Paraconsistent Reasoning for OWL 2

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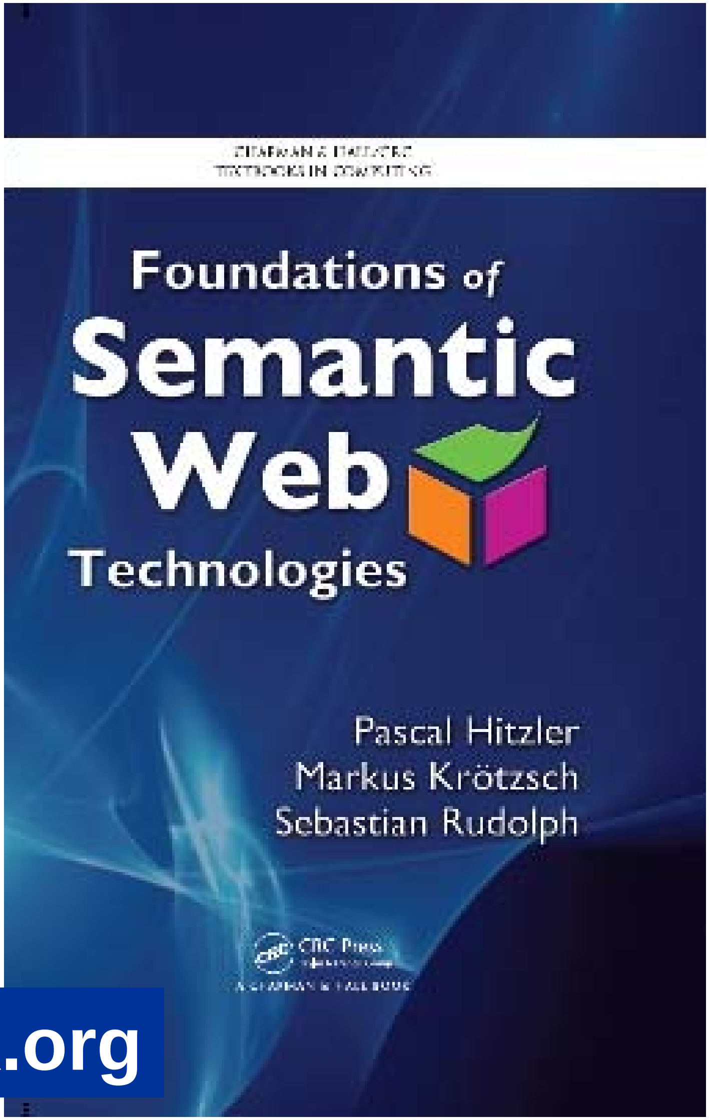
Book Announcement

Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph

Foundations of Semantic Web Technologies
Chapman & Hall/CRC, 2009

Grab a flyer!



http://www.semantic-web-book.org

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In a Nutshell

- Paraconsistent semantics which can deal with inconsistent OWL 2 DL ontologies, based on 4-valued logic
- PolyTime transformation into OWL 2 DL (i.e. standard OWL reasoner can be used)
- Tractability of OWL 2 EL and OWL 2 QL retained under paraconsistent semantics
- Prototype implementations exist

Contents

- **Motivation**
- The Semantics
- PolyTime Transformation to classical OWL
- Tractable Fragments
- Implementation
- What needs to be done

Paraconsistent Reasoning

Idea:

Rather than repairing inconsistencies change semantics to provide for them

Rationales:

- Inconsistencies occur naturally, i.e. they do not need repair but dealing with
- Repair is too difficult or too expensive

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Standard Approach

- Use 4 truth values instead of 2:
  - true
  - talse
  - undefined / unknown
  - overdefined / both / inconsistent

- Make reasonable truth tables (choices exist)

- Lift semantics to the 4 truth values

how to guide the choices?

Properties of Our Semantics

- Does not increase OWL 2 computational complexity
- Tractable fragments of OWL 2 remain tractable

- Polytime transformations to 2-valued semantics

- Standard equivalences from 2-valued semantics still hold (e.g. DeMorgan)

Lifting the Semantics

Constructor Syntax	Semantics
A	$A^I = \langle P, N \rangle$, where $P, N \subseteq \Delta^I$
R	$R^I \subseteq \Delta^I \times \Delta^I$
o	$o^I \in \Delta^I$
$\top$	$\langle \Delta^I, \emptyset \rangle$
$\bot$	$\langle \emptyset, \Delta^I \rangle$
$C_1 \sqcap C_2$	$\langle P_1 \cap P_2, N_1 \cup N_2 \rangle$, if $C_i^I = \langle P_i, N_i \rangle$ for $i = 1, 2$
$C_1 \sqcup C_2$	$\langle P_1 \cup P_2, N_1 \cap N_2 \rangle$, if $C_i^I = \langle P_i, N_i \rangle$ for $i = 1, 2$
$\neg C$	$(\neg C)^I = \langle N, P \rangle$, if $C^I = \langle P, N \rangle$
$\exists R.C$	$\langle \{x \mid \exists y, (x, y) \in R^I \text{ and } y \in \mathit{proj}^+(C^I)\}$, $\{x \mid \forall y, (x, y) \in R^I \text{ implies } y \in \mathit{proj}^-(C^I)\} \rangle$
$\forall R.C$	$\langle \{x \mid \forall y, (x, y) \in R^I \text{ implies } y \in \mathit{proj}^+(C^I)\}$, $\{x \mid \exists y, (x, y) \in R^I \text{ and } y \in \mathit{proj}^-(C^I)\} \rangle$

Lifting the Semantics

Constructor	Semantics
$\geq nR.C$	$\langle \{x \mid \#(y.(x,y) \in R^I \wedge y \in proj^+(C^I)) \geq n\}$, $\{x \mid \#(y.(x,y) \in R^I \wedge y \notin proj^-(C^I)) < n\} \rangle$
$\leq nR.C$	$\langle \{x \mid \#(y.(x,y) \in R^I \wedge y \notin proj^-(C^I)) \leq n\}$, $\{x \mid \#(y.(x,y) \in R^I \wedge y \in proj^+(C^I)) > n\} \rangle$
$\{o_1, ...o_n\}$	$\langle \{o_1^I, ..., o_n^I\}, N \rangle$, where $N \subseteq \Delta^I$

- Nominals are basically treated like named classes; just that their positive part is fixed.

Lifting the Semantics

Axiom Name	Syntax	Semantics
material inclusion	$C_1 \mapsto C_2$	$\Delta^I \setminus proj^-(C_1^I) \subseteq proj^+(C_2^I)$
internal inclusion	$C_1 \sqsubset C_2$	$proj^+(C_1^I) \subseteq proj^+(C_2^I)$
strong inclusion	$C_1 \rightarrow C_2$	$proj^+(C_1^I) \subseteq proj^+(C_2^I)$ and $proj^-(C_2^I) \subseteq proj^-(C_1^I)$
individual assertions	$C(a)$	$a^I \in proj^+(C^I)$
	$R(a,b)$	$(a^I, b^I) \in R^I$

- Three choices for resolving class inclusion exist – they differ in semantic strength.
- Note roles are 2-valued!

Class Inclusions

$$\varphi \mapsto \psi \text{ is definable as } \neg\varphi \vee \psi. \quad \text{(Material Implication)}$$

$$\varphi \supset \psi \quad \text{evaluates to} \quad \begin{cases} \psi & \text{if } \varphi \in \{t, \ddot{\top}\} \\ t & \text{if } \varphi \in \{f, \ddot{\bot}\} \end{cases} \quad \text{(Internal Implication)}$$

$$\varphi \rightarrow \psi \text{ is definable as } (\varphi \supset \psi) \wedge (\neg\psi \supset \neg\varphi) \quad \text{(Strong Implication)}$$

- Material is the weakest of the three
- Internal satisfies the deduction theorem
- Strong additionally satisfies contraposition

- When to choose which implication is still unclear

4-Satisfiability

- Every knowledge base has a four-valued model
- (under any mix of class inclusions)
- Caveat: Have to remove $\top$ and $\bot$ first

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PolyTime Transformation

- (in fact, linear)

- Standard method:
  Rewrite $\neg$A to new class name A'
  and treat them separately.
  Then lift this transformation over the structure of formulae $\Rightarrow \pi$.

- KB $\models_4 \alpha$ iff π(KB) $\models_2 \pi(\alpha)$

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Polytime Fragments of OWL 2

- OWL 2 EL: π(K) is in this fragment if
  - K is and
  - only internal inclusion is used
- Horn-SHIQ: Transformation needs modification. π_H(K) is in Horn-SHIQ if
  - K is and
  - only internal inclusion is used
- OWL 2 QL: Can be retained, but semantics needs modifications

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Prototype Implementations

- By Steffen Stadtmüller
  Universität Karlsruhe

  Part of the RaDON plugin of the NeOn Toolkit
  See ESWC2009 Demo paper on RaDON
  http://www.neon-toolkit.org

- By Fred Maier, Florida Institute for Human and Machine Cognition

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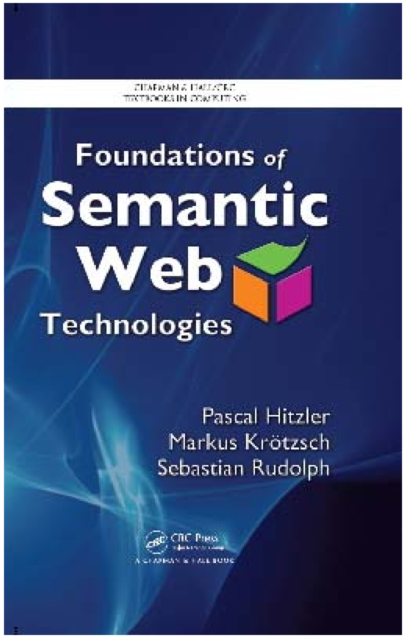
What needs to be done

- Extensive testing of the tool
  - efficiency
  - comparison with other approaches (e.g. debugging)
- Investigate which class inclusion to use in which context
  - automatic classification?
  - iterative weakening?
  - are there other ways to resolve this?
- Apply in realistic application scenarios

Thanks!



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