Knowledge Graphs

Lecture 5 – Ontological Engineering for Smarter Knowledge Graphs

Excursion 7: The Semantic Web Rule Language SWRL

Prof. Dr. Harald Sack
FIZ Karlsruhe – Leibniz Institute for Information Infrastructure
AIFB – Karlsruhe Institute of Technology
Autumn 2023

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Knowledge Graphs

Lecture 5: Ontological Engineering for Smarter Knowledge Graphs

5.1 Beyond the Limits of OWL

Excursion 7: The Semantic Web Rule Language SWRL

5.2 How to design your own Ontology

5.3 How to design better Ontologies

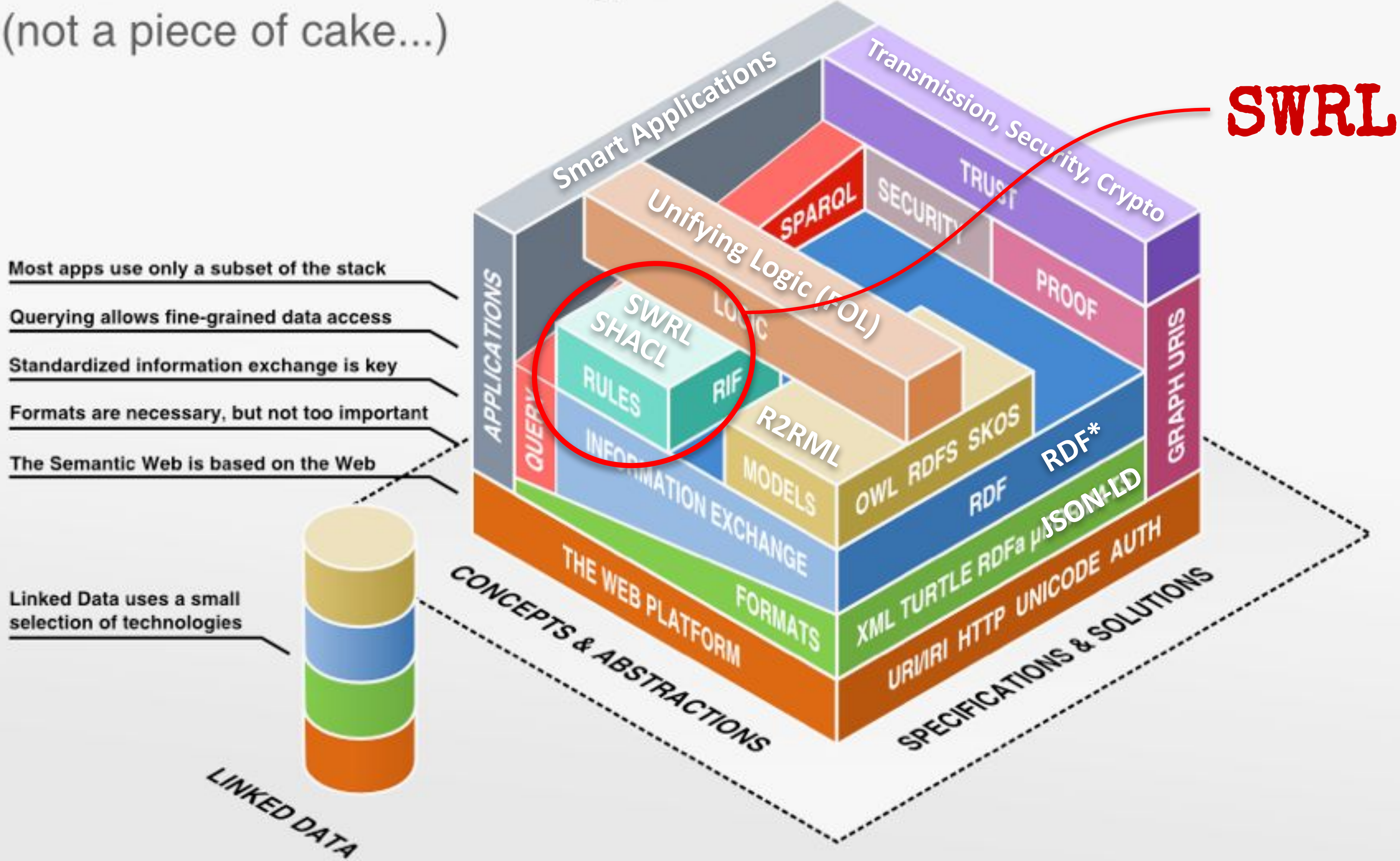
5.4 Ontological Engineering

5.5 Knowledge Graph Construction

5.6 Ontologies & Knowledge Graphs – Best Practices

[1]

The Semantic Web Technology Stack
(not a piece of cake...)



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Semantic Web Rule Language – SWRL

- based on the combination of parts of **OWL** and **RuleML/**DATALOG
- **Idea**: DATALOG rules that apply on OWL ontologies
  Symbols in rules can be OWL identifiers (or new DATALOG identifiers)
- W3C Submission (already in May 2004)
  (developed by the Joint US/EU ad hoc Agent Markup Language Committee (JC) in collaboration with RuleML Initiative, http://www.w3.org/Submission/SWRL/)
- **Syntax**:
  - XML Concrete Syntax (extends OWL XML Presentation Language)
  - RDF Concrete Syntax and abstract Syntax
- In SWRL rules are represented as Implication of an **Antecedent** (Body) and a **Consequent** (Head).
- SWRL is **undecidable**

Semantic Web Rule Language – SWRL

Antecedent → Consequent

- Antecedent and Consequent are **Conjunctions** of assertions (atoms) of the form
  - `C(x)` or `P(x,y)`
  - `sameAs(x,y)`, `differentFrom(x,y)`
- where `x,y` are variables, OWL individuals or elements of an OWL concrete domain
- `C(x)` is an OWL class description
- `P(x,y)` is an OWL property description

Semantic Web Rule Language – SWRL

- SWRL Rule

  $a \leftarrow b_1,\dots,b_n$ where a: head, $b_1,\dots,b_n$: body

- SWRL Knowledge Base

  $k=(\Sigma,P)$ where Σ is an OWL knowledge base

  P is a finite rule set

- Atoms are defined as

  $\text{Atom} \leftarrow C(i)\,|\,D(v)\,|\,R(i,j)\,|\,U(i,v)\,|\,\text{builtIn}(p,v_1,\dots,v_n)\,|\,i=j\,|\,i\neq j$

  - *C ... Class, D ... Datatype*
  - *R ... Object Property*
  - *U ... Datatype Property*
  - *i,j ... Variable / Individual identifier*
  - *$v,v_1,\dots v_n$ ... Datatype Variable / Value Identifier*
  - *p ... name of a BuiltIn function*

SWRL Semantics

- OWL DL (Description Logics) and DATALOG are applying the same interpretations
  - OWL *individuals* are DATALOG *constants*
  - OWL *classes* are unary DATALOG *predicates*
  - OWL *properties* are binary DATALOG *predicates*
- Interpretation can be modelled for OWL ontology as well as for a set of DATALOG rules

▶ Entailment for OWL/DATALOG combination is possible

SWRL Semantics

Let $I=(\Delta^I, \Delta^D, .^I, .^D)$ be an interpretation with

- Δ^I = Object Interpretation domain
- Δ^D = Datatype Interpretation domain
- $.^I$ = Object Interpretation function
- $.^D$ = Datatype Interpretation function
- with $\Delta^I \cap \Delta^D = \perp$
- V_{IX} are object variables with $V_{IX} \rightarrow 2^{\Delta I}$
- V_{DX} are datatype variables with $V_{DX} \rightarrow 2^{\Delta D}$

SWRL Semantics

Interpretation of SWRL atoms:

SWRL atom	Interpretation
C(i)	$i^{\mathcal{I}} \in C^{\mathcal{I}}$
R(i,j)	$(i^{\mathcal{I}}, j^{\mathcal{I}}) \in R^{\mathcal{I}}$
U(i,v)	$(i^{\mathcal{I}}, v^{\mathcal{D}}) \in U^{\mathcal{I}}$
D(v)	$v^{\mathcal{D}} \in D^{\mathcal{D}}$
builtIn($p, v_1, \ldots, v_n$)	$v_1^{D}, \ldots, v_n^{D} \in p^{D}$
i=j	$i^{\mathcal{I}} = j^{\mathcal{I}}$
i≠j	$i^{\mathcal{I}} \neq j^{\mathcal{I}}$

SWRL Semantics

- SWRL **Antecedent** is satisfied, iff
  - antecedent is empty (trivial) **or**
  - all atoms of the antecedent are satisfied
- SWRL **Consequent** is satisfied, iff
  - it is not empty **and**
  - the atom of the consequent is satisfied
- A **Rule** is satisfied for an Interpretation $\mathcal{I}$, iff

  the Interpretation $\mathcal{I}$, which satisfies the antecedent also satisfies the consequent.

SWRL Example

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```
hasUncle(?x,?z) ← hasParent(?x,?y) ∧ hasBrother(?y,?z)
```

```
<ruleml:imp>
   <ruleml:_rlab ruleml:href="#onkel"/>
   <owlx:Annotation>
      <owlx:Documentation>The Uncle Rule</owlx:Documentation>
   </owlx:Annotation>
   <ruleml:_body>
      <swrlx:individualPropertyAtom swrlx:property="&family;hasParent">
         <ruleml:var>x</ruleml:var>
         <ruleml:var>y</ruleml:var>
      </swrlx:individualPropertyAtom>
      <swrlx:individualPropertyAtom swrlx:property="&family;hasBrother">
         <ruleml:var>y</ruleml:var>
         <ruleml:var>z</ruleml:var>
      </swrlx:individualPropertyAtom>
   </ruleml:_body>
   <ruleml:_head>
      <swrlx:individualPropertyAtom swrlx:property="&family;hasUncle">
         <ruleml:var>x</ruleml:var>
         <ruleml:var>z</ruleml:var>
      </swrlx:individualPropertyAtom>
   </ruleml:_head>
</ruleml:imp>
```

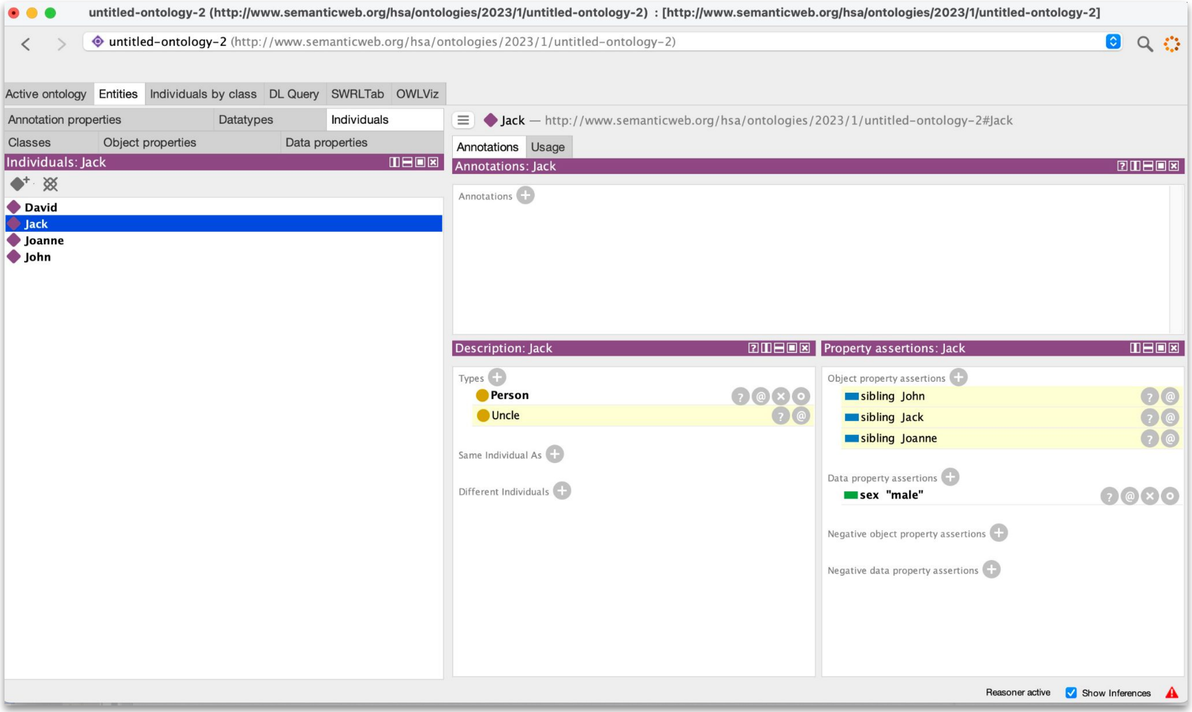
swrlx	http://www.w3.org/2003/11/swrlx
owlx	http://www.w3.org/2003/05/owl-xml
ruleml	http://www.w3.org/2003/11/ruleml

SWRL Example

- Logical Inference for OWL+SWRL is **undecidable**
- There is **no known algorithm that is able to entail all possible inferences for all SWRL knowledge bases**,
- even with unlimited resources and time
- But, from a **practical perspective**, there are
    - Algorithms that are able to entail **all possible inferences for some SWRL knowledge bases**
    - Algorithms that are able to entail **some inferences for all SWRL knowledge bases**

Tool Support for SWRL

- Bossam, R2ML, Hoolet, Pellet, KAON2, RacerPro,
- Jess, SWRLTab, SWRLQueryTab



How to Design your own Ontology

Next Lecture...

[4]

Bibliographic References:

Ian Horrocks, Peter F. Patel-Schneider, Harold Boley, Said Tabet, Benjamin Grosof, Mike Dean, *SWRL: A Semantic Web Rule Language Combining OWL and RuleML*, W3C Member Submission 21 May 2004.

Picture References:

[1] “A large owl in a space suit floating in deep space next to its spaceship over the surface of Mars.”, created via ArtBot, Deliberate, 2023, [CC-BY-4.0], https://tinybots.net/artbot

[2] Benjamin Nowack, *The Semantic Web - Not a Piece of cake…*, at bnode.org, 2009-07-08 , [CC BY 3.0], https://web.archive.org/web/20220628120341/http://bnode.org/blog/2009/07/08/the-semantic-web-not-a-piece-of-cake

[3] “A Scifi movie poster of "Planet Mars - the isle of the Dead". A small rover crosses the lonely Martian dessert towards the isle of the dead, on board we see two silent astronauts. Some zombies are chasing after the astronauts.”, created via ArtBot, Deliberate, 2023, [CC-BY-4.0], https://tinybots.net/artbot