How to best teach Prolog (to different audiences)

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ICLP2023, London, UK
July 14, 2023

Main reference: **Some Thoughts on How to Teach Prolog**,
(M. Hermenegildo, J.F. Morales, and P. Lopez-Garcia.)
In **Prolog - The Next 50 Years**, Warren et al. (Eds.), Springer, LNCS 13900.

How to best teach Prolog

- Prolog / LP / CLP *must* be taught in CS programs,
  - Only of few major programming paradigms →
    A CS graduate is simply not complete without knowledge of Prolog.

  and also in other majors, and in schools, ...?

- But it has to be done right!
  - It is a different paradigm, and needs to be taught differently.
  - The standard 'programming paradigms' approach can be counter-productive:
    - Not possible in a couple of weeks emulating Prolog in Scheme.
    - But, what to do if that is the only slot available?

- The main message: **do show the beauty!**

⇒ Start by explaining "Green's dream"...

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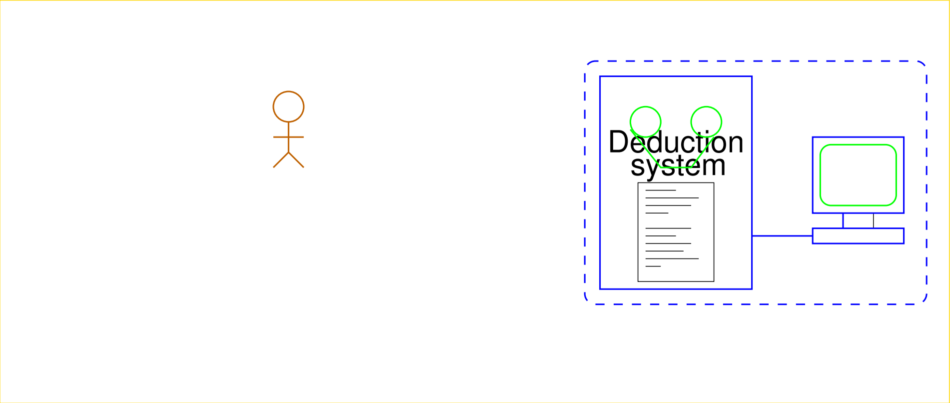
What is the best way to program a computer?

A New View of Computing



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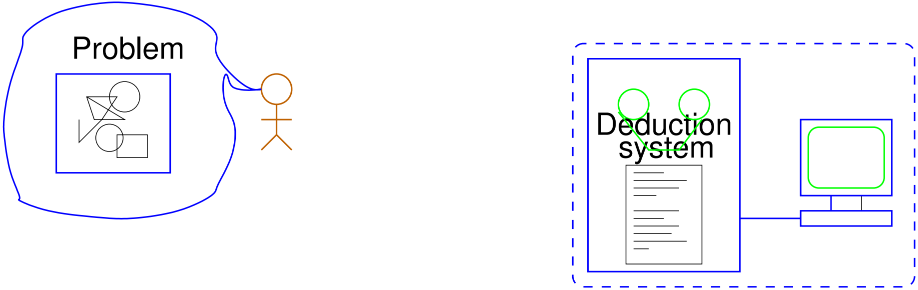

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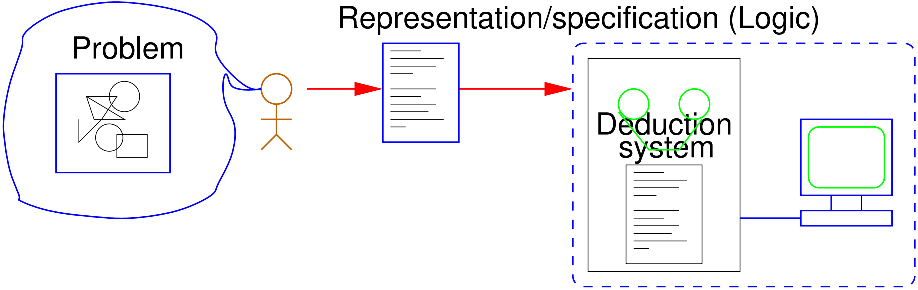

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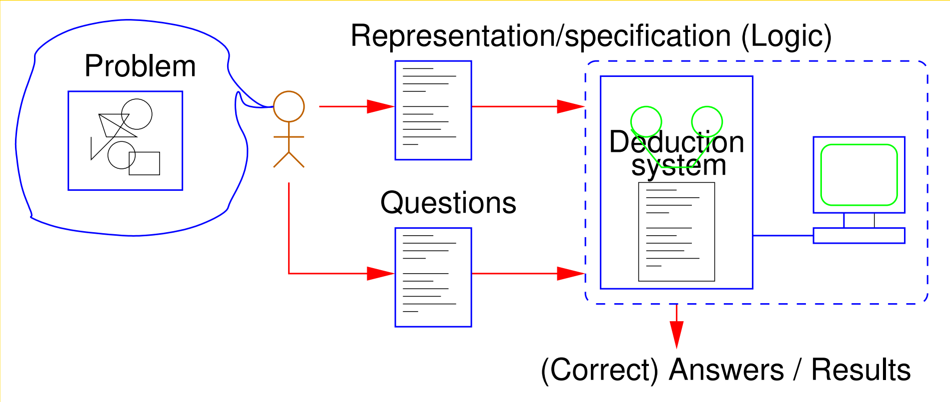

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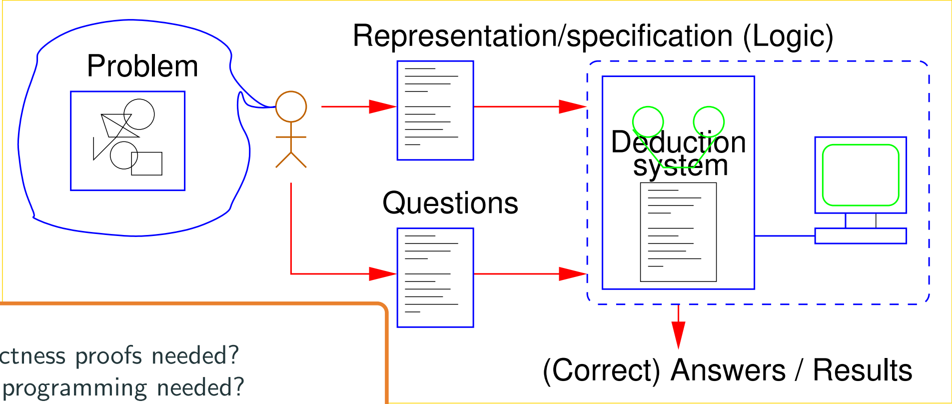

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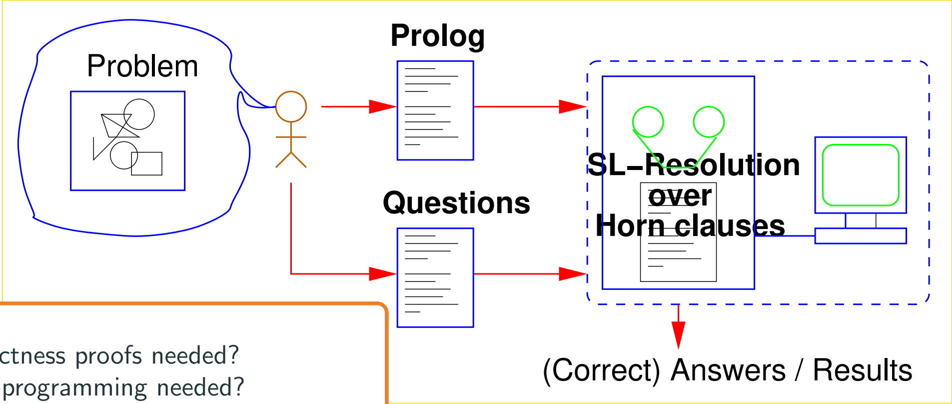
- No correctness proofs needed?
- Even no programming needed?
- Is this possible?

Prolog is the Materialization of this Dream!



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→ Prolog (LP)!

A Specification and also a Program

Problem: calculate the squares of the naturals < 5. Show imperative program – is it correct?

Let's develop a specification (and program): (click here▶ to run)

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(And show also a *constraints* version: we also have efficient arithmetic of course!)

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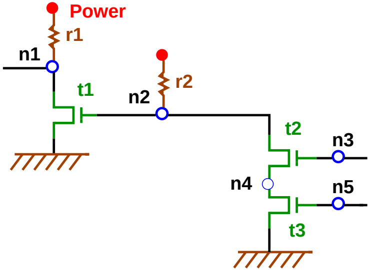
Circuit topology



run▶

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transistor(n5,ground,n4).
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nand_gate(Input1,Input2,Output) :-
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and_gate(Input1,Input2,Output) :-
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`?- and_gate(In1,In2,Out)` ⇝ `In1=n3, In2=n5, Out=n1`

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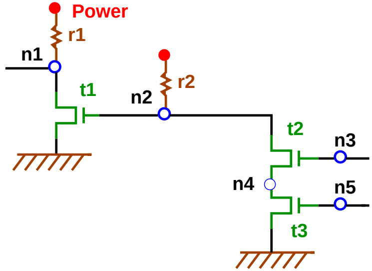

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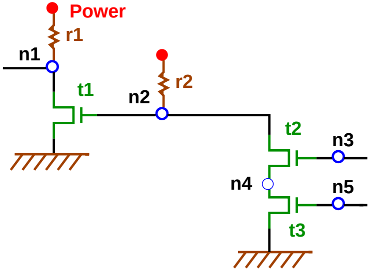


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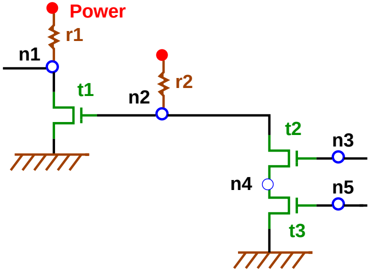

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How to best teach Prolog: Show the Beauty!

- Explain the limits:
  - discuss for what logics we have effective deduction procedures,
  - justify the choice of FOL, SLD-resolution, semi-decidability (see pictures later)

  $\rightarrow$ classical LP (Kowalski/Colmerauer).

- Show how logic programs are both logical theories (with declarative meaning) and procedural programs that can be debugged, followed step by step, etc.

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  - discuss for what logics we have effective deduction procedures,
  - justify the choice of FOL, SLD-resolution, semi-decidability (see pictures later)

  → classical LP (Kowalski/Colmerauer).

- Show how logic programs are both logical theories (with declarative meaning) and procedural programs that can be debugged, followed step by step, etc.

- Show with examples (and benchmarking them) how you can go from executable specifications to efficient algorithms gradually, and as needed.

Show the Beauty: from Specifications to Efficient Programs

The modulo operation, `mod(X,Y,Z)` *where Z is the remainder from dividing* **X** *by* Y*:*

$$\exists Q s.t.\ X = Y * Q + Z \land Z < Y$$

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We can express this definition/specification directly in Prolog!: run▶

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mod(X,Y,Z) :-
  mult(Y,Q,W), add(W,Z,X), less(Z, Y).
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?- op(500,fy,s).
yes
?- mod(X,Y, s 0).
X = s 0,
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Or write a more efficient version, also within (pure) Prolog: run▶

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mod(X,Y,X) :- less(X, Y).
mod(X,Y,Z) :- add(X1,Y,X), mod(X1,Y,Z).
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R = s(0) ?
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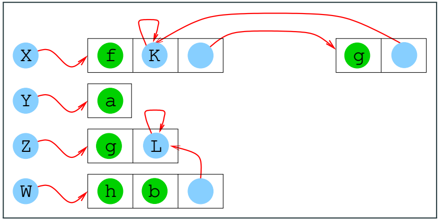
Again, we can also show the *constraints* version.

And we can discuss **modes** and how they affect *determinacy, cost, termination,* etc.

How to best teach Prolog: Show the Beauty!

- Show how unification is also a device for *constructing and matching complex data structures with (declarative) pointers*. Show it in the top level, giving "the data structures class."

```
?-  X=f(K,g(K)),
    Y=a,
    Z=g(L),
    W=h(b,L),
    % Heap memory at this point ⟶
    p(X,Y,Z,W).
```



- Do use types (and properties in general): define them as predicates, show them used to check if something is in the type (dynamic checking), or "run backwards" to generate the "inhabitants"; property-based testing for free!

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natlist([]).
natlist([H|T]) :- natural(H), natlist(T).
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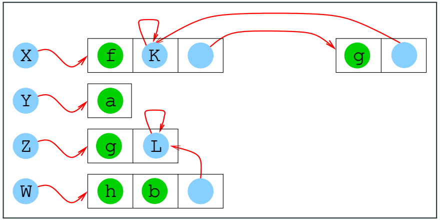

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How to best teach Prolog: Show the Beauty!

- Show the (3-line) meta-interpreter!
  - It is a thing of beauty.
  - An excellent demonstrator of the unique powers of Prolog.

- Use motivational examples that involve search (puzzles, etc.).
  - it is a unique characteristic of the language

  and give advice on how to control it.

- Incomplete data structures, DCGs, ...

- Show that there are plenty of interfaces to other languages, data representations, etc.

How to best teach Prolog: Dispel the Unfounded Myths!

Dispel unfounded myths about the language, and show that many of the shortcomings of early Prologs have been *addressed over the years*.

- "Prolog gets into infinite loops."

  This is true –in fact, of any programming language or proof system.
  However, it is likely to discourage beginners if not explained well:

  - Use/build system to run *alternatively and selectively* in breadth-first, iterative deepening, tabling, etc.
  - Start by running all predicates, e.g., breadth-first – everything works!
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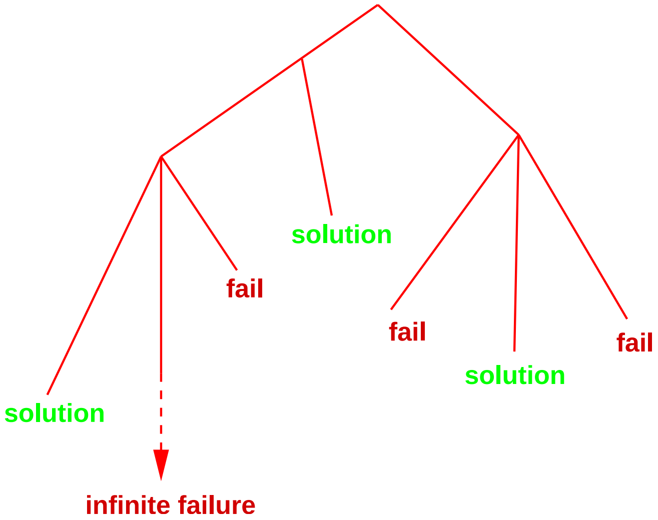
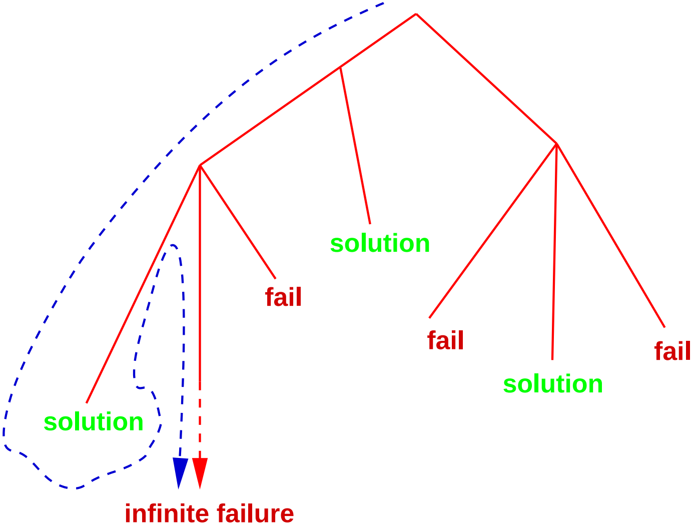
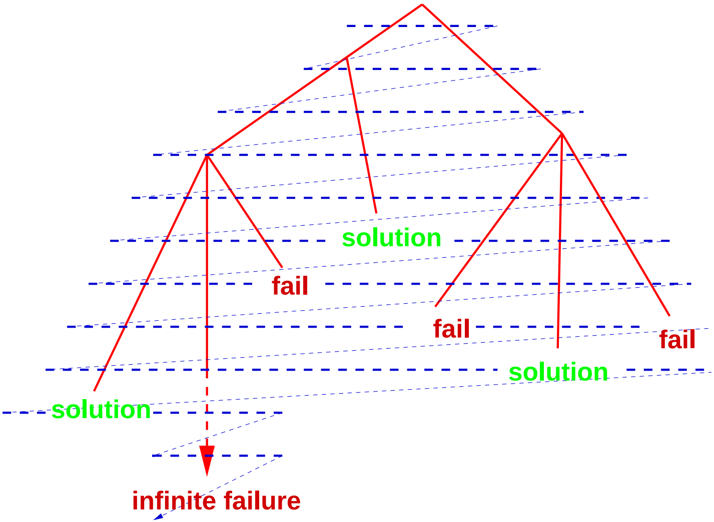
Characterization of the search tree



Depth-First Search



Breadth-First Search



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  - Discuss advantages and disadvantages of search rules (time, memory).
    Motivate the choices made for Prolog benchmarking actual executions.

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- “Arithmetic is not reversible.”
  - Start with Peano arithmetic: beautiful but slow.
  - Then justify Prolog arithmetic for efficiency.
  - Then show (arithmetic) constraint domains: beautiful and efficient!
- “There is no occur check.”
  - Explain why, and that there is a built-in for it.
  - Have a package (expansion) that calls it by default for all unifications.
  - Explain the existence of infinite tree unification (as a constraint domain).
- “Prolog is not pure (cut, assert, etc.)”
  - Have a pure mode in the implementation so that impure built-ins simply are not present.
  - Develop pure libraries (including monad-style).
  - Develop purer built-ins.

  and accept that impurity is necessary sometimes, but we keep it as encapsulated as possible.
- “Prolog has no applications / interest / is a toy language...”
  - Show the many examples of impressive applications (cf. Prolog Year/Book).

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- "Prolog is a strange language."
  - Show that Prolog *subsumes* functional and imperative programming (after SSA). It is *simply more*. (Useful for analysis of other languages!) → Use optionally functional **syntax** (sometimes compact): (Read ~ as "the result of" = "last argument of.")

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grandparent(X,~parent(~parent(X))). ⇝
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?-  E = ~append(~append(A,B),D). ⇝
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  - Show that it is completely normal if used in one direction and one definition per procedure.
  - But it can also have several definitions, search, run backwards, etc.
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```
grandparent(X,~parent(~parent(X))).  ⇝
grandparent(X,~parent(Z)) :- parent(X,Z).  ⇝
grandparent(X,Y) :- parent(X,Z), parent(Z,Y).
```

```
?-  E = ~append(~append(A,B),D).  ⇝
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