:Titel>
</rdf:Description>
```

Language Information and Datatypes

- language information can only be provided for untyped literals
- Example:

XML:

```
<rdf:Description rdf:about="http://springer.com/Publisher">
 <ex:Name xml:lang="de">Springer Verlag</ex:Name>
 <ex:Name xml:lang="en">Springer Science+Business
                        Media</ex:Name>
</rdf:Description>
```

Turtle:

```
<http://springer.com/Publisher> <http://example.org/Name>
"Springer Verlag"@de, "Springer Science+Business Media"@en .
```

Language Information and Datatypes

According to the spec, the following literals are all different from each other:

```
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>
<http://springer.com/Verlag> <http://example.org/Name>
"Springer Verlag", "Springer Verlag"@de,
"Springer Verlag"^^xsd:string .
```

In practice they are, however, often implemented as equal.

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Multi-Valued Relationships

- Cooking with RDF:
  "For the preparation of Chutney, you need 1 lb green mango, a teaspoon Cayenne pepper, . . . "
- first modeling attempt:

```
@prefix ex: <http://example.org/> .
ex:Chutney ex:hasIngredient "1lb green mango",
                            "1 tsp. Cayenne pepper",
                            ...
```

- Not satisfactory: ingredients plus amounts encoded as one string. Search for recipes containing green mango not possible (or difficult).

Multi-Valued Relationships

- Cooking with RDF:
  "For the preparation of Chutney, you need 1 lb green mango, a teaspoon Cayenne pepper, . . . "
- second modeling attempt:

```
@prefix ex: <http://example.org/> .
ex:Chutney ex:hasIngredient ex:geenMango;
           ex:amount "1 lb";
           ex:hasIngredient ex:CayennePepper;
           ex:amount "1 tsp.";
           ...
```

- Even worse: no unique assignment of ingredient and amounts possible.

Multi-Valued Relationships

- Problem: we have a proper three-valued (aka: ternary) relationship (cf. databases)

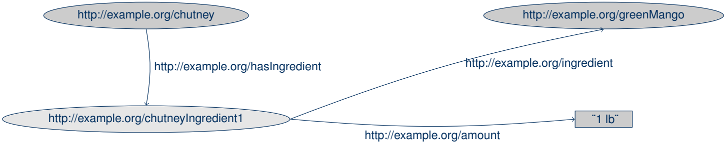
dish	ingredient	amount
chutney	geen mango	1 lb
chutney	Cayenne pepper	1 tsp.

- direct representation in RDF not possible
- solution: introduction of auxiliary nodes

Multi-Valued Relationships

auxiliary nodes in RDF:

- as graph



- Turtle syntax (using rdf:value for the primary component)

```
@prefix ex: <http://example.org/> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
ex:chutney             ex:hatZutat ex:chutneyIngredient1 .
ex:chutneyIngredient1  rdf:value   ex:greenMango;
                       ex:amount   "1 lb" .
...
```

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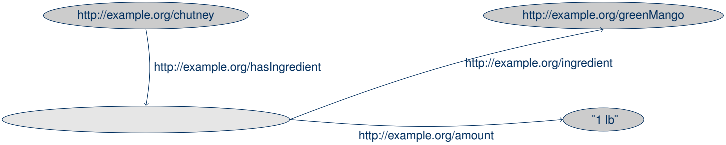
- RDF in Practice

Blank Nodes

auxiliary nodes in RDF:

- blank nodes (aka bnodes) can be used for resources that need not be named (e.g. auxiliary nodes)
- can be interpreted as existential statement
- syntax (as graph):



Blank Nodes

RDF/XML-Syntax:

```
<rdf:Description rdf:about="http://example.org/chutney">
  <ex:hatZutat rdf:nodeID="id1" />
</rdf:Description>
<rdf:Description rdf:nodeID="id1">
  <ex:ingredient rdf:resource="http://example.org/greenMango" />
  <ex:amount>1 lb<ex:amount/>
</rdf:Description>
```

abbreviated:

```
<rdf:Description rdf:about="http://example.org/chutney">
  <ex:hasIngredient rdf:parseType="Resource">
    <ex:ingredient rdf:resource="http://example.org/greenMango" />
    <ex:amount>1 lb<ex:amount/>
  </ex:hatsIngredient>
</rdf:Description>
```

Blank Nodes

Turtle syntax:

```
@prefix ex: <http://example.org/> .
ex:chutney ex:hasIngredient  _:id1 .
_:id1      ex:ingredient     ex:greenMango ;
           ex:amount         "1 lb" .
```

abbreviated:

```
@prefix ex: <http://example.org/> .
ex:chutney ex:hasIngredient [
           ex:ingredient ex:greenMango ;
           ex:amount     "1 lb" ] .
```

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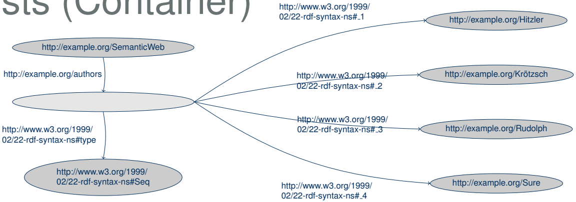
Lists

- General data structures for enumerating arbitrary many resources (where order is relevant), e.g. autors of a book
- distinction between
  - open lists (container)
    new entries can be added
  - closed lists (collections)
    new entries can not be added
- These structures are modeled using the already discussed means of representation, i.e. no additional expressivity!

Open Lists (Container)

graph:



abbreviated in RDF/XML:

```
<rdf:Description rdf:about="http://example.org/SemanticWeb">
  <ex:authors>
    <rdf:Seq>
      <rdf:li rdf:resource="http://example.org/Hitzler />
      <rdf:li rdf:resource="http://example.org/Krötzsch />
      <rdf:li rdf:resource="http://example.org/Rudolph />
      <rdf:li rdf:resource="http://example.org/Sure />
    </rdf:Seq>
  </ex:authors>
</rdf:Description>
```

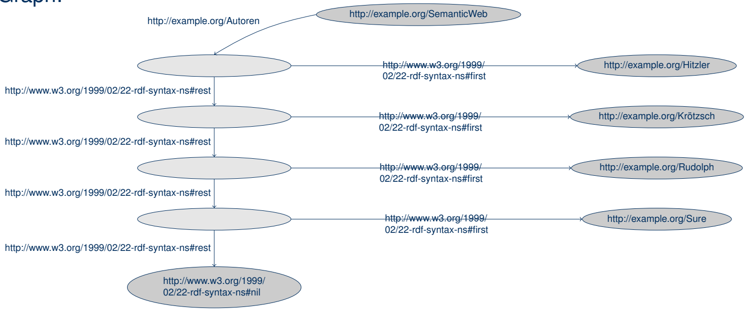
Types of Open Lists

Via `rdf:type` the a list type is assigned to the root node of the list:

- rdf:Seq
  ordered list (sequence)
- rdf:Bag
  unordered set
  indicates that the encoded order is irrelevant
- rdf:Alt
  set of alternatives
  normally only one entry will be relevant

Closed Lists (Collections)

Graph:



underlying idea: recursive deconstruction of the list into head element and (possibly empty) rest list

Closed Lists (Collections)

RDF/XML-Syntax

```
<rdf:Description rdf:about="http://example.org/SemanticWeb>
  <ex:authors rdf:parseType="Collection">
    <rdf:Description rdf:about="http://example.org/Hitzler />
    <rdf:Description rdf:about="http://example.org/Krötzsch />
    <rdf:Description rdf:about="http://example.org/Rudolph />
    <rdf:Description rdf:about="http://example.org/Sure />
  </ex:authors>
</rdf:Description>
```

Turtle

```
@prefix ex: <http://example.org/> .
ex:SemanticWeb ex:authors
  ( ex:Hitzler ex:Krötzsch ex:Rudolph ex:Sure ) .
```

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Graph Definitions

- An RDF triple consists of three components:
  1. the subject, which can be a URI or a bnode,
  2. the predicate, which has to be a URI, and
  3. the object, which can be a URI, a bnode or a Literal.
- The predicate is also denoted as property.
- An RDF graph (or simply graph) is a set of RDF triples. The graph nodes are the subjects and objects of these triples.
- A (proper) subgraph of an RDF graph is a (proper) subset of its triples.
- A ground graph is an RDF graph without bnodes.

Graph Definitions

- A name is a URI reference or a literal.
- A typed literal comprises two names: the literal itself and its type reference (URI)
- A set of names is referred to as a vocabulary.
- The vocabulary of a graph is the set of all names occurring as subject, predicate or object in one of its triples.
- Remark: The URI references which only occur inside the typed literals do not belong to the graph's vocabulary.

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Graph Definitions

- Let M be a mapping from bnodes to a set of literals, bnodes and URI references. We denote M as instance mapping.
- Every graph G' obtained by substituting (some or all) bnodes ℓ in G by $M(\ell)$, is an instance of G.
- An instance with respect to a vocabulary V is an instance in which all names replacing bnodes are from V.
- A proper instance of a graph is an instance wherein at least one bnode has been replaced by a name or identified with another bnode.
- Graphs that only differ in the labels of their bnodes are considered equivalent.

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Graph Definitions

- An RDF graph is lean if it does not have an instance that is a proper subgraph of it.

$\leadsto$ Non-lean graphs are internally redundant.

```
{ex:a ex:p _:x .  _:y ex:p _:x .}        (1)
{ex:a ex:p _:x .  _:x ex:p _:x .}        (2)
```

Graph Definitions

- An RDF graph is lean if it does not have an instance that is a proper subgraph of it.

$\rightsquigarrow$ Non-lean graphs are internally redundant.

```
{ex:a ex:p _:x .  _:y ex:p _:x .}    (1)
{ex:a ex:p _:x .  _:x ex:p _:x .}    (2)
```

- (1) is not lean, but (2) is

Graph Definitions

The merge of two RDF graphs G_1 and G_2 is defined as follows:

- if G_1 and G_2 do not have common bnodes, the merge is the union $G_1 \cup G_2$
- otherwise, the merge of G_1 and G_2 is the union of G_1' und G_2', where G_1' and G_2' are equivalent to G_1 and G_2, respectively, but do not have blank nodes in common
- if this renaming of variables is carried out, one usually says “blank nodes have been are standardized apart”

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Popularty of RDF

- today, a plethora of RDF tools exists
- there are libraries for virtually all programming languges
- freely available systems to work with large RDF data sets (so-called RDF Stores or Triple Stores)
- also commercial players (like Oracle) support RDF
- RDF is basis for other data formats: RSS 1.0, XMP (Adobe), SVG (vector graphics)

Assessment of RDF

- widely supported standard for data storage and interchange
- enables syntax-independent representation of distributed information via a graph-based data model
- pure RDF very oriented toward idividuals
- few possibilities to encode schema knowledge
- $\rightarrow$ RDF Schema (next lecture)

RDFa – RDF-in-attributes

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML+RDFa 1.0//EN"
    "http://www.w3.org/MarkUp/DTD/xhtml-rdfa-1.dtd">
<html xmlns="http://www.w3.org/1999/xhtml"
    xmlns:foaf="http://xmlns.com/foaf/0.1/"
    xmlns:dc="http://purl.org/dc/elements/1.1/"
    version="XHTML+RDFa 1.0" xml:lang="en">
  <head>
    <title>John’s Home Page</title>
    <base href="http://example.org/john-d/" />
    <meta property="dc:creator" content="Jonathan Doe" />
    <link rel="foaf:primaryTopic"
        href="http://example.org/john-d/#me" />
  </head>
```

RDFa – RDF-in-attributes

```
  <body about="http://example.org/john-d/#me">
    <h1>John's Home Page</h1>
    <p>My name is <span property="foaf:nick">John D</span>
       and I like <a href="http://www.neubauten.org/"
       rel="foaf:interest" xml:lang="de">Einstürzende
       Neubauten</a>.
    </p>
    <p>
      My <span rel="foaf:interest"
      resource="urn:ISBN:0752820907">favorite book is the
      inspiring <span about="urn:ISBN:0752820907"><cite
      property="dc:title">Weaving the Web</cite> by
      <span property="dc:creator">Tim Berners-Lee</span>
      </span>
     </span>
    </p>
  </body>
</html>
```

RDFa – RDF Version

```
<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:foaf="http://xmlns.com/foaf/0.1/"
    xmlns:dc="http://purl.org/dc/elements/1.1/">
  <rdf:Description rdf:about="http://example.org/john-d/">
    <dc:creator xml:lang="en">Jonathan Doe</dc:creator>
    <foaf:primaryTopic>
      <rdf:Description rdf:about="http://example.org/john-d/#me">
        <foaf:nick xml:lang="en">John D</foaf:nick>
        <foaf:interest rdf:resource="http://www.neubauten.org/"/>
        <foaf:interest>
          <rdf:Description rdf:about="urn:ISBN:0752820907">
            <dc:creator xml:lang="en">Tim Berners-Lee</dc:creator>
            <dc:title xml:lang="en">Weaving the Web</dc:title>
          </rdf:Description>
        </foaf:interest>
      </rdf:Description>
    </foaf:primaryTopic>
  </rdf:Description>
</rdf:RDF>
```

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