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Description Logic in a nutshell

Seminar „Resources for Computational Linguists“
SS 2007

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Motivation

- We have seen all those great ontologies - how can we make use of them?

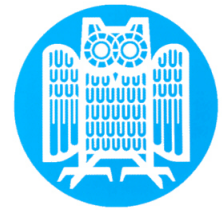
- How can we add logic inference to our world knowledge? (Aristotle is a human, humans are mortal ->
  Aristotle is mortal)

- How can we do all that without having to wait for ages?

Outline

- Some curses of FOL
- Some solutions: Description Logics
  - Basics and Terms
  - Reasoning: RACER

Some curses of FOL



- FOL is not decidable

  Provide a system with the following:
  (The universe shall consist of natural numbers)

  $\forall x \exists y$ `bigger_than(x,y)`

  $\forall x \forall y \forall z$`((bigger_than(x,y)` $\wedge$ `bigger_than(y,z))` $\rightarrow$
  `bigger_than(x,z))`

  Finding a prove for the following statement may take forever:

  $\exists x$ `bigger_than(x,x)`

Some curses of FOL (cont.)

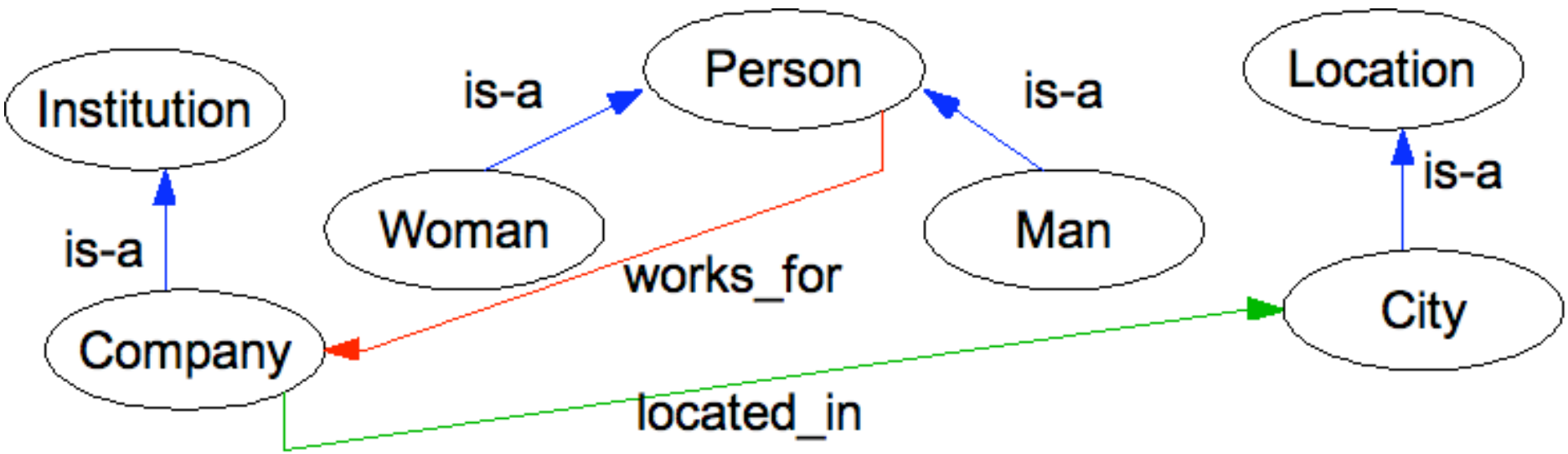
- Even if a prover will find a prove, it may take an unreasonable amount of time
- How do we encode all the world knowledge with first order logic?
- There are some more curses - but this talk won‘t provide any solution for them :-)

Description Logic

- A decidable fragment of FOL
- efficient reasoners (RACER) exist
- some big knowledge bases are already encoded in description logics (like OWL e.g.)
- We won‘t look at a special DL now, but introduce some elements they all have in common

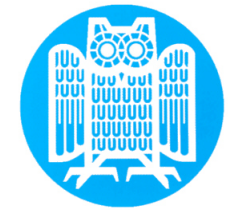
Description Logic - basics

- Designed for knowledge representations



- allowing to encode general knowledge (as above) as well as world models (with individuals, s.a. *john*)

Description Logic - basics (cont.)



- T-Box: The world‘s rules (as described in the knowledge base)

$$\begin{aligned} \text{man} &\sqsubseteq \text{person} \\ \text{woman} &\sqsubseteq \text{person} \\ \text{city} &\sqsubseteq \text{location} \\ \forall \text{located\_in.location} & \\ & \\ \dots & \end{aligned}$$

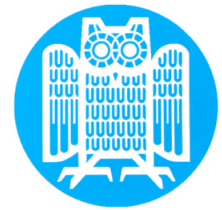
- A-Box: Relations between and properties of individuals

person(mary)	works_for(mary, c1)
person(john)	located_in(NY, c1)
loves(mary, john)	woman(mary)
loves(john, mary)	man(john)

Description Logic - Terms

- (atomic) concepts C denoting sets of individuals (*person*)
  ≈ unary predicates in FOL
- (atomic) roles R: (*loves)* ≈ binary predicates in FOL
- complex concepts:
  - conjunction and disjunction of concepts: $C_1 \sqcap C_2$, $C_1 \sqcup C_2$
  - negation (the complementary concept): ¬C
  - existential restriction: ∃R.C (set of all *a* having an *x* s.t. R(a,x) & C(x))
  - value restriction: ∀R.C (set of all *a* s.t. for all *x s.t.* R(a,x), C(x) holds)

Description Logic - Terms (cont.)



- inverse roles R^{-1}: loves(john, mary) ≡ $loves^{-1}$(mary, john)

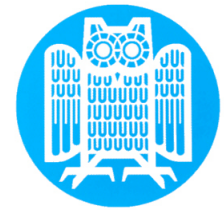
- the empty concept ⊥ and the universal concept ⊤

- concept equality: C1 ≐ C2
  (abbreviates C1 ⊑ C2 ∧ C2 ⊑ C1)

- ‚at most' and ‚at least' number restrictions:
  $\exists_{\leq m}$R: Set of all a s.t. there are at most m (different) *x* for which

  R(a,x) holds

Description Logic - Example



A-BOX

man(john)	loves(john,mary)
woman(mary)	loves(mary,sam)
man(sam)	married(sam,sue)
woman(sue)	happy(sam)

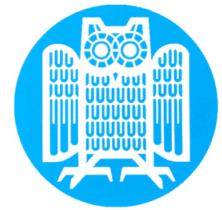
Some assertions...

T-BOX

...and some rules:

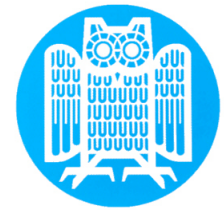
bachelor $\doteq \neg \exists$married.$\top \sqcap$ man	*„bachelors are unmarried men“*
married $\doteq$ married^{-1}	(being married to so. is reflexive)
$\exists$married.$\top \sqsubseteq$ happy	*„all married people are happy“*
$\exists_{\geq 2}$ love $\sqsubseteq \bot$	*„you can love at most one person“*
$\exists$married.woman $\sqsubseteq \exists$love.woman	*„someone married to a woman also loves a woman“*

Description Logic - RACER



- a reasoner for description logic
- provides reasoning with T-Boxes and (multiple) A-Boxes
- performs consistency checks (of A-Boxes, T-Boxes or both)
- several retrieval tasks:
  - all individuals of a concept, all concepts of an individual
  - check for subsumption (*„are cities locations?“*)

Description Logic - RACER (cont.)

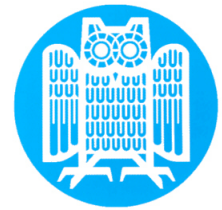


- several retrieval tasks:
  - find the *parent concepts* parents of C are the most specific C‘ s.t. C $\sqsubseteq$ C‘ (*children* analogously)
  - find *predecessors* (*successors*): predecessors of C are all C‘ s.t. C $\sqsubseteq^*$ C‘ (*successors* analogously)
  - determine *domain* and *fillers* of a role:

    fillers of R are all f s.t. $\exists x.R(x,f)$ ($\doteq \exists R^{-1}.\top$)

    domain of R consists of all d s.t. $\exists x.R(d,x)$ ($\doteq \exists R.\top$)

Description Logic - RACER (cont.)



- Example queries:

  Is Sue happy?
  (Does ‚happy' contain Sue?)

  Can Mary love John?
  (loves(mary, john) -> consistent?)

  What properties does Mary have?
  (Concepts containing mary)

A-BOX

man(john)	loves(john,mary)
woman(mary)	loves(mary,sam)
man(sam)	married(sam,sue)
woman(sue)	happy(sam)

T-BOX

$\text{bachelor} \doteq \neg\, \exists \text{married}.\top \sqcap \text{man}$

$\text{married} \doteq \text{married}^{-1}$

$\exists \text{married}.\top \sqsubseteq \text{happy}$

$\exists_{\geq 2}\, \text{love} \sqsubseteq \bot$

$\exists \text{married.woman} \sqsubseteq \exists \text{love.woman}$

What about Aristotle?

- What‘s needed to answer the question whether or not Aristotle is mortal?

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A-BOX

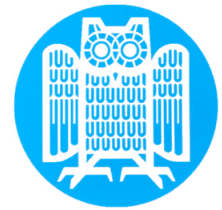
human(Aristotle)

T-BOX

human $\sqsubseteq$ mortal

Aristotle $\in$ mortal ?

References



- Ian Horrocks and Ulrike Sattler: Tutorial on description logics. Slides: http://www.cs.man.ac.uk/~horrocks/Slides/IJCAR-tutorial/Display/

- V. Haarslev and R. Möller. RACER System Description. In Proceedings of IJCAR-01, 2001.