

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 $2 * (x - 15) = x$.

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, ...

Knowledge Representation and Reasoning

Program vs. Knowledge

`f = m*a;`

vs.

$F = m \cdot a$

Prolog

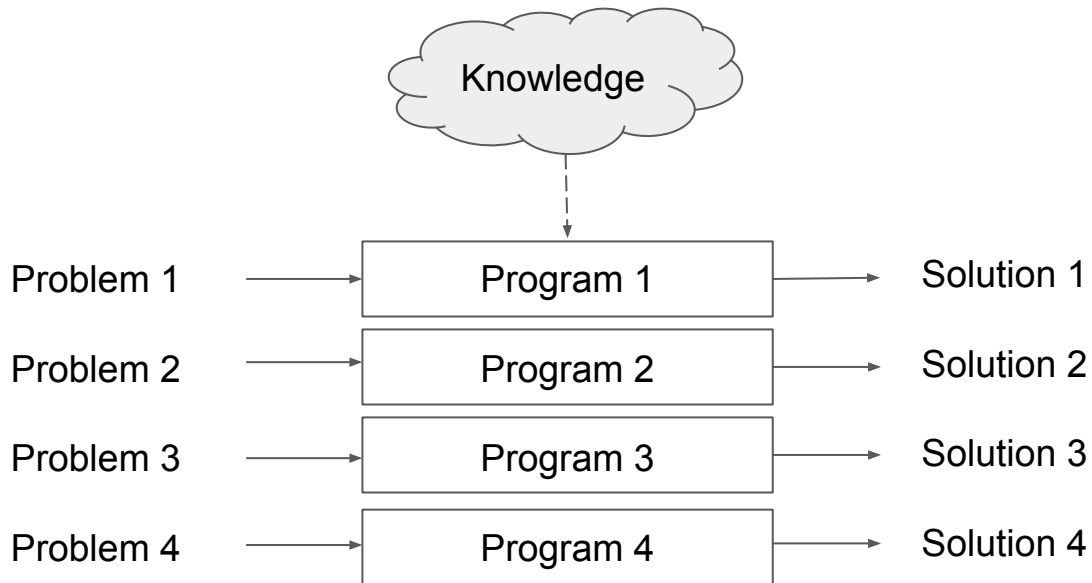
```
vote :- moreThan18.
```

vs.

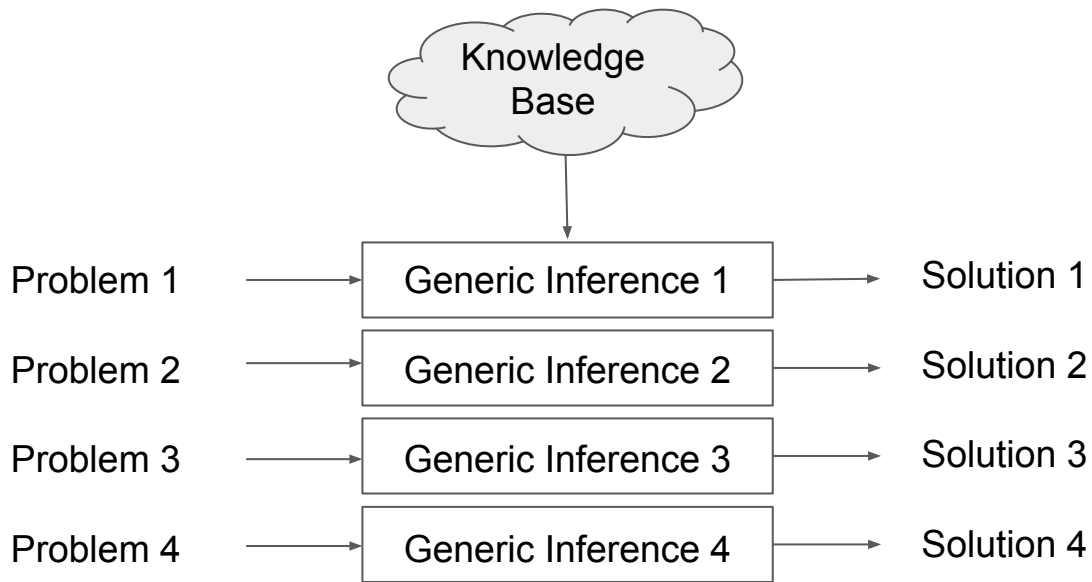
```
vote ⇔ age ≥ 18.
```

Prolog is a programming language !

Programming



The Knowledge Base paradigm



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



Propositional attitudes

(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, ..)

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/

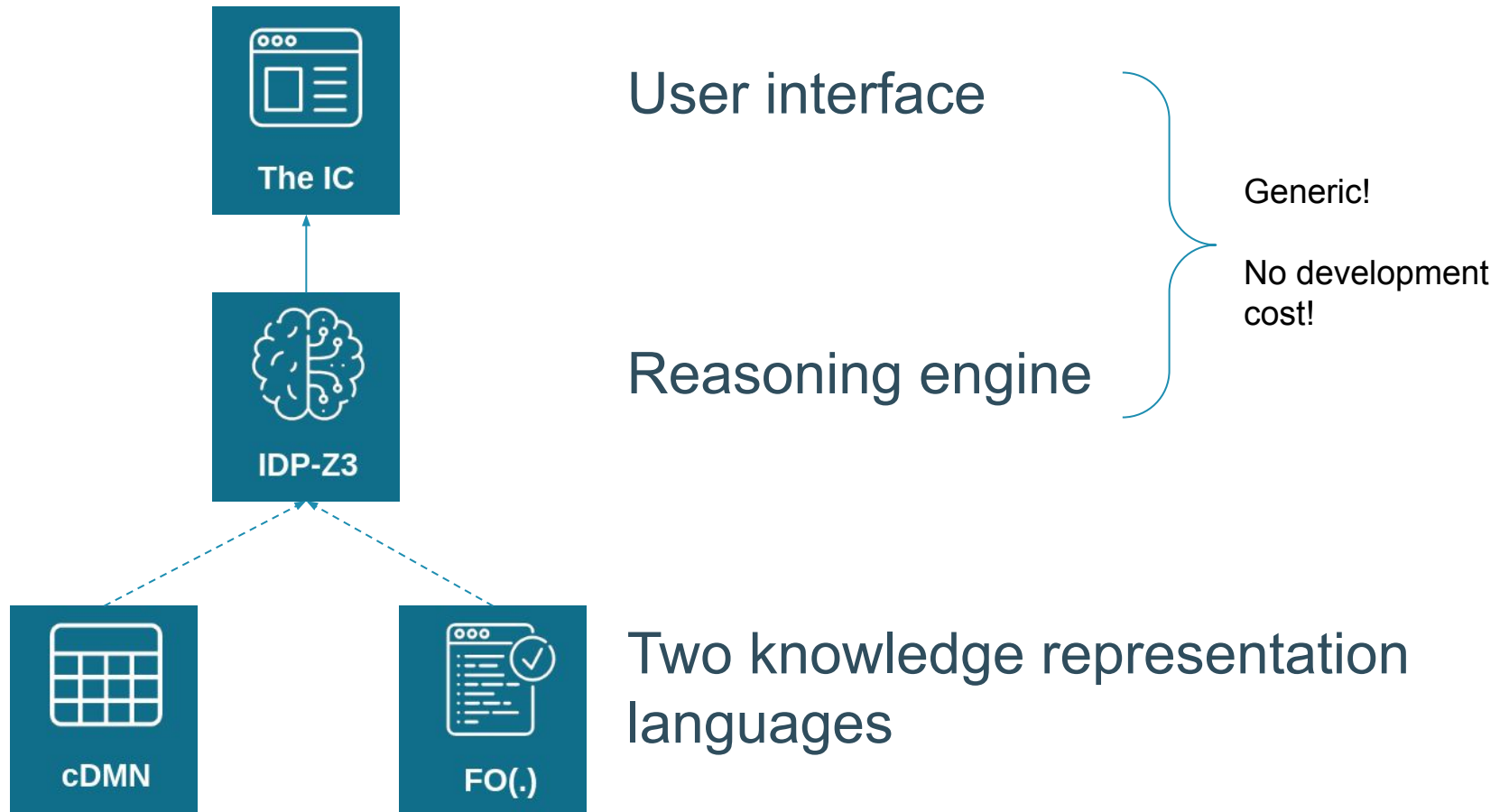
Examples

```
activity() = Outdoor_sport ⇒  
  (end_time() ≤ 8) ∧ ( have_masks() ∨ have_Covid_Safe_Ticket() ).
```

```
∀ c ∈ course: #{s ∈ student: attend(s,c)} ≤ capacity(room(c)).
```

```
{  
  [1% tax for Heritage in Flemish region]  
  tax_rate() = 1 ← registration_type() = Heritage  
  | | | | | ∧ region() = Flemish_Region.  
  
  [2% tax for Social Dwellings in Flemish region]  
  tax_rate() = 2 ← registration_type() = Social_Dwelling  
  | | | | | ∧ region() = Flemish_Region.  
}
```

Core technologies developed by KUL



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



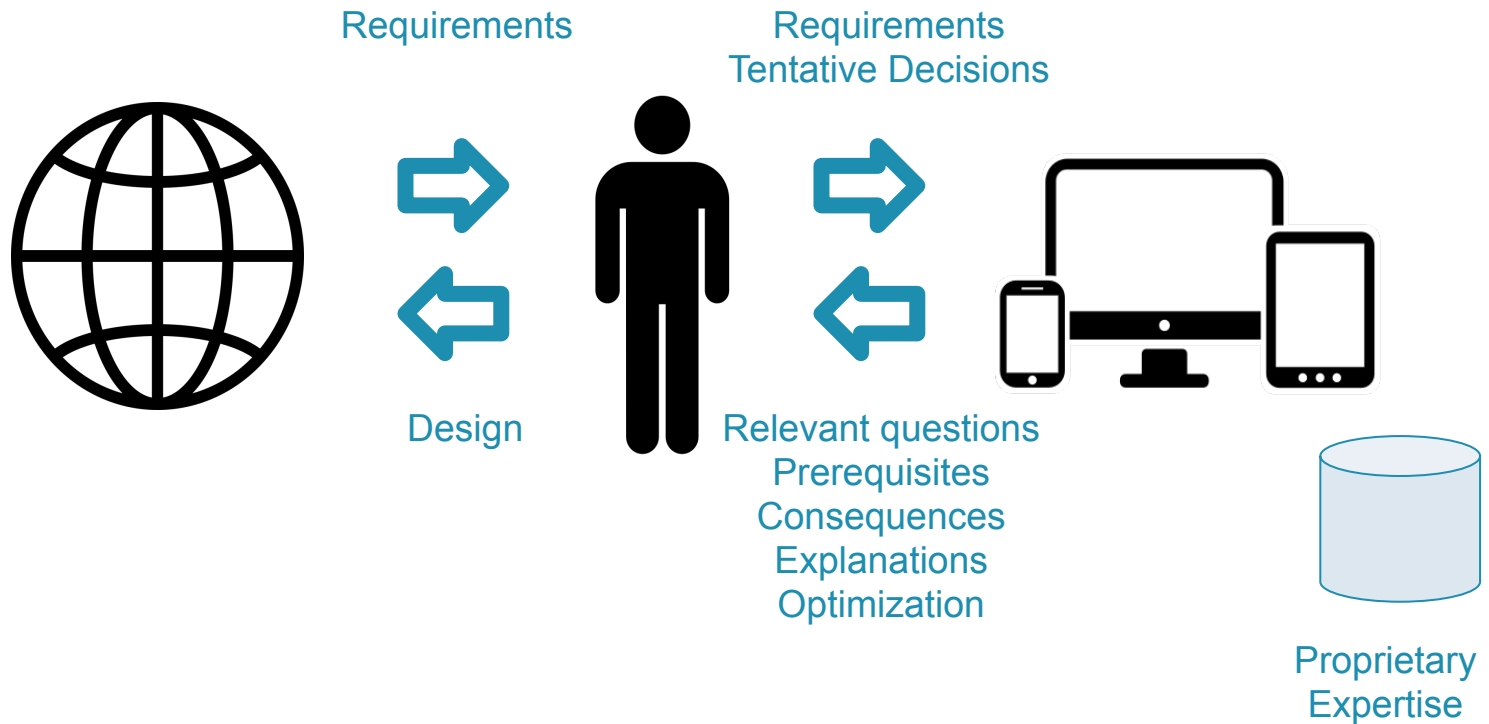
Challenge

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



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^[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”)