OWL and
Description Logics DL

By:
A.Aziz Altowayan @ Pace University
4/01/2014

Description Logics (DL)

What:

- Knowledge **representation** language.
  (serving primarily for formal description of concepts and roles (relations)).

Why:

- Used for formal **reasoning** on the concepts of a domain.

OWL’s relation to DL:
"In the beginning, IS-A was quite simple. Today, however, there are almost as many meanings for this inheritance link as there are knowledge-representation systems."
Ronald Brachman 1983

DL Terminologies

In OWL:

- A **class** is a collection of objects.
- A **property** is a directed binary relation.
- An **instance** is an object.

In DL, the above corresponds to:

- A **concept**.
- A **role**.
- An **individual**.

A **concept** corresponds to a *unary predicate* while a **role** corresponds to a *binary predicate*.

Concept (**Formulae**):	e.g. Human, Male, Female, Animal
Roles (**Modalities)**:	e.g. hasChild, hasParent, loves
Individuals (**Ground term**):	e.g. Aziz, Lixin, USA

DL modeling and Knowledge Base

KR based on DLs, consists of 2 components:

- **TBox**, "*Terminological Box*" (describes terminology).
  - contains sentences describing concept hierarchies (i.e., relations between concepts).
    - e.g.) Every employee is a person.

- **ABox**, "*Assertion Box*" (assertions about individuals).
  - contains ground sentences stating where in the hierarchy individuals belong (i.e., relations between individuals and concepts).
    - e.g.) Bob is an employee.

> *“**Reasoning** in ontologies and knowledge bases is one of the reasons why a specification needs to be formal one.”*

Formal description and notations

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

See:

- DL wiki

OWL syntax, DL syntax, and semantics

OWL abstract syntax	DL syntax	Semantics
Class descriptions		
Class (A)	A	$A^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}}$
owl:Thing	$\top$	$\top^{\mathcal{I}} = \Delta^{\mathcal{I}}$
owl:Nothing	$\bot$	$\bot^{\mathcal{I}} = \varnothing$
intersectionOf ($C_1 \ldots C_n$)	$C_1 \sqcap \cdots \sqcap C_n$	$(C_1 \sqcap \cdots \sqcap C_n)^{\mathcal{I}} = C_1^{\mathcal{I}} \cap \cdots \cap C_n^{\mathcal{I}}$
unionOf ($C_1 \ldots C_n$)	$C_1 \sqcup \cdots \sqcup C_n$	$(C_1 \sqcup \cdots \sqcup C_n)^{\mathcal{I}} = C_1^{\mathcal{I}} \cup \cdots \cup C_n^{\mathcal{I}}$
complementOf (C)	$\neg C$	$(\neg C)^{\mathcal{I}} = \Delta^{\mathcal{I}} \backslash C^{\mathcal{I}}$
oneOf($w_1 \ldots w_n$)	$\{w_1, \ldots, w_n\}$	$(w_1, \ldots, w_n)^{\mathcal{I}} = \{w_1^{\mathcal{I}}, \ldots, w_n^{\mathcal{I}}\}$
restriction (P someValuesFrom(E))	$\exists P.E$	$(\exists P.E)^{\mathcal{I}} = \{a \mid \exists w. \langle a, w \rangle \in P^{\mathcal{I}} \wedge w \in E^{\mathcal{I}}\}$
restriction (P allValuesFrom(E))	$\forall P.E$	$(\forall P.E)^{\mathcal{I}} = \{a \mid \forall w. \langle a, w \rangle \in P^{\mathcal{I}} \rightarrow w \in E^{\mathcal{I}}\}$
restriction (P hasValue(w))	$\exists P.\{w\}$	$(\exists P.w)^{\mathcal{I}} \{a \mid \langle a, w^{\mathcal{I}} \rangle \in P^{\mathcal{I}}\}$
restriction (P minCardinality(n))	$\geq n P$	$(\geq n P)^{\mathcal{I}} = \{a \mid \#\{w \mid \langle a, w \rangle \in P^{\mathcal{I}}\} \geq n\}$
restriction (P maxCardinality(n))	$\leq n P$	$(\leq n P)^{\mathcal{I}} = \{a \mid \#\{w \mid \langle a, w \rangle \in P^{\mathcal{I}}\} \leq n\}$
restriction (P cardinality(n))	$= n P$	$(\geq n P \cap \geq n P)^{\mathcal{I}}$
$P \in \{R, T\}$ $w \in \{a, v\}$ $E \in \{C, d\}$		

See:

- complete list
- DL syntax and semantic

DL ALC and its concepts

Attributive concept Language with Complements ALC is a member of DL family, where:

- **top** is a concept.
- **bottom** is a concept.
- all **atomic concepts** are concepts
- the **intersection** of two concepts is a concept
- the **union** of two concepts is a concept
- the **complement** of a concept is a concept
- the **universal restriction** of a concept by a role is a concept
- the **existential restriction** of a concept by a role is a concept

Inference in DL (Decision problems)

“Description logics are created with the focus on tractable reasoning.”

Examples of tasks required from reasoners are:

- Instance checking. *(is a an instance of A?)*
- Relation checking. *(is a related to b?)*
- Subsumption. *(is A a subset of C?)*
- Concept consistency. *(is there any contradiction in A’s definition?)*

Finally,
Tradeoff between Expressive Power and Efficient Reasoning Support.

The **richer** the language is, the **more inefficient** the reasoning support becomes.