B4M36DS2, BE4M36DS2: **Database Systems 2**

http://www.ksi.mff.cuni.cz/~svoboda/courses/181-B4M36DS2/

Lecture 2

Data Formats

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Lecture Outline

Data formats

- XML – Extensible Markup Language
- JSON – JavaScript Object Notation
- BSON – Binary JSON
- RDF – Resource Description Framework
- CSV – Comma-Separated Values
- Protocol Buffers

XML

Extensible Markup Language

Introduction

XML = *Extensible Markup Language*

- **Representation and interchange of semi-structured data**
  - + a family of related technologies, languages, specifications, …
- Derived from **SGML**, developed by **W3C**, started in 1996
- Design goals
  - Simplicity, generality and usability across the Internet
- File extension: ***.xml**, content type: `text/xml`
- Versions: 1.0 and 1.1
- W3C recommendation
  - http://www.w3.org/TR/xml11/

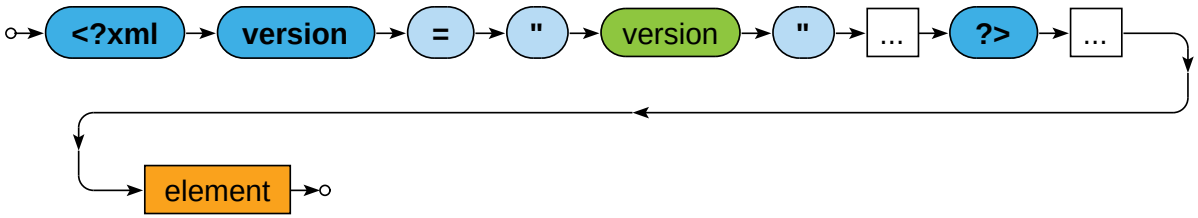
Example

```
<?xml version="1.1" encoding="UTF-8"?>
<movie year="2007">
  <title>Medvídek</title>
  <actors>
    <actor>
      <firstname>Jiří</firstname>
      <lastname>Macháček</lastname>
    </actor>
    <actor>
      <firstname>Ivan</firstname>
      <lastname>Trojan</lastname>
    </actor>
  </actors>
  <director>
    <firstname>Jan</firstname>
    <lastname>Hřebejk</lastname>
  </director>
</movie>
```

Document Structure

Document

- Prolog: XML version + some other stuff
- Exactly one root element
  - Contains other nested elements and/or other content



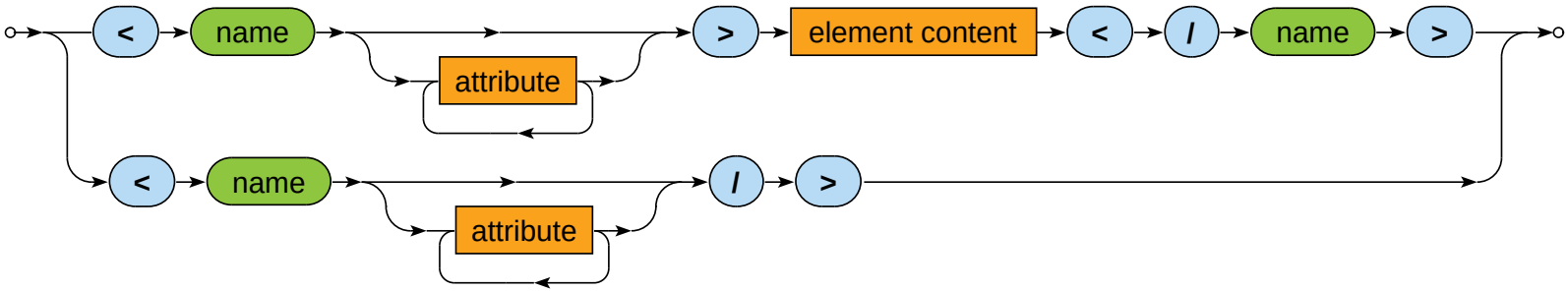
Example

```
<?xml version="1.1" encoding="UTF-8"?>
<movie>
  ...
</movie>
```

Constructs

Element

- Marked using **opening and closing tags**
  - … or just an abbreviated tag in case of empty elements
- Each element can be associated with a **set of attributes**



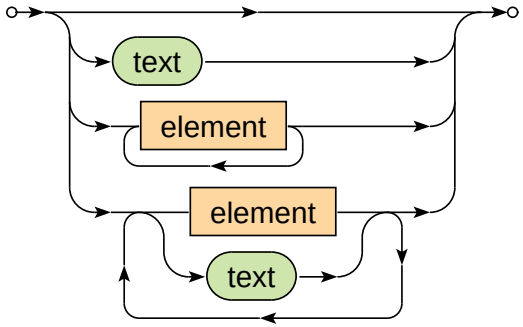
Examples

```
<title>...</title>
<actors/>
```

Constructs

Types of element content

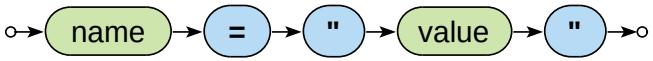
- **Empty** content
- **Text** content
- **Element** content
  - Sequence of nested elements
- **Mixed** content
  - Elements arbitrarily interleaved with text values



Constructs

Attribute

- Name-value pair



Escaping sequences (predefined entities)

- Used within values of attributes or text content of elements
- E.g.:
  - `<` for <
  - `>` for >
  - `&quot;` for "
  - …

XML Conclusion

XML constructs

- Basic: element, attribute, text
- Additional: comment, processing instruction, …

Schema languages

- DTD, XSD (*XML Schema*), RELAX NG, Schematron

Query languages

- XPath, XQuery, XSLT

XML formats = particular languages

- XSD, XSLT, XHTML, DocBook, ePUB, SVG, RSS, SOAP, …

JSON

JavaScript Object Notation

Introduction

JSON = *JavaScript Object Notation*

- **Open standard for data interchange**
- Design goals
  - **Simplicity**: text-based, easy to read and write
  - **Universality**: object and array data structures
    - Supported by majority of modern programming languages
    - Based conventions of the C-family of languages (C, C++, C#, Java, JavaScript, Perl, Python, …)
- Derived from JavaScript (but language independent)
- Started in 2002
- File extension: ***.json**
- Content type: `application/json`
- http://www.json.org/

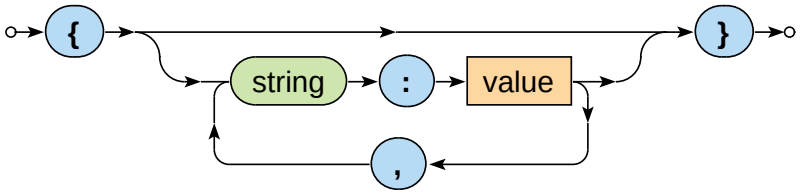
Example

```
{
  "title" : "Medvídek",
  "year" : 2007,
  "actors" : [
    {
      "firstname" : "Jiří",
      "lastname" : "Macháček"
    },
    {
      "firstname" : "Ivan",
      "lastname" : "Trojan"
    }
  ],
  "director" : {
    "firstname" : "Jan",
    "lastname" : "Hřebejk"
  }
}
```

Data Structure

Object

- **Unordered collection of name-value pairs** (properties)
  - Correspond to structures such as objects, records, structs, dictionaries, hash tables, keyed lists, associative arrays, …
- Values can be of different types, **names should be unique**



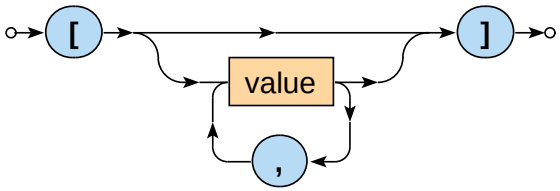
Examples

- `{ "name" : "Ivan Trojan", "year" : 1964 }`
- `{ }`

Data Structure

Array

- **Ordered collection of values**
  - Correspond to structures such as arrays, vectors, lists, sequences, …
- Values can be of different types, duplicate values are allowed



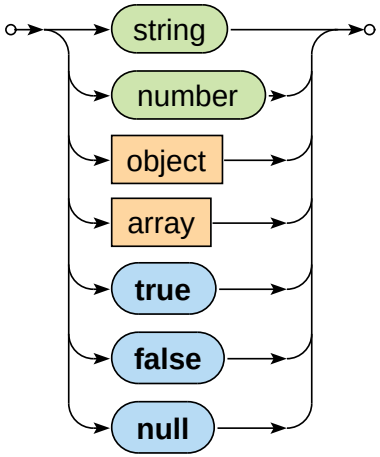
Examples

- `[ 2, 7, 7, 5 ]`
- `[ "Ivan Trojan", 1964, -5.6 ]`
- `[ ]`

Data Structure

Value

- Unicode string
  - Enclosed with double quotes
  - Backslash escaping sequences
  - Example: `"a \n b \" c \\ d"`
- Number
  - Decimal integers or floats
  - Examples: `1`, `-0.5`, `1.5e3`
- **Nested object**
- **Nested array**
- Boolean value: `true`, `false`
- Missing information: `null`



JSON Conclusion

JSON constructs

- Collections: object, array
- Scalar values: string, number, boolean, null

Schema languages

- JSON Schema

Query languages

- JSONiq, JMESPath, JAQL, …

BSON

Binary JSON

Introduction

BSON = *Binary JSON*

- **Binary-encoded serialization of JSON documents**
  - Extends the set of basic data types of values offered by JSON (such as a string, …) with a few new specific ones
- Design characteristics: **lightweight**, **traversable**, **efficient**
- Used by **MongoDB**
  - Document NoSQL database for JSON documents
  - Data storage and network transfer format
- File extension: ***.bson**
- http://bsonspec.org/

Example

JSON

```
{
  "title" : "Medvídek",
  "year" : 2007
}
```

BSON

```
24 00 00 00
02 74 69 74 6C 65 00 0A 00 00 00 4D 65 64 76 C3 AD 64 65 6B 00
10 79 65 61 72 00 D7 07 00 00
00
```

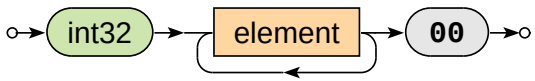
Document Structure

Document = serialization of **one JSON object or array**

- JSON object is serialized directly
- JSON array is first transformed to a JSON object
  - Property names derived from numbers of positions
  - E.g.:

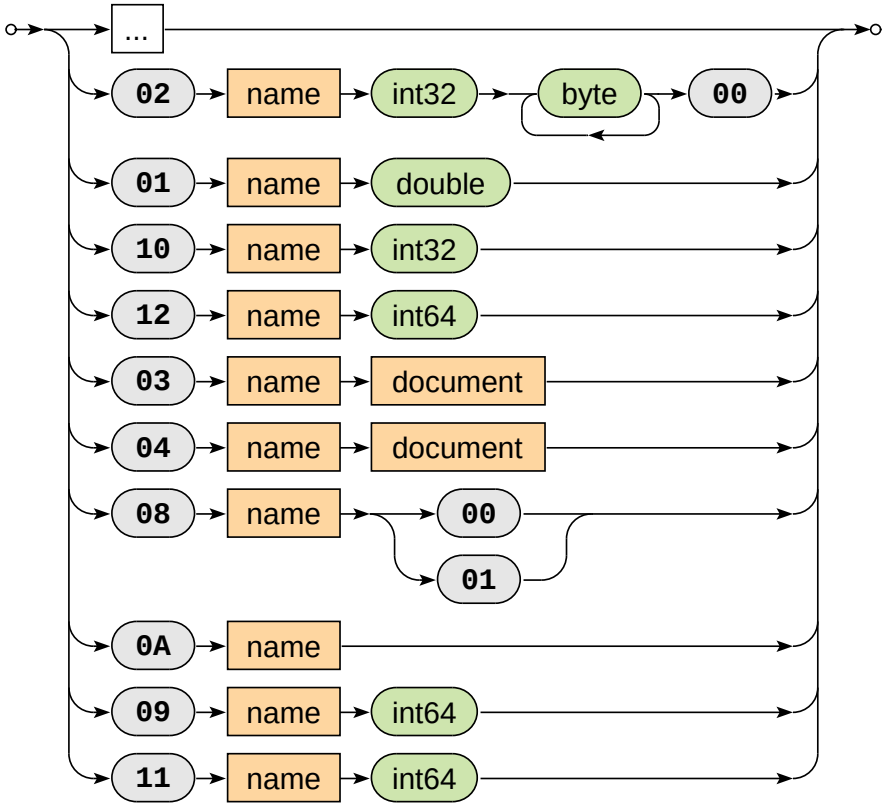
    `[ "Trojan", "Svěrák" ]` $\rightarrow$

    `{ "0" : "Trojan", "1" : "Svěrák" }`
- Structure
  - **Document size** (total number of bytes)
  - Sequence of **elements** (encoded JSON properties)
  - Terminating hexadecimal 00 byte



Document Structure

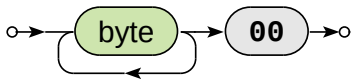
Element = serialization of **one JSON property**



Document Structure

Element = serialization of **one JSON property**

- Structure
  - **Type** selector
    - `02` (**string**)
    - `01` (double), `10` (32-bit **integer**), `12` (64-bit integer)
    - `03` (**object**), `04` (**array**)
    - `08` (**boolean**)
    - `0A` (**null**)
    - `09` (datetime), `11` (timestamp)
    - …
  - Property **name**
    - Unicode string terminated by `00`



  - Property **value**

RDF

Resource Description Framework

Introduction

RDF = *Resource Description Framework*

- Language for **representing information about resources** in the World Wide Web
  - + a family of related technologies, languages, specifications, …
  - Used in the context of the **Semantic Web**, **Linked Data**, …
- Developed by **W3C**
- Started in 1997
- Versions: 1.0 and 1.1
- W3C recommendations
  - https://www.w3.org/TR/rdf11-concepts/
    - Concepts and Abstract Syntax
  - https://www.w3.org/TR/rdf11-mt/
    - Semantics

Statements

Resource

- Any real-world entity
  - Referents = **resources identified by IRI**
    - E.g. physical things, documents, abstract concepts, …
  - Values = **resources for literals**
    - E.g. numbers, strings, …

Statement about resources = one RDF **triple**

- Three components: subject, predicate, and object

Examples

```
<http://db.cz/movies/medvidek>
<http://db.cz/terms#actor>
<http://db.cz/actors/trojan> .
```

```
<http://db.cz/movies/medvidek>
<http://db.cz/terms#year>
"2007" .
```

Statements

Triple components

- **Subject**
  - Describes a resource the given statement is about
  - *IRI* or *blank node identifier*
- **Predicate**
  - Describes the property or characteristic of the subject
  - *IRI*
- **Object**
  - Describes the value of that property
  - *IRI* or *blank node identifier* or *literal*

Although triples are inspired by natural languages, they have nothing to do with processing of natural languages

Example

```
<http://db.cz/movies/medvidek>
  <http://db.cz/terms#actor> <http://db.cz/actors/machacek> .

<http://db.cz/movies/medvidek>
  <http://db.cz/terms#actor> <http://db.cz/actors/trojan> .

<http://db.cz/movies/medvidek>
  <http://db.cz/terms#year> "2007" .

<http://db.cz/movies/medvidek>
  <http://db.cz/terms#director> _:n18 .

_:n18
  <http://db.cz/terms#firstname> "Jan" .

_:n18
  <http://db.cz/terms#lastname> "Hřebejk" .
```

Identifiers and Literals

IRI = *Internationalized Resource Identifier*

- Absolute (not relative) IRIs with optional fragment identifiers
- RFC 3987
- Unicode characters
- Examples
  - `http://db.cz/movies/medvidek`
  - `http://db.cz/terms#actor`
  - `mailto:svoboda@ksi.mff.cuni.cz`
  - `urn:issn:0167-6423`
- **URLs are often used** in practice $\rightarrow$ information about given resources are then intended to be published / retrieved via standard HTTP

Identifiers and Literals

Literals

- Plain values
  - E.g.: `"Medvídek"`, `"2007"`
- Typed values
  - E.g.: `"Medvídek"^^xs:string`, `"2007"^^xs:integer`
  - XML Schema simple data types are adopted and used
- Strings with language tags
  - E.g.: `"Medvídek"@cs`
- *Types and language tags cannot be mutually combined*

Identifiers and Literals

Blank node identifiers

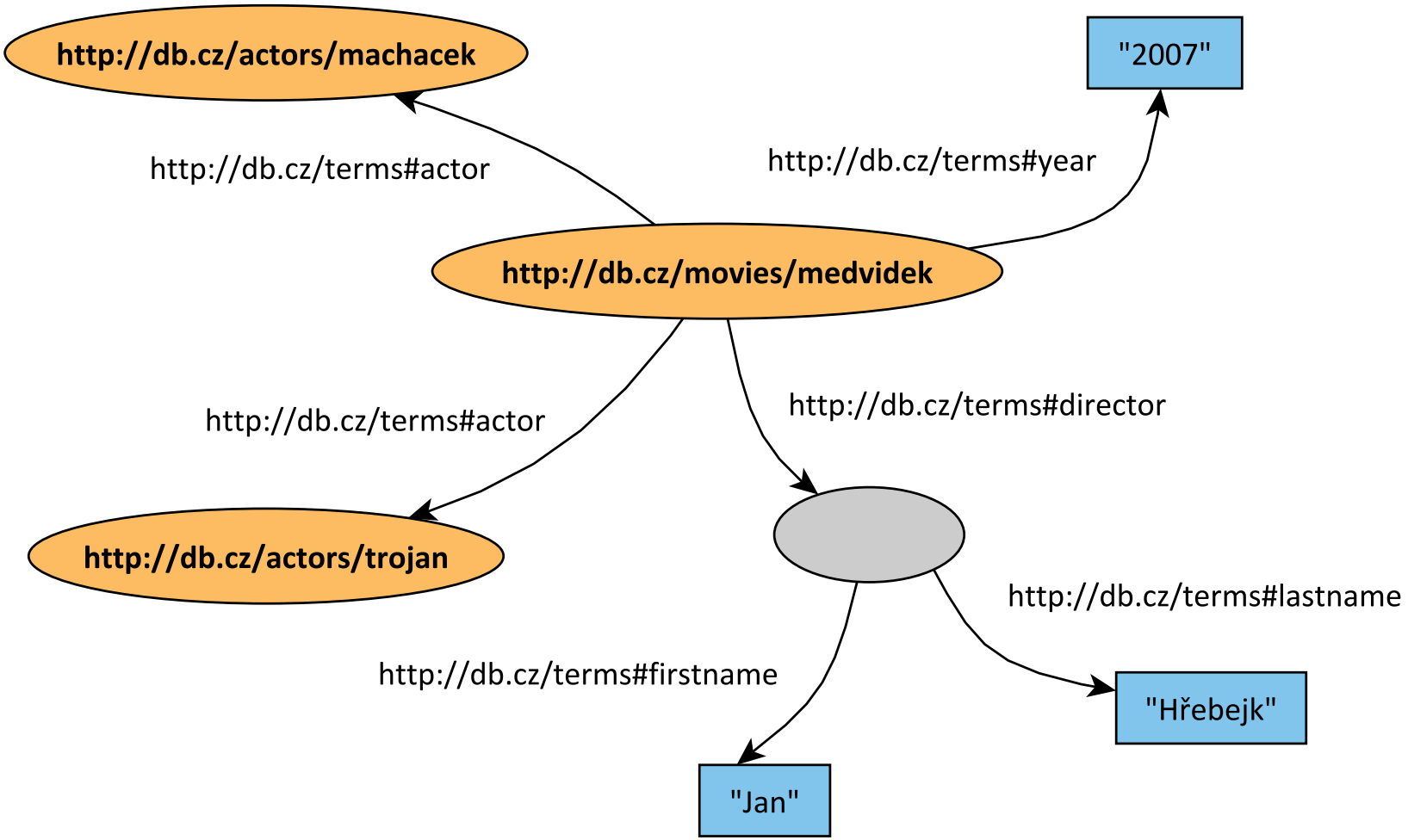
- Blank nodes (anonymous resources)
  - Allow to express statements about resources without explicitly naming (identifying) them
- **Blank node identifiers** only have **local scope of validity**
  - E.g. within a given file, query expression, …
- Particular syntax depends on a serialization format
  - E.g.: `_:node18`

Data Model

Directed labeled multigraph

- Vertices
  - **One vertex for each IRI or literal value**
- Edges
  - **One edge for each individual triple**
  - Edges are directed $subject \xrightarrow{predicate} object$
  - Property names (predicate IRIs) are used as edge labels

Example


http://db.cz/actors/machacek
"2007"
http://db.cz/terms#actor
http://db.cz/terms#year
http://db.cz/movies/medvidek
http://db.cz/terms#actor
http://db.cz/terms#director
http://db.cz/actors/trojan
http://db.cz/terms#lastname
http://db.cz/terms#firstname
"Hřebejk"
"Jan"

Serialization

Available approaches

- **N-Triples** notation
  - https://www.w3.org/TR/n-triples/
- **Turtle** notation (*Terse RDF Triple Language*)
  - https://www.w3.org/TR/turtle/
- **RDF/XML** notation
  - XML syntax for RDF
  - https://www.w3.org/TR/rdf-syntax-grammar/
- **JSON-LD** notation
  - JSON-based serialization for Linked Data
  - https://www.w3.org/TR/json-ld/
- …

N-Triples Notation

RDF **N-Triples** notation = *A line-based syntax for an RDF graph*

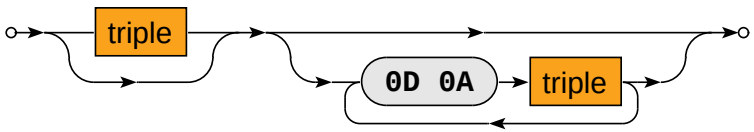
- Simple, line-based, plain text format
- File extension: ***.rdf**
- https://www.w3.org/TR/n-triples/

Example

- *Already presented…*

Document

- Statements are terminated by dots, delimited by EOL

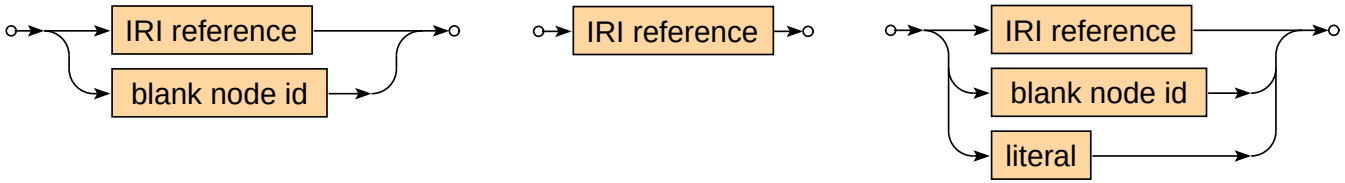


N-Triples Notation

Statement

- Individual triple components are delimited by spaces

Triple components: subject, predicate, object

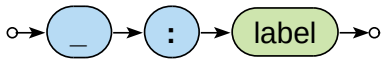


N-Triples Notation

IRI reference

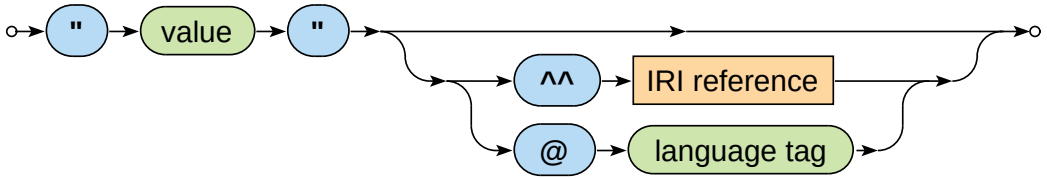
- IRIs are enclosed in angle brackets

Blank node identifier



Literal

- Literals are enclosed in double quotes



Turtle Notation

Turtle = *Terse RDF Triple Language*

- Compact text format,
  various abbreviations for common usage patterns
- File extension: ***.ttl**
- Content type: `text/turtle`
- https://www.w3.org/TR/turtle/

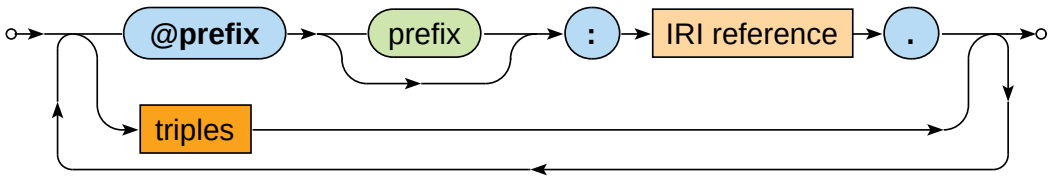
Example

```
@prefix i: <http://db.cz/terms#> .
@prefix m: <http://db.cz/movies/> .
@prefix a: <http://db.cz/actors/> .
m:medvidek
  i:actor a:machacek , a:trojan ;
  i:year "2007" ;
  i:director [ i:firstname "Jan" ; i:lastname "Hřebejk" ] .
```

Turtle Notation

Document

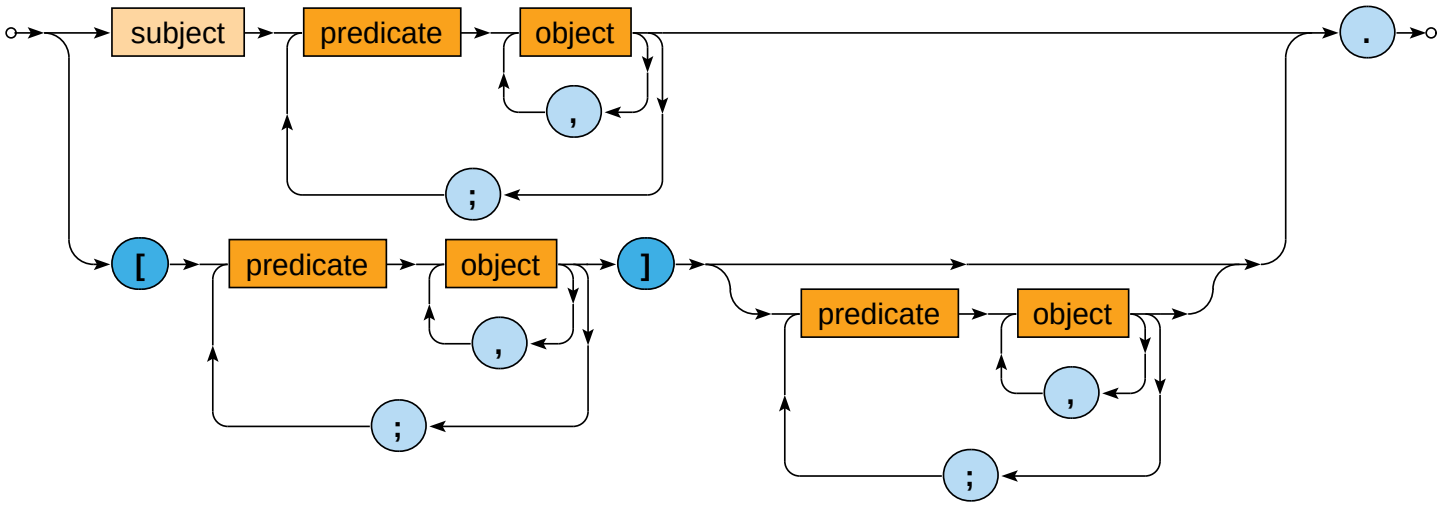
- Contains a **sequence of triples and/or declarations**
- Prefix declarations
  - **Prefixed names** can then be used instead of full IRI references
- Groups of triples
  - Individual groups are terminated by dots



Turtle Notation

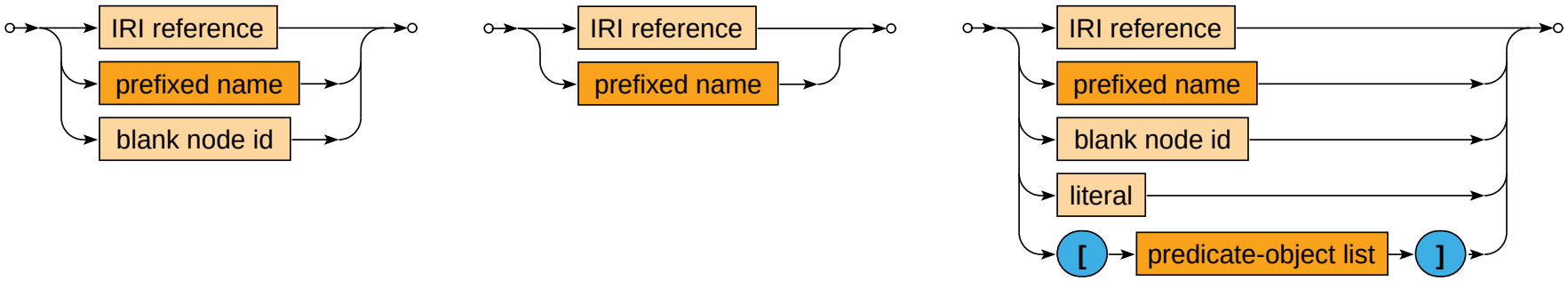
Triples

- Triples sharing the same subject and object or at least the same subject can be *grouped* together
  - object list for a **shared subject and predicate**
  - predicate-object list for a **shared subject**
- Brackets can be used to define blank nodes

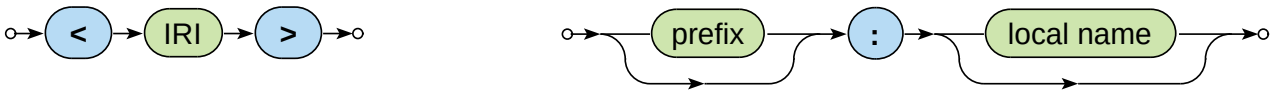


Turtle Notation

Triple components: subject, predicate, object



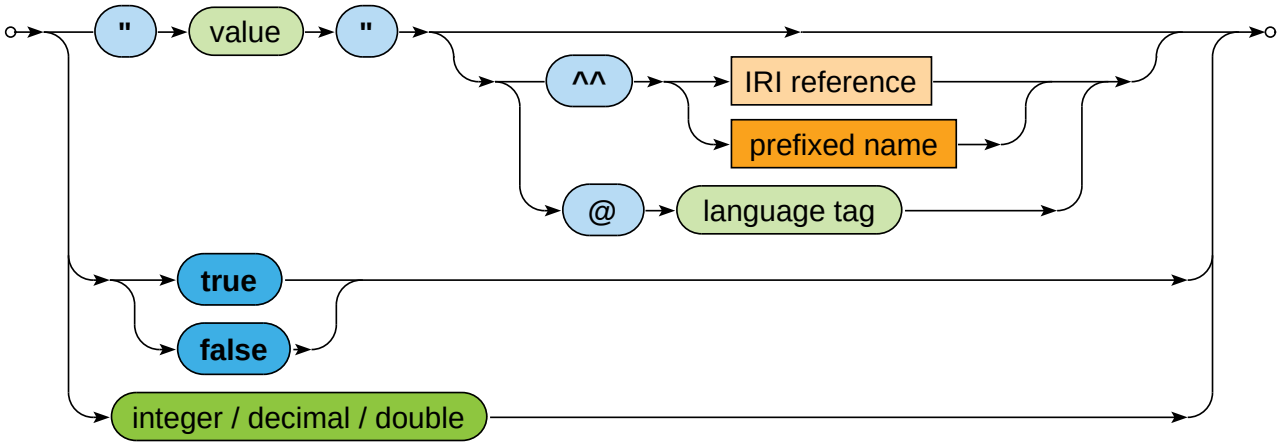
IRI reference / prefixed name



Turtle Notation

Literal

- Traditional literals
  + new abbreviated forms of numeric and boolean literals



Example

Example revisited

```
@prefix i: <http://db.cz/terms#> .
@prefix m: <http://db.cz/movies/> .
@prefix a: <http://db.cz/actors/> .
m:medvidek
  i:actor a:machacek , a:trojan ;
  i:year "2007" ;
  i:director [ i:firstname "Jan" ; i:lastname "Hřebejk" ] .
```

RDF Conclusion

RDF statements

- Subject, predicate, and object components

Schema languages

- RDFS (*RDF Schema*)
- OWL (*Web Ontology Language*)

Query languages

- SPARQL (*SPARQL Protocol and RDF Query Language*)

CSV

Comma-Separated Values

Introduction

CSV = *Comma-Separated Values*

- Unfortunately **not fully standardized**
  - Different field separators (commas, semicolons)
  - Different escaping sequences
  - No encoding information
- RFC 4180, RFC 7111
- File extension: ***.csv**
- Content type: `text/csv`

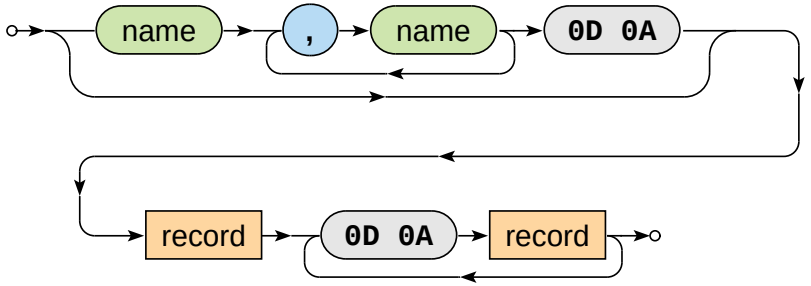
Example

```
firstname,lastname,year
Ivan,Trojan,1964
Jiří,Macháček,1966
Jitka,Schneiderová,1973
Zdeněk,Svěrák,1936
Anna,Geislerová,1976
```

Document Structure

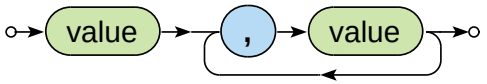
Document

- Optional **header** + list of **records**



Record

- Comma separated list of **fields**



Protocol Buffers

Introduction

Protocol Buffers

- **Extensible mechanism for serializing structured data**
  - Used in communication protocols, data storage, …
- Design goals
  - Language-neutral, platform-neutral
  - **Small, fast, simple**
- Developed (and widely used) by **Google**
- Started in 2008 internally and 2011 publicly
- Versions: proto2, proto3
- File extension: ***.proto**
- https://developers.google.com/protocol-buffers/
- Real-world usage: RiakKV, HBase

Introduction

Intended usage

- Schema creation $\rightarrow$ automatic source code generation $\rightarrow$ sending messages between applications

Components

- **Interface description language**
- **Source code generator** (`protoc` compiler)
  - Supported languages
    - Official: C++, C#, Java, Python, Ruby …
    - 3rd party: Perl, PHP, Scala, …
- **Binary serialization format**
  - Compact, not self-describing

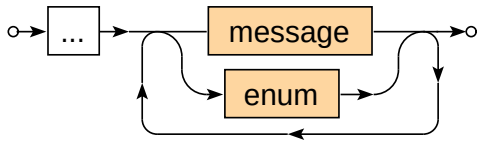
Example

```
syntax = "proto3";
message Actor {
  string firstname = 1;
  string lastname = 2;
}
message Movie {
  string title = 1;
  int32 year = 16;
  repeated Actor actors = 17;
  enum Genre {
    UNKNOWN = 0;
    COMEDY = 1;
    FAMILY = 2;
  }
  repeated Genre genres = 2048;
}
```

Schema Structure

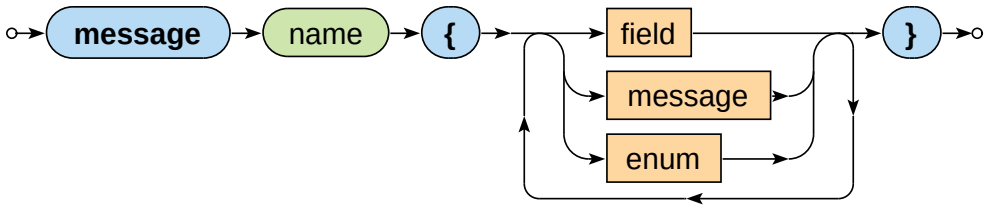
Schema

- One schema may contain multiple **message descriptions**
  - Other constructs are allowed as well, e.g. **enumerations**



Message

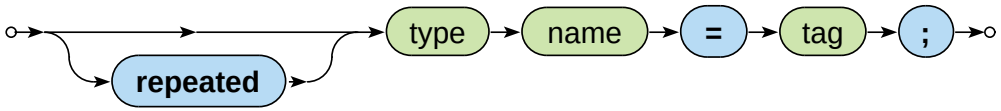
- Represents a small logical record of information
  - Defines a **set of uniquely numbered fields**
  - Nested messages or enumerations are allowed too



Schema Structure

Field

- Describes one data value



- **Rule** – allowed number of value occurrences
  - Default = 0 or 1 value
  - `repeated` = 0 or more values (i.e. an arbitrary number)
    - The order of individual values is preserved
- …

Schema Structure

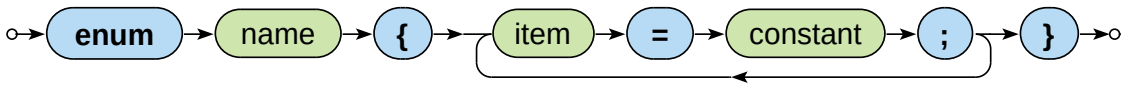
Field

- **Type**
  - Atomic: `int32`, `int64`, `double`, `string`, `bool`, `bytes`, …
    - Mappings to data types of particular programming languages as well as default values are introduced
  - Composed: messages, enumerations, …
- **Name** – name of a given field
- **Tag** – internal integer identifier
  - Used to identify individual fields of a message in a binary format
  - Frequently used fields should be assigned lower tags
    - Since lower number of bytes will then be needed

Schema Structure

Enumeration

- Description of a **predefined list of values**
- The first item is considered to be the default value and its value must be equal to 0



A few other constructs are available too (e.g. maps)

Lecture Conclusion

Data formats

- Tree: **XML**, **JSON**
- Graph: **RDF**
- Relational: **CSV**

Binary serializations

- **BSON**, **Protocol Buffers**