Concepts of programming languages

Janus

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Calculating (n+1)-th and (n+2)-th Fibonacci number

```
procedure fib
    if n = 0 then
        x1 += 1    ; -- 1st Fib nr is 1.
        x2 += 1    ; -- 2nd Fib nr is 1.
    else
        n -= 1
        call fib
        x1 += x2
        x1 <=> x2
    fi x1 = x2     ; -- Why do we need this?
```

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        x1 <=> x2
    fi x1 = x2      ; -- To be able to invert the procedure.
```

- ▶ Q: How do we calculate the inverse?
- ▶ A: Using the statement inverter.
  $\mathcal{I}[\![\text{if } e_1 \text{ then } s_1 \text{ else } s_2 \text{ fi } e_2]\!] \quad = \text{if } e_2 \text{ then } \mathcal{I}[\![s_1]\!] \text{ else } \mathcal{I}[\![s_2]\!] \text{ fi}$

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Calculating (n+1)-th and (n+2)-th Fibonacci number

The inverse of fib calculates n given the (n+1)-th and (n+2)-th Fibonacci numbers

```
procedure fib'      ; -- The inverse of fib.
    if x1 = x2 then
        x2 -= 1     ; -- 2nd Fib nr is 1.
        x1 -= 1     ; -- 1st Fib nr is 1.
    else
        x1 <=> x2
        x1 -= x2
        call fib'
        n += 1
    fi n = 0
```

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Example 2: Probability Density Function of Exp distribution.

- ▸ PDF of exp: $\frac{1}{b}e^{\frac{-x}{b}}$
- ▸ But Janus doesn't allow negative integers, so:
- ▸ PDF of exp: $\frac{1}{b}\frac{1}{e^{\frac{x}{b}}}$
- ▸ Let's also introduce a parameter $\lambda = \frac{1}{b}$:
- ▸ PDF of exp: $\lambda\frac{1}{e^{x\lambda}}$
- ▸ PDF of exp: $\frac{\lambda}{e^{x\lambda}}$
- ▸ This is still most probably going to be a real number...
- ▸ Solution: multiply everything times a very large constant

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Relational Programming

Injective Programming
r-Turing Complete
backwards deterministic
restricted language constructs

Relational Programming
Turing Complete
backwards non-deterministic
search procedure (aka *resolution*)

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Prolog basics

A logic programs consists of *facts* and *rules*.

```prolog
parent(alice, joe).
parent(bob, joe).
parent(joe, mary).
parent(gloria, mary).


ancestor(X, Y) :- parent(X, Y).
ancestor(X, Y) :- parent(X, Z), ancestor(Z, Y).


descendant(X, Y) :- ancestor(Y, X).
```

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The user can then *query* the runtime system, as such:

```
?- parent(X, joe).
X = alice;
X = bob.

?- ancestor(X, mary).
X = joe;
X = gloria;
X = alice;
X = bob.

?- ancestor(X, mary), descendant(X, alice).
X = joe.
```

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Demonstration - Type Inference

Assume a `type` predicate, relating expressions with types:

```
type(expr, t) :- ... .
```

You would normally use it to perform *type-checking*:

```
?- type(1 + 1, int).
true.
?- type(1 + 1, string).
false.
```

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But you can also performing *type-inference*:

```
?- type(1 + 1, Type).
Type = int.
?- type("hello world", Type).
Type = string.
?- type(\x:int -> x, Type).
Type = int -> int.
?- type(\x -> x, Type).
Type = ?42 -> ?42.
?- type(\x -> x, int -> Type).
Type = int.
```

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Going in the reverse direction, you can query the expression:

```
?- type(Expr, int).
Expr = 1;
Expr = 2;
...
Expr = 1 + 1;
Expr = 1 + 2;
...
Expr = if true then 1 else 1;
...
```

Of course, this does not make much sense without a sufficiently expressive type system.

Demonstration - Program Synthesis

Assume you have implemented a *relational interpreter*:

```
eval(program, result) :- ... .

?- eval(map (+ 1) [1 2 3], Result).
Result = [2 3 4].
```

But you can also perform *program synthesis* by-example:

```
?- eval(F 1, 2),...,eval(map F [1 2 3], [2 3 4]).
...
F = \x -> x + 1;
...
F = \x -> x - 10 + 10 + 1;
...
```

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Quine generation is pretty straightforward:

```
?- eval(Quine, Quine).
...
Quine = (\a -> a ++ show a) "(\\a -> a ++ show a) ";
...
```

Logic Programming IRL

In practice, bi-directionality breaks with the usage of *extra-logical* features:

- ► **Variable projection**: inspecting values at runtime
- ► **Cut (!)**: disables backtracking in certain places
- ► **Assert/Retract**: Dynamically insert/remove facts

MiniKanren is a more recent logic programming language, which avoids extra-logical features (as much as possible).

Higher abstraction

- Relational programming, as well as functional programming, both belong to the *declarative* paradigm.
- They both raise the level of abstraction, by enabling the programmer to express *what* needs to be done, instead of *how.*

Question

How can we combine them, to get the best of both worlds?

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Hanus: Janus embedded in Haskell

In our research project, we use *TemplateHaskell* and *QuasiQuotation* to embed Janus in Haskell:

```
[hanus|
  procedure encode(im :: Image, ret :: [Byte]) {
    -- Janus commands containing Haskell code
    -- e.g. janus_variable += <Haskell code>
  }
|]
encode :: Image -> [Byte]
encode = call encode
decode :: [Byte] -> Image
decode = uncall encode
```

Come and check out our poster in de Vagant!

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Thanks!

Feel free to ask any questions

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