Knowledge Representation

CSC480: Semantic Web Technologies

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Knowledge Representation

- Using formal symbols to represent a collection of propositions
- Reasoning
  - Draw of inferences, conclusions or judgements
  - Formal manipulation of symbols representing a collection of propositions to produce representations of new ones
- Logic
  - Study of entailment relations

Expressiveness vs. Efficiency

- Expressiveness
  - Breadth of ideas that can be represented by language
- Efficiency
  - Time, effort or cost to complete a task
- Trade-off

Logic or Knowledge Representation Languages

- Propositional Logic
- Predicate Logic
  - First Order Logic (FOL)
  - Predicate Calculus
- Description Logic

First Order Logic (FOL)

- Objects
- Concepts
- Functions

FOL Symbols

- Logical Symbols
  - Punctuation
  - Connectives
  - Variables
- Non-logical Symbols
  - Function
  - Predicates

FOL Expressions

- Terms
  - Something in the world
- Formulas
  - Expresses a proposition
- Arity
  - Number of “arguments”

FOL Terms

- The set of terms of FOL is the least set satisfying these conditions:
  - Every variable is a term
  - If $t_1,\ldots..,t_n$ are terms, and f is a function symbol of arity n, then $f(t_1,\ldots..,t_n)$ is a term.

FOL Formulas

- The set of formulas of FOL is the least set satisfying these constraints:
  - If $t_1,\ldots,t_n$ are terms, and P is a predicate symbol of arity n, then $P(t_1,\ldots,t_n)$ is a formula
  - If t_1 and t_2 are terms, then $t_1 = t_2$ is a formula
  - If α and β are formulas, and x is a variable, then $\neg\alpha$, $(\alpha \wedge \beta)$, $(\alpha \vee \beta)$, $\forall x.\alpha$, and $\exists x.\alpha$ are formulas.

FOL Syntax

S := <Sentence> ;

<Sentence> := <AtomicSentence> |
<Sentence> <Connective> <Sentence> |
<Quantifier> <Variable>,... <Sentence> |
"NOT" <Sentence> |
"(" <Sentence> ")";

FOL Syntax (2)

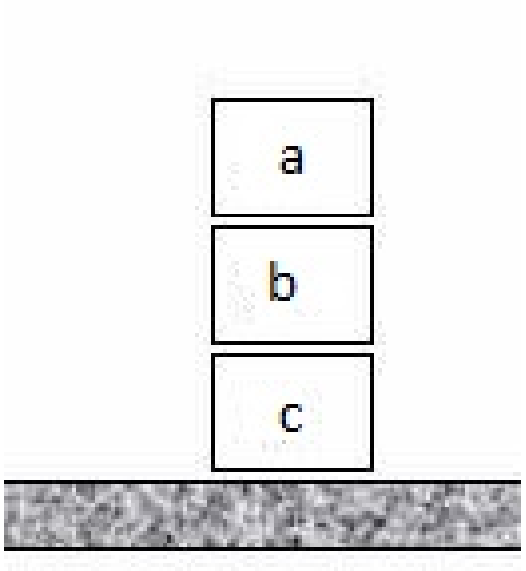
<AtomicSentence> := <Predicate> "(" <Term>,...")" |
<Term> "=" <Term>;
<Term> := <Function> "(" <Term>, ... ")" |
<Constant> |
<Variable>;

FOL Syntax (3)

<Connective> := "AND" | "OR" |
"IMPLIES" | "EQUIVALENT";
<Quantifier> := "EXISTS" | "FORALL" ;
<Constant> := "A" | "X1" | "John" | ... ;
<Variable> := "a" | "x" | "s" | ... ;
<Predicate> := "Before" | "HasColor" |
"Raining" | ... ;
<Function> := "Mother" | "LeftLegOf" | ... ;

FOL Example

- Suppose there are three colored blocks stacked on a table. The top block is green the bottom block is not green and the middle block's color is not known. The question is whether there is a green block directly on top of a nongreen block.



FOL Example (2)

- Blocks have names a, b, c
- Predicate symbols
  - G green
  - O on

FOL Example (3)

- Facts in S
  - {O(a,b), O(b, c), G(a), ¬G(c)}
- These facts ***entail***
  - There is a green block on top of a nongreen block
  - $S \models \alpha$
- α is $\exists x \exists y: G(x) \wedge \neg G(y) \wedge O(x,y)$

More FOL Symbols

- Implies
  - $\Rightarrow$
  - $\rightarrow$
  - $\supset$
- Defines
  - $\equiv$

FOL Examples: Assumptions

- Terms
  - John
  - Jane
  - jim
- Predicates
  - Rich
  - Adult
  - Man
  - Loves
  - Woman
  - Blackmails

FOL Examples

- Jane loves either John or Jim
- All rich men in our world love Jane
- In our world, all women, except Jane, love John
- No one who loves someone will blackmail the one he or she loves
- Some adult is blackmailing John

FOL Terminological Facts

- Disjointness
- Subtypes
- Exhaustiveness
- Symmetry
- Inverses
- Type restrictions
- Full definitions

Description Logics (DL)

- Family of knowledge representation languages
- Represent knowledge of an application domain (“world”)
  - Concepts
  - Properties
- Formal foundation of OWL

DL Vocabulary

- Concepts
  - Individuals
- Roles
  - Binary relationships between individuals
- Sentences
  - Expressions intended to be true or false

DL Knowledge Base

- TBox
  - Terminology
  - Concepts and properties
- Abox
  - Assertions
  - Facts associated with terminology

DL Syntax

- Logical Symbols
  - Punctuation
  - Concept-forming operators
  - Connectives and Quantifiers
  - Symbols for numbers
- Non-logical Symbols
  - Atomic concepts
  - Roles
  - Constants

DL Notation

Symbol	Description	Read
$\top$	all concept names	top
$\bot$	empty concept	bottom
$\sqcap$	intersection or conjunction of concepts	C and D
$\sqcup$	union or disjunction of concepts	C or D
$\neg$	negation or complement of concepts	not C
$\forall$	universal restriction	all R-successors are in C
$\exists$	existential restriction	an R-successor exists in C
$\sqsubseteq$	Concept inclusion	all C are D
$\equiv$	Concept equivalence	C is equivalent to D
$\doteq$	Concept definition	C is defined to be equal to D
:	Concept assertion	a is a C
:	Role assertion	a is R-related to b

DL Miscellaneous

- Definitions
  - Complex descriptions
- Restrictions
  - Quantified
  - Number

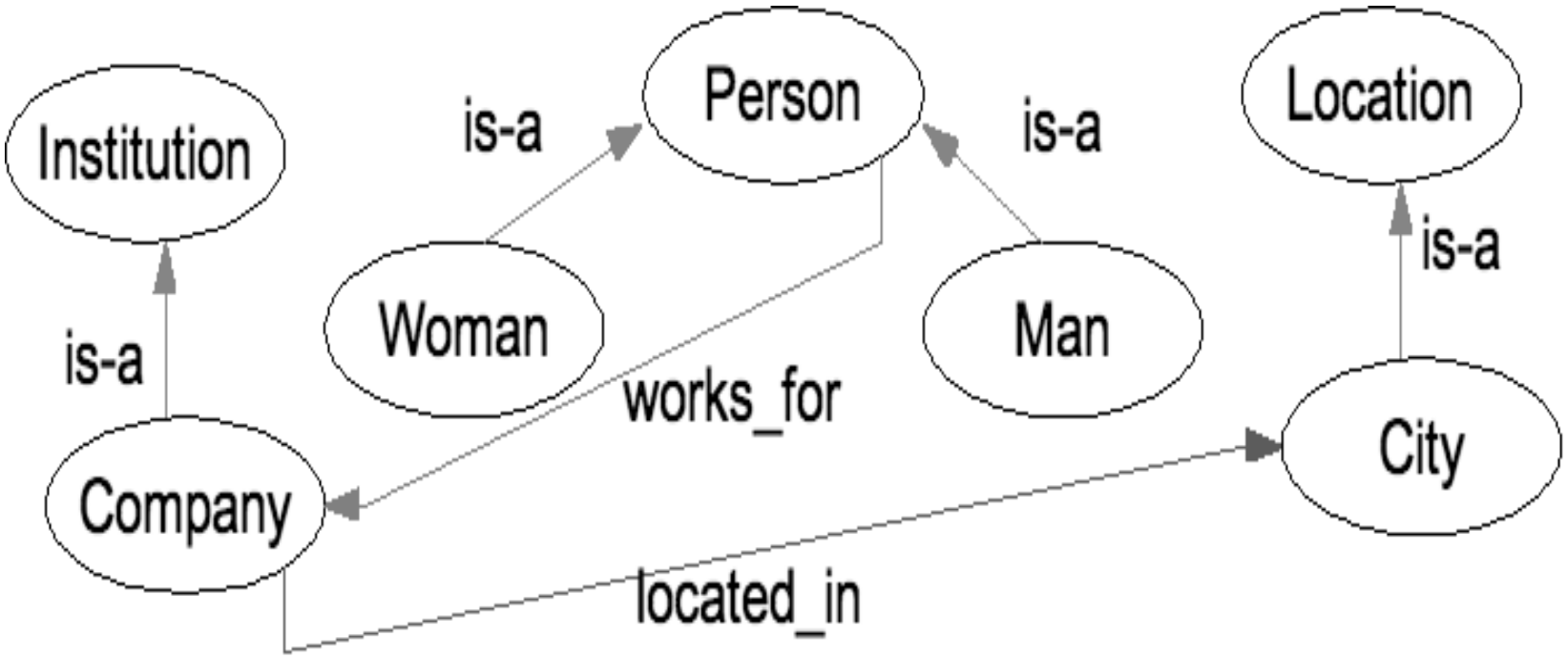
DL Examples: Assumptions

- Concepts
  - Person
  - Female
- Roles
  - hasChild

DL Examples

- Woman
- Man
- Mother
- Father
- Parent
- Grandmother
- MotherWithManyChildren
  - 3+
- MotherWithoutDaughter
- Wife

DL Example


Institution
is-a
Person
is-a
Location
is-a
Woman
Man
is-a
works_for
City
Company
located_in