TRIPLE—An RDF Query, Inference, and Transformation Language

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Overview

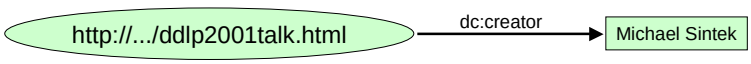
- Introductions to
  - RDF, RDF Schema
  - DAML
- TRIPLE
  - Motivation
  - Language Description
  - Layered Architecture
  - Realization
  - Conclusion

A Very Short Introduction to RDF ("Resource Description Framework") I

- (Syntactical) basis of the "semantic web"
- Similar to semi-structured data: graphs (RDF ~ OEM)
- Three basic object types:
  - *resources*: all things being described; named by URIs
  - *properties*: attributes to describe a resource
  - *statements*: subject + predicate + object;
    are all resources (object can also be a literal)
- Example:
  - "the *creator* of *this talk* is *Michael Sintek*"
    - subject: http://www.dfki.uni-kl.de/.../ddlp2001talk.html
    - predicate: http://www.purl.org/dc/.../creator
    - object: "Michael Sintek"

A Very Short Introduction to RDF II

- Representation
  - as graph:

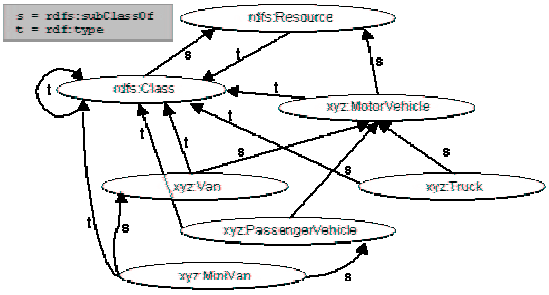


  - serialized in XML ("RDF/XML"):

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://www.purl.org/dc/elements/1.0/">
  <rdf:Description about=" http://.../ddlp2001talk.html ">
    <dc:creator>Michael Sintek</dc:creator>
  </rdf:Description>
</rdf:RDF>
```


A Very Short Introduction to RDF Schema

- *RDF* = simple data model
- *RDF Schema* allows definition of vocabularies for RDF data
- Simple frame system / ontology language:
  - classes, subclasses, properties, sub-properties, domain, range
- Extension of RDF *in* RDF
- Example:



A Very Short Introduction to DAML ("DARPA Agent Markup Language")

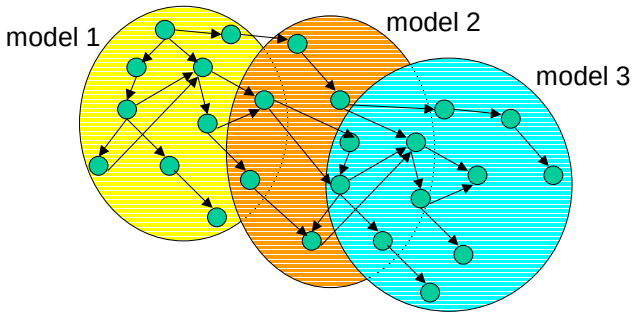
- Motivation:
  - support WWW content that is easily used by intelligent agents and other programs
  - enable the *Semantic Web*
- DAML language ("DAML+OIL") extension of RDF[S]:
  - description logics:
    - class expressions: union, intersection, complement
    - inverse, transitive, ... properties
    - cardinality constraints
  - support for concrete types (from XML Schema)
  - usually enacted by DL classifier (e.g., FaCT)

TRIPLE: Motivation

- RDF used in various scenarios:
  - meta-data for documents on the web (e.g., in PDF files)
  - distributed knowledge (e.g., ontologies)
  - exchange of complex semi-structured or object-oriented data (e.g., between companies)
  - message content language in agent systems (e.g., FIPA)
- Needed: query and inference language for RDF:
  - intelligent information retrieval (search heuristics etc.)
  - ontology mapping, information integration, ...
- Existing/ongoing approaches:
  - SiLRI, DQL, RQL, N3, Squish, ...

What's Wrong With Existing Approaches?

- Built-in *semantics* (e.g. SiLRI, RQL)
  - but: many RDF-based languages with different semantics (DAML+OIL, RDF Schema, UML/RDF, ...)
- No support for RDF *models*
  - one large heap of RDF data



TRIPLE: Language Overview

- Native support for
  - Resources & namespaces, abbreviations
  - Models (sets of RDF statements)
  - Reification
  - Rules with expressive bodies (full FOL syntax)
  - Transformations
- Syntactical extension of Horn Logic
- Syntactically similar to F-Logic (and SiLRI):
  - *subject*[*predicate*→*object*] ("molecule")

Language Description I

- Namespace and resource abbreviations:
  - rdf := "http://www.w3.org/1999/02/22-rdf-syntax-ns#".
  - isa := rdf:subClassOf.
- Statements, triples, molecules:
  - *subject*[*predicate*→*object*]
  - *subject*[p_1→o_1; p_2 →o_2; ...]
  - s_1[p_1 → s_2[p_2→o]]
- Models, model expressions, parameterized models:
  - *s*[*p*→*o*]@*m* "triple <*s*,*p*,*o*> in model *m*"
  - *s*[*p*→*o*]@($m_1 \cap m_2$) model intersection
  - *s*[*p*→*o*]@sf(m1, X, Y) Skolem function

Language Description II

- Reification:
  - stefan[believes → <Ora[isAuthorOf→homepage]>]
- Logical formulae:
  - usual logical connectives and quantifiers: ∧ ∨ ¬ ∀ ∃
  - all variables introduced via ∀ (or ∃)
- Clauses:
  - facts: $s[p_1 \rightarrow o_1; p_2 \rightarrow o_2; ...]$.
  - rules: $\forall X \; s_1[p_1 \rightarrow X] \leftarrow s_2[p_2 \rightarrow X] \wedge ...$.
- Blocks:
  - *@model* { *clauses* }
  - ∀*Mdl* *@model*(*Mdl*) { *clauses* }

Example: Dublin Core

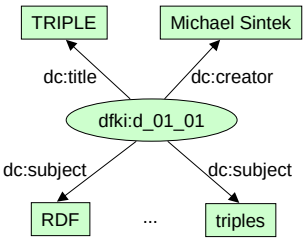
```
dc := “http://purl.org/dc/elements/1.0/”.
dfki := “http://www.dfki.de/”.

@dfki:documents {
   dfki:d_01_01 [
      dc:title → “TRIPLE”;
      dc:creator → “Michael Sintek”;
      dc:subject → RDF;
      dc:subject → triples; ... ].
   ∀S,D  search(S,D) ←
      D[dc:subject → S].
}
```

namespace abbreviations

block

fact

rule



Layered Architecture

- TRIPLE supports the definition of semantical RDF extensions in a modular way
  - RDF Schema (and other “simple” frame systems): semantics can be directly defined in TRIPLE as a parameterized model (see next slide)
  - OIL, DAML+OIL (i.e., expressive ontology languages, DL): requires interaction with foreign reasoning components (e.g., DL classifier)
- Goal: use various semantics in one inference (e.g., for information integration)

TRIPLE/RDFS: RDF Schema Model

```
rdf := 'http://www.w3.org/...rdf-syntax-ns#'.
rdfs := 'http://www.w3.org/.../PR-rdf-schema-...#'.
type := rdf:type.
subPropertyOf := rdfs:subPropertyOf.
subClassOf := rdfs:subClassOf.
FORALL Mdl @rdfschema(Mdl) {
  transitive(subPropertyOf).
  transitive(subClassOf).
  FORALL O,P,V   O[P->V] <-
     O[P->V]@Mdl.
  FORALL O,P,V   O[P->V] <-
    EXISTS S   S[subPropertyOf->P] AND O[S->V].
  FORALL O,P,V   O[P->V] <-
    transitive(P) AND
    EXISTS W   (O[P->W] AND W[P->V]).
  FORALL O,T   O[type->T] <-
    EXISTS S   (S[subClassOf->T] AND O[type->S]).
}
```

namespace abbreviations

resource abbreviations

model block

“copy” triples from *Mdl*

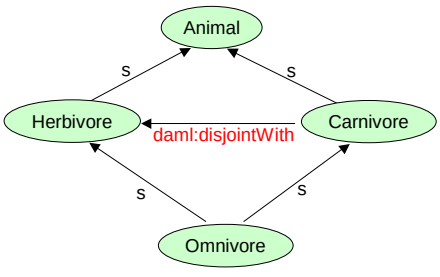
transitivity of subPropertyOf and subClassOf

TRIPLE/DAML+OIL

- daml_oil(Mdl) model realized by accessing a DL classifier (e.g., FaCT)
- access only allowed in rule bodies
- results in hybrid rule language similar to Carin, but more pragmatic approach: powerful but incomplete

TRIPLE/DAML+OIL Example

```
daml := 'http://www.daml.org/.../daml+oil#'.
animals := 'http://www.example.org/animals#'.
@animals:ontology {
 animals:Animal[rdf:type -> daml:Class].
 animals:Herbivore[rdf:type -> daml:Class;
  rdfs:subClassOf -> animals:Animal].
 animals:Carnivore[rdf:type -> daml:Class;
  rdfs:subClassOf -> animals:Animal;
  daml:disjointWith -> animals:Herbivore].
 animals:Omnivore[rdf:type -> daml:Class;
  rdfs:subClassOf -> animals:Herbivore;
  rdfs:subClassOf -> animals:Carnivore].
}
FORALL Ont   @check(Ont) {
  FORALL C   unsatisfiable(C) <-
    C[daml:subClassOf -> daml:Nothing]@daml_oil(Ont).
}
```



find all unsatisfiable classes (will detect Omnivore)

Realization: Mapping to Horn Logic

- First implementation (and informal semantics) by mapping to Horn Logic / XSB system (Prolog with tabled resolution)
- Lloyd-Topor transformation for quantifiers etc.
- RDF-specific transformations given as rewrite rules:

$$
\begin{array}{rcl}
A : N & \longrightarrow & \mathrm{resource}(A, N) \\
O[P \rightarrow V] & \longrightarrow & \mathrm{statement}(O, P, V) \\
S@M & \longrightarrow & \mathrm{true}(S, M) \quad \text{for statements } S \\
<S> & \longrightarrow & S \quad \text{for statements } S \\
O[P_1 \rightarrow V_1; P_2 \rightarrow V_2; \ldots]@M & \longrightarrow & O[P_1 \rightarrow V_1]@M \ \wedge \\
 & & O[P_2 \rightarrow V_2]@M \ \wedge \ \ldots \\
\mathrm{true}(S, M_1 \cap M_2) & \longrightarrow & \mathrm{true}(S, M_1) \ \wedge \ \mathrm{true}(S, M_2) \\
\mathrm{true}(S, M_1 \backslash M_2) & \longrightarrow & \mathrm{true}(S, M_1) \ \wedge \ \neg \ \mathrm{true}(S, M_2) \\
X \ := \ Y. \ S(X) & \longrightarrow & \forall \ X \quad (X = Y \ \wedge \ S(X)) \\
 & & \text{for clause sequences } S(X)
\end{array}
$$

Conclusions

- TRIPLE is a new RDF-specific query and inference language
- Allows specification of/access to multiple semantics
- Every Horn Logic inference engine can be used
- First implementation available (for a subset of TRIPLE called TRIPLE_0): http://www.dfki.uni-kl.de/frodo/triple/
- Representation of TRIPLE_0 in RDF exists
- Part of RuleML initiative: http://www.dfki.uni-kl.de/ruleml/

