IDP-Z3, a reasoning engine for FO(.)

A truly declarative approach to programming

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The Turing test

I'm twice the age of my son, who is 15 years younger than me. How old am I?

Let $x$ be your age. Your son's age is $x - 15$.
You are twice the age of your son, so $2 \times (x - 15) = x$.
Therefore, $3x = 15 + 2x$.
Solving for $x$, you get $x = 45$.
So you are 45 years old.
Technical challenges

- use natural language
- sense of humor
- cognitive skills = capability...
  - ... to learn from others through symbolic communication,
  - ... to apply knowledge in new ways to perform new tasks,
  - ... to ask relevant questions,
  - ... to explain its own reasoning,
Program vs. Knowledge

\[ f = m \times a; \]

vs.

\[ F = m \cdot a \]
Prolog

vote :- moreThan18.

vs.

vote ⇔ age ≥ 18.

Prolog is a programming language!
Programming

Knowledge

Problem 1 → Program 1 → Solution 1
Problem 2 → Program 2 → Solution 2
Problem 3 → Program 3 → Solution 3
Problem 4 → Program 4 → Solution 4
The Knowledge Base paradigm

Knowledge Base

Problem 1 -> Generic Inference 1 -> Solution 1
Problem 2 -> Generic Inference 2 -> Solution 2
Problem 3 -> Generic Inference 3 -> Solution 3
Problem 4 -> Generic Inference 4 -> Solution 4
What is knowledge, anyway?

A statement of knowledge is a statement that is true…

... in all possible worlds
... or in all acceptable worlds
... or in all desirable worlds
... or in a particular world

(Tractatus, Wittgenstein, on possible world semantics)
Attributes of a good Knowledge Representation language

- it uses symbols with simple semantics (no complex “data structures”)
- its statements are close to natural language
- it is expressive (it has constructs such as quantification)
First Order logic is insufficient as a KR language

- it uses symbols with simple semantics (no complex “data structures”)
- its statements are close to natural languages
- it is expressive (has constructs such as quantification, aggregates, inductive definitions, ..)

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Introducing FO(.) (FO-dot)

FO(.) = First Order Logic extended with:

- Types
- (Inductive) definitions
- Linear arithmetic
- Aggregates (cardinality, min, max)
- Partial functions
- Intensional objects

fo-dot.readthedocs.io/
Examples

activity(Outdoor_sport) \Rightarrow (\text{end\_time}() \leq 8) \land (\text{have\_masks}() \lor \text{have\_Covid\_Safe\_Ticket}())

\forall c \in \text{course}: \#\{s \in \text{student}: \text{attend}(s, c)\} \leq \text{capacity}(room(c))

\{
[1\% \text{ tax for Heritage in Flemish region}]
\text{tax\_rate}() = 1 \land \text{registration\_type}() = \text{Heritage} \\
\land \text{region}() = \text{Flemish\_Region}.

[2\% \text{ tax for Social Dwellings in Flemish region}]
\text{tax\_rate}() = 2 \land \text{registration\_type}() = \text{Social\_Dwelling} \\
\land \text{region}() = \text{Flemish\_Region}.
\}
Core technologies developed by KUL

User interface

Reasoning engine

Two knowledge representation languages

The IC

IDP-Z3

cDMN

FO(.)

Generic!

No development cost!
IDP-Z3

IDP-Z3 is a reasoning engine for FO(.), with the following artificial cognitive skills:

• “Is it possible?” = Model checking
• “What is possible?” = Model generation / expansion
• “What is relevant?” = Relevance
• “What are the logical consequences?” = Propagation
• “Why is this a consequence?” = Explanation
• “What is the optimal possible world?” = Optimization

www.idp-z3.be   Host language: Python
The Interactive Consultant

Challenge
Engineer a design that meets customer requirements

Solution
A novel class of applets that performs various forms of reasoning in a domain of expertise.
Interactions with the engineer

- Requirements
- Tentative Decisions
- Relevant questions
- Prerequisites
- Consequences
- Explanations
- Optimization

Demo
Research Partners

- <Industrial multinational>
- Siemens
- Flanders Make
- Intelli-Select
- Notaries

⇒ Reduce decision time from 3 hours to 5 minutes.
⇒ Low development cost (< 10 days)
Case study

Experts in custom industrial components\textsuperscript{[2]}

- assembled from 31 components (27 properties)
- 60 materials (* 10 properties)

Ten international workshops to model the knowledge of experts.

Benefits:

- It empowers young engineers
- Designs are “right the first-time”
- Knowledge becomes a managed asset in a learning organization
Why now?

- SAT and SMT solvers can now solve previously intractable symbolic problems
- we have new understanding of the complexity and variety of knowledge
- we have new understanding of the various inferences required (beyond deduction)
Questions?

Hands-on tutorial in Gent on Monday, Feb 6, 13:30-16:30.  (Google “vaia idp”)