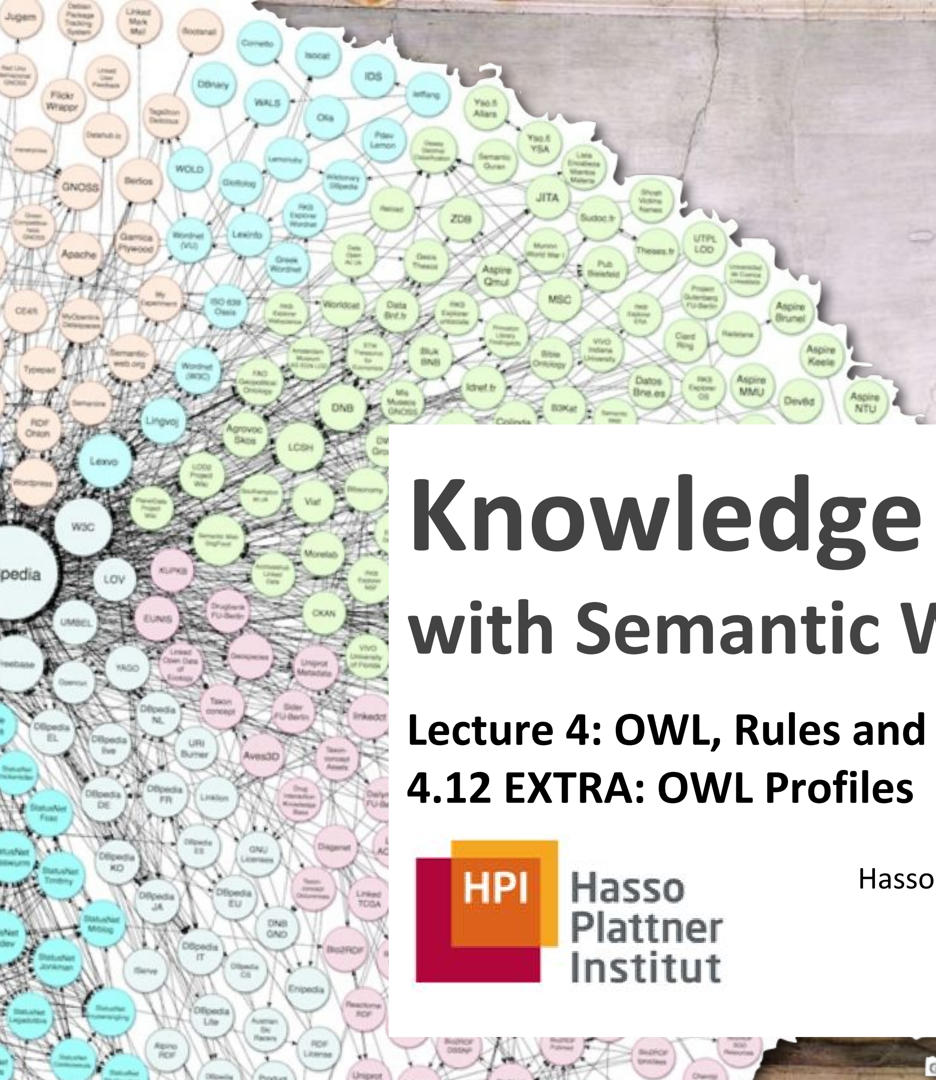

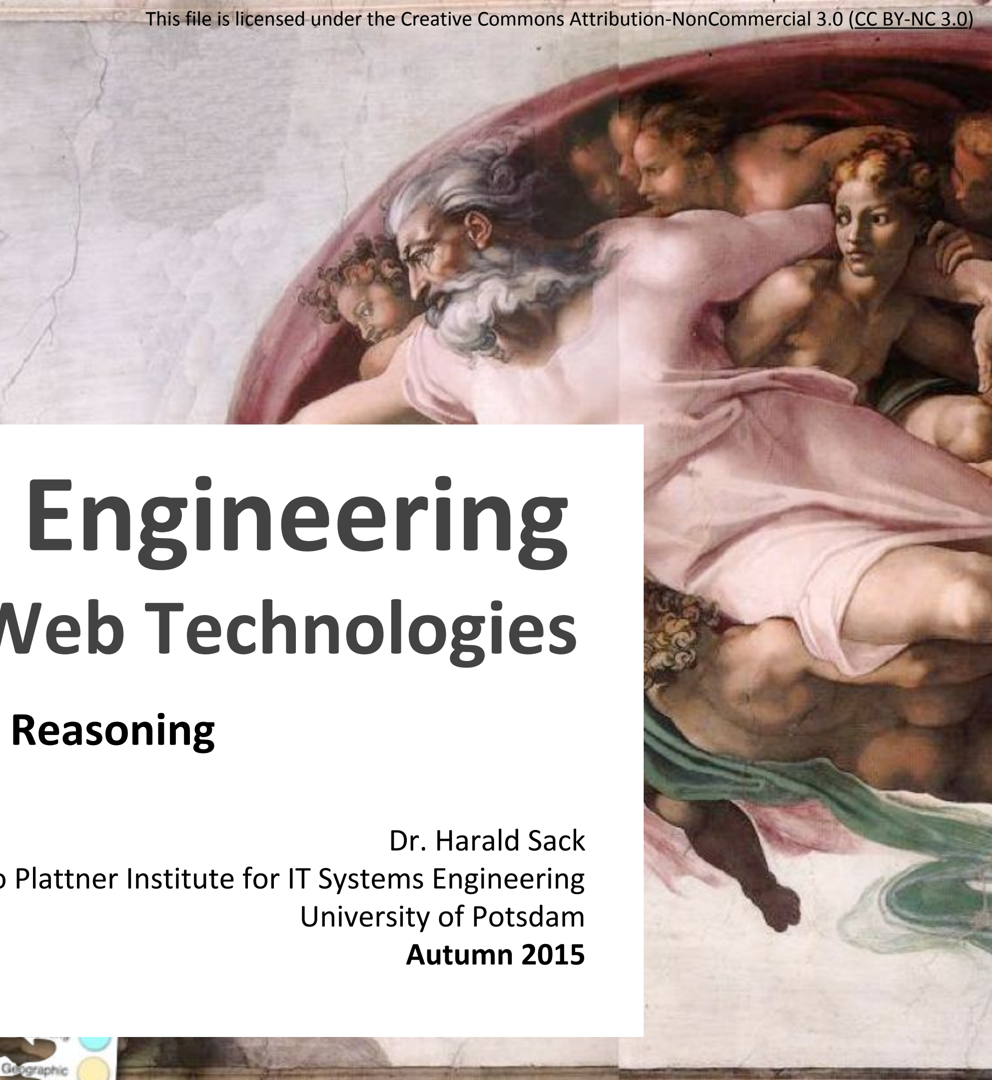

Knowledge Engineering with Semantic Web Technologies

Lecture 4: OWL, Rules and Reasoning
4.12 EXTRA: OWL Profiles

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OWL Profiles

- Reasoning with OWL is hard
  - OWL Full is **undecidable** with RDF-based semantics
  - OWL DL ($\mathcal{SROIQ}(\mathcal{D})$) with some structural restrictions on regularity and simplicity is **decidable** in N2ExpTime

- **Idea**:
  - Identify maximal OWL sublanguages (fragments) for which reasoning is easier, i.e. that are decidable in **polynomial time**

OWL Profiles

- Main reason for super-polynomial runtime: **Non-Determinism** (requires guessing / backtracking)
  - Disjunction or Negation + Conjunction
  - Maximum number restrictions
  - Combination of existential and universal quantification in one superclass
  - Non-unary enumerated classes
  - ▸ therefore not allowed for OWL Profiles
- ***Attention***: *many other features may also lead to non-determinism...*

OWL 2 EL is based on the description logic $\mathcal{EL}$++

Description Logic $\mathcal{EL}$++

- Conjunction $C \sqcap D$, existential Restriction $\exists R.C$, $\top$ and $\bot$
- Nominals, restricted property ranges, self restriction
- General property inclusion (RBox), Transitivity, Reflexivity
- *NOT ALLOWED*: *universal quantification, disjunction, complement, number restrictions, disjoint and inverted properties*

- **Advantages**:
  - Polynomial complexity for standard entailment, i.e. decidability, class membership, etc.
  - simple implementation
  - supports important ontologies (e.g. SNOMED-CT)

F. Baader, S. Brandt, C. Lutz: Pushing the EL envelope, IJCAI 2005, http://www.ijcai.org/papers/0372.pdf

OWL 2 EL Examples

- $\exists$has.Sorrow $\sqsubseteq$ $\exists$has.Liqueur
- $\exists$married.$\top$ $\sqcap$ CatholicPriest $\sqsubseteq$ $\bot$
- German $\sqsubseteq$ $\exists$knows.{merkel}
- $\exists$livesIn.{europe} $\sqsubseteq$ European
- hasParent $\circ$ hasParent $\sqsubseteq$ hasGrandparent
- CEO $\sqsubseteq$ $\exists$supervisedBy.Self

OWL 2 QL is based on the description logic $\mathcal{DL}$-Lite

Description Logic $\mathcal{DL}$-Lite

- Superclasses (R⊑**S**): ⊓, ¬, ∃R.C, ⊤, ⊥
- Subclasses (**R**⊑S): ∃R.⊤, ⊤, ⊥
- inverse properties, simple property hierarchies
- ABox like $\mathcal{SROIQ(D)}$
- NOT ALLOWED: *universal quantification, enumerated classes, disjunction, self, functional and inverse functional properties, number restrictions, transitivity, general property inclusion, equality of individuals*

- **Advantages**:
  - Sub-polynomial complexity (related to Relational Databases), Instance retrieval in LogSpace
  - fast implementations available, scalable

D. Calvanese, G. de Giacomo, D. Lembo, M. Lenzerini, R. Rosati: Tractable Reasoning and Efficient Query Answering in Description Logics: The DL-Lite Family. J. of Automated Reasoning 39(3):385–429, 2007 , http://www.dis.uniroma1.it/~degiacom/papers/2007/calv-etal-JAR-2007.pdf

OWL 2 QL Examples

- $\exists$married.$\top \sqsubseteq$ Lucky $\sqcap$ $\exists$has.NoSorrows
- Doctor $\sqsubseteq$ $\exists$treats.Patients
- Professor $\sqsubseteq$ $\neg$Student
- Cat $\sqsubseteq$ $\exists$preysOn.(Animal $\sqcap$ Small)
- $\exists$preysOn.$\top \sqsubseteq$ Predator
- $\exists$preysOn^{-}.$\top \sqsubseteq$ Animal

OWL 2 RL is based on Horn-Rule fragment of OWL2

- Subclass axioms ($R \sqsubseteq S$) can be interpreted as rules ($R \rightarrow S$)

Horn-Rule fragment of OWL 2:

- Superclasses ($R \sqsubseteq \mathbf{S}$): $\sqcap$, $\exists R.\{a\}$, $\forall R.C$, $\leq 1 R.C$, $\bot$, $\neg$
- Subclasses ($\mathbf{R} \sqsubseteq S$): $\sqcap$, $\sqcup$, $\exists R.C$, $\exists R.\{a\}$, $\bot$
- inverse properties, general property inclusion, disjointness, symmetry, asymmetry, transitivity, functionality, inverse functionality
- NOT ALLOWED: *disjoint union, reflexivity,* $\top$

- **Advantages**:
  - Polynomial complexity (PTime-complete)
  - Simple Implementation (OWL Axioms as Rules)
  - Related to rule languages

B. Grosof, I. Horrocks, R. Volz, S. Decker: Description Logic Programs: Combining Logic Programs with Description Logic, WWW2003, http://www.mit.edu/~bgrosof/paps/dlp-www2003.pdf

OWL 2 RL Examples

- $\exists$parentOf.$\exists$parentOf.$\top \sqsubseteq$ Grandparent
  as rule: parentOf(x,y) $\wedge$ parentOf(y,z) $\rightarrow$ Grandparent(x)
- Orphan $\sqsubseteq$ $\forall$hasParenxt.Dead
  as rule: Orphan(x) $\wedge$ hasParent(x,y) $\rightarrow$ Dead(y)
- Monogamous $\sqsubseteq$ $\leq$1 married.Alive
  as rule: Monogamous(x)$\wedge$married(x,y)$\wedge$Alive(y)$\wedge$married(x,z)$\wedge$Alive(z) $\rightarrow$ y=z
- childOf $\circ$ childOf $\sqsubseteq$ grandchildOf
  as rule: childOf(x,y) $\wedge$ childOf(y,z) $\rightarrow$ grandchildOf(x,z)

OWL 2 Profiles - Feature Overview

Sub	$\top$	$\bot$	$\sqcap$	$\sqcup$	$\neg$	$\exists R.C$	$\exists R.\top$	$\forall R.C$
RL		✔	✔	✔		✔	✔	
EL	✔	✔	✔			✔	✔	
QL	✔	✔					✔	
Super	$\top$	$\bot$	$\sqcap$	$\sqcup$	$\neg$	$\exists R.C$	$\exists R.\top$	$\forall R.C$
RL		✔	✔		✔			✔
EL	✔	✔	✔			✔	✔	
QL	✔	✔	✔		✔	✔	✔	

http://korrekt.org/talks/2012/OWL_2_Profiles_Reasoning-Web-2012.pdf

Do we need so many OWL Fragments?

- The union of any two of the OWL profiles is no longer light-weight!
  QL+RL, QL+EL, RL+EL all ExpTime-hard
- Restricting to fewer profiles = giving up potentially useful feature combinations
- **Rationale**:
  - profiles are "maximal" (well, not quite) well-behaved OWL 2 fragments
  - select a suitable feature set for your applications

13 EXTRA - SWRL - Semantic Web Rule Language

OpenHPI - Course Knowledge Engineering with Semantic Web Technologies

Lecture 4: OWL, Rules, and Reasoning