Description Logics

Lecture

Tuesdays and Thursdays 16:40 – 18:10
(Rafael Peñaloza)

Tutorial

Wednesdays 14:50 – 16:20
(Marcel Lippmann)

http://lat.inf.tu-dresden.de/teaching/ws2013-2014/DL/

Literature

Baader, Calvanese, McGuinness, Nardi, Patel-Schneider (eds.)
The Description Logics Handbook
Cambridge University Press (2003)

Baader, Lutz
Description Logics
In *Handbook of Modal Logics*. Elsevier (2006)

Baader
Description Logics
LNCS 5689. Springer (2009)

Description Logics

subfield of knowledge representation
which is a subfield of artificial intelligence

Description

comes from concept description:
a formal expression that determines a set of individuals

Logics

comes from the semantics being defined using logic:
most Description Logics are fragments of First Order Logic

Naming

Description Logics

name of the research field

Description Logics

a family of knowledge representation languages

Description Logic

a member of this family

DL(s)

Knowledge Representation

Goal [Brachman & Nardi, 2003]

develop formalisms for providing high-level description of the world that can be effectively used to build intelligent applications

- formalism: well-defined syntax; formal, unambiguous semantics
- high-level description: only relevant aspects represented
- intelligent applications: reason about the knowledge; infer implicit knowledge
- effectively used: practical reasoning tools and efficient implementations

Syntax

explicit symbolic representation of the knowledge

not implicit (as e.g. in neural networks)

$Woman \equiv Person \sqcap Female$
$Man \equiv Person \sqcap \neg Female$
$Mother \equiv Woman \sqcap \exists hasChild.\top$

$hasChild(stephen, marc)$
$hasChild(marc, anna)$
$hasChild(john, maria)$
$hasChild(anna, jason)$

$Male(john)$
$Male(marc)$
$Male(stephen)$
$Male(jason)$
$Female(jill)$
$Female(anna)$
$Female(maria)$

Semantics

connection between the symbolic representation and the “real world” entities it represents

Declarative semantics

- map symbols to an abstraction of the “world” (interpretation)
- notion of when a symbolic expression is true in the world (model)

NO procedural semantics:
should not just express how specific programs should behave

Expressive Power

(what can be expressed) depends on syntax and semantics

Equilibrium

- not too low: can all the relevant knowledge be represented?
- not too high: are all the elements really necessary for the application?

Reasoning

deduce implicit knowledge from the explicit representation

$\forall x.\forall y.(male(y) \land \exists z.(child(x,z) \land child(z,y))) \rightarrow grandson(x,y)$

$child(john, mary)$
$child(mary, paul)$
$male(paul)$

grandson(john,paul)

Knowledge Representation Systems

should provide inference tools to deduce implicit consequences

answers should depend on semantics; not on the syntactic representation
(same semantics must yield the same answer)

Reasoning Procedures

Decision Procedure

- sound: all positive answers are correct
- complete: all negative answers are correct
- terminating: always provides an answer in finite time

Efficient

ideally, optimal w.r.t. worst-case complexity of the problem

Practical

easy to implement and optimize
behave well in applications

Examples of Formalisms

First-order logic

satisfiability in FOL does not have a decision procedure
    is thus not an appropriate knowledge representation formalism

Propositional logic

satisfiability in propositional logic has a decision procedure
the problem is NP-complete

- ✓ highly optimized SAT solvers behave well in practice
- ✗ expressive power is often insufficient

Terminological Knowledge

formalize the terminology (names) of the application domain:

- define important notions of the domain (classes, relations, objects)
- constrain the interpretations of these notions
- deduce consequences: subclass, instance relationships

Example

university domain

- classes (concepts): Person, Teacher, Course, Student, . . .
- relations (roles): gives, attends, likes, . . .
- objects (individuals): DL_WS13, Marcel, Daniel, . . .
- constraints:

  every course is given by a teacher,
  every student must attend at least one course

Ontologies

is the modern name for knowledge bases

Applications

- semantic web enable a common understanding of notions for semantic labeling of Web content
- information retrieval support automatic extraction of information from text
- medicine formal definitions that can be used by doctors, patients, insurance companies, etc, to communicate with each other
- . . .

Description Logics

a class of logic-based knowledge representation formalisms for representing terminological knowledge

Prehistory

early approaches for representing terminological knowledge

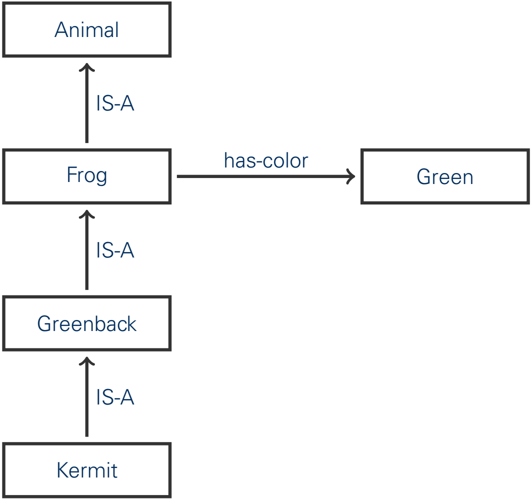
- semantic networks (Quillian, 1968)
- frames (Minsky, 1975)

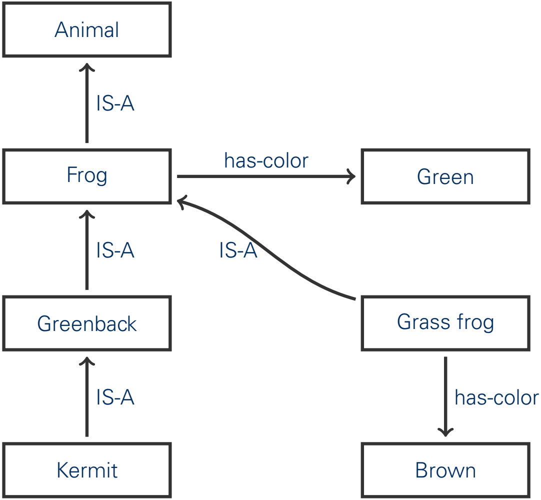
problems with missing semantics led to

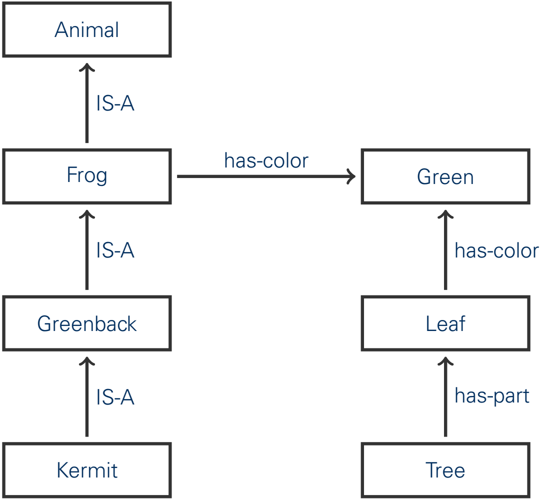
- structured inheritance networks
- the first DL system KL-ONE

Chapter 1

Examples of Early Knowledge Representation Formalisms


Animal
IS-A
Frog
has-color
Green
IS-A
Greenback
IS-A
Kermit


Animal
IS-A
Frog
has-color
Green
IS-A
IS-A
Greenback
Grass frog
IS-A
has-color
Kermit
Brown


Animal
IS-A
Frog
has-color
Green
IS-A
has-color
Greenback
Leaf
IS-A
has-part
Kermit
Tree

```
Generic Restaurant Frame
    Specialization-of:  Business-Establishment
    Types:
        range:      (Cafeteria, Fast-Food, Seat-Yourself,
                    Wait-to-be-seated)
        default:    Wait-to-be-seated
        if-needed:  IF plastic-orange-counter THEN Fast-Food,
                    IF stack-of-trays THEN Cafeteria,
                    IF wait-for-waitress-sign THEN Wait-to-be-seated,
                    OTHERWISE Seat-yourself.
    Location:
        range:      an ADDRESS
        if-needed:  (Look at the Menue)
    Name:
        if-needed:  (Look at the Menue)
    Food-Style:
        range:      (Burgers, Chinese, American, Seafood)
        default:    American
```