How to best teach Prolog (to different audiences)

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Based on the talk at the workshop:

@ ICLP2023, London, UK, July 14, 2023

Main reference: "Some Thoughts on How to Teach Prolog",
In "Prolog - The Next 50 Years", Warren et al. (Eds.), Springer, LNCS 13900.

How to best teach Prolog

- Lots of good material and systems already exist!

- Our objective here:
  Some complementary thoughts and lessons from our experience teaching Prolog:
  - Mostly to CS undergrads.
  - At U.T. Austin, U. of New Mexico, and T.U.Madrid (UPM).

  (and also as developers of the Ciao prolog system, where we have added many features aimed at teaching Prolog, based on this experience).

- Students have typically been exposed to other languages (imperative/OO, sometimes functional) and possibly logic, specifications, some notions of PL implementation, etc.
  - Challenge: make the material attractive, intriguing, and challenging for this audience.
  - But also great audience, which can appreciate and be impressed!

Our related teaching materials (slides, examples, ALDs): `https://cliplab.org/logalg`

How to best teach Prolog

- Prolog / LP / CLP *must* be taught in CS programs,
  - Only of few major programming paradigms,
    really interesting, different, and useful →
    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? (→ Challenge for the LP community.)

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

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

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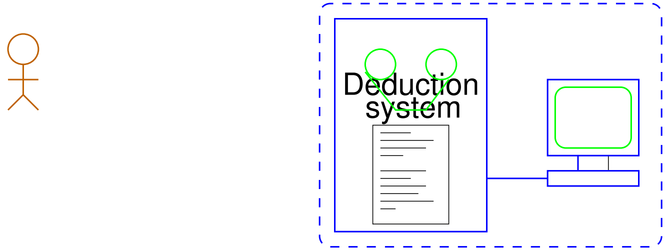
What is the best way to program a computer?

A New View of Computing



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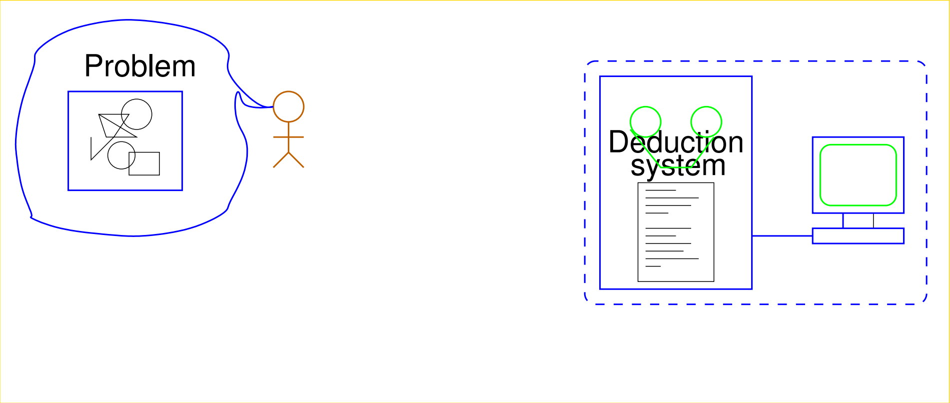

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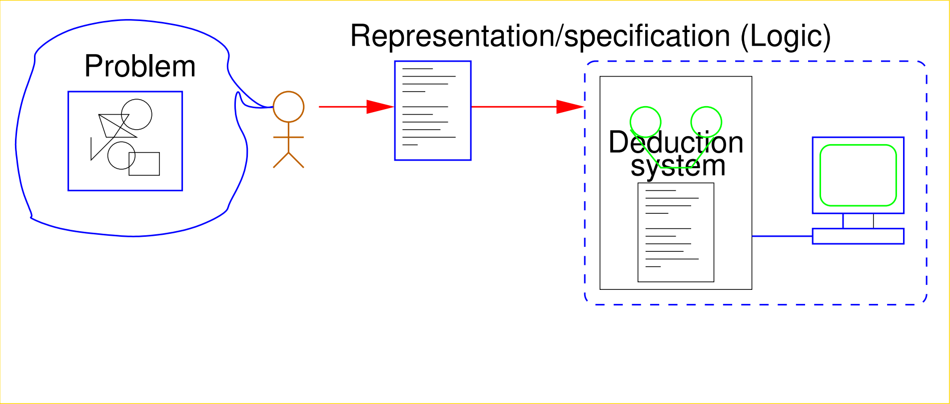

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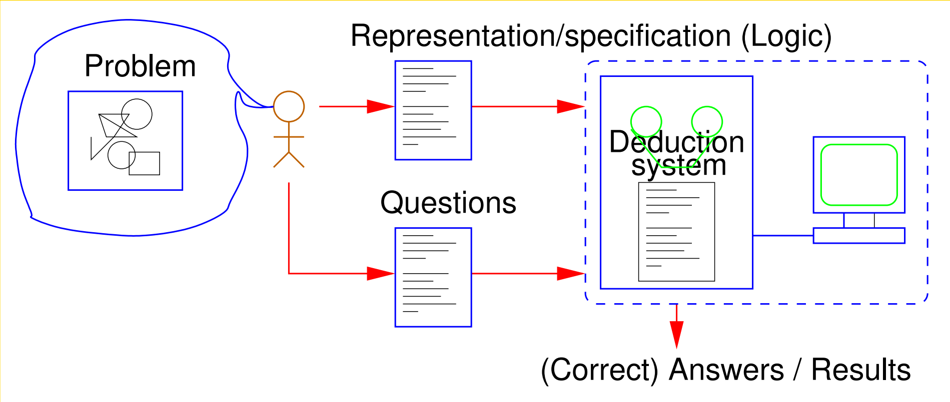

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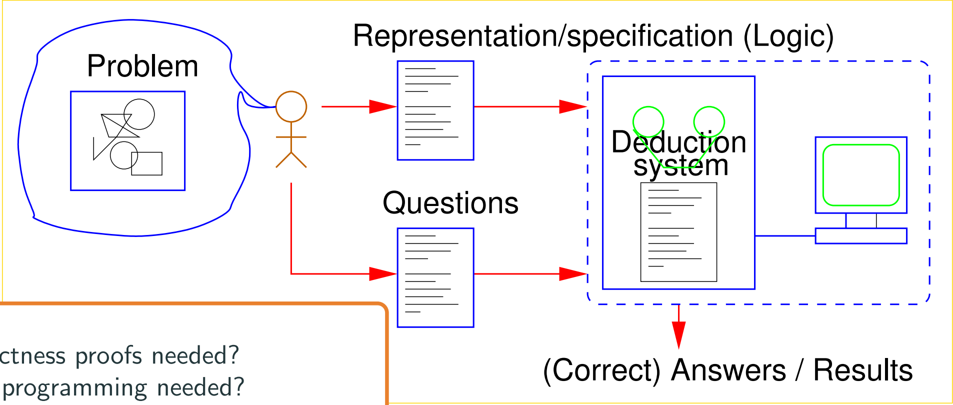

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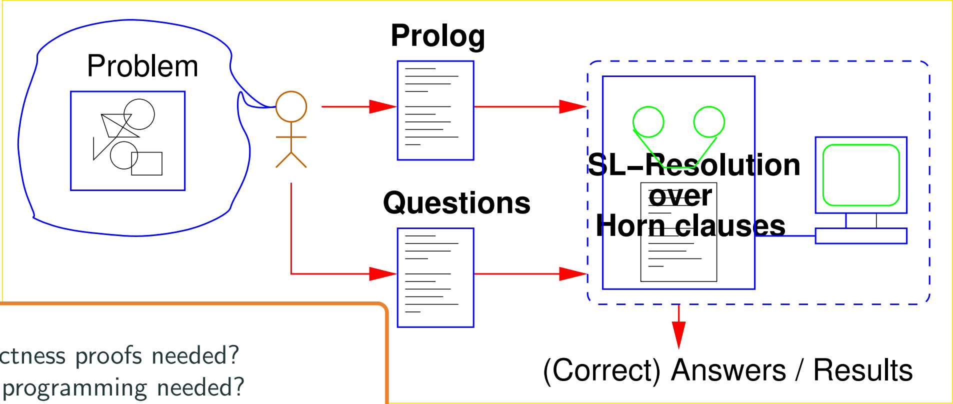
- No correctness proofs needed?
- Even no programming needed?
- Is this possible?

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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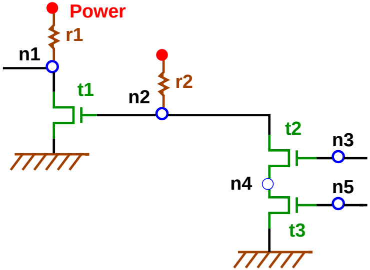
Circuit topology



run▶

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inverter(Input,Output) :-
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nand_gate(Input1,Input2,Output) :-
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and_gate(Input1,Input2,Output) :-
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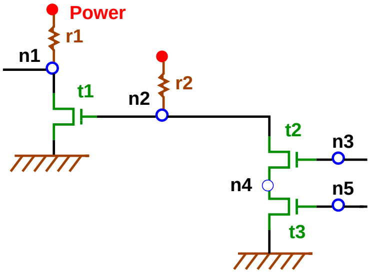

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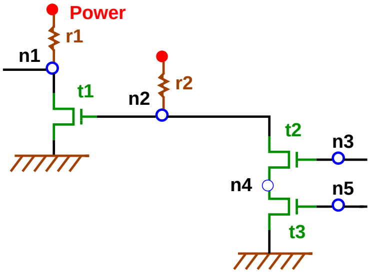

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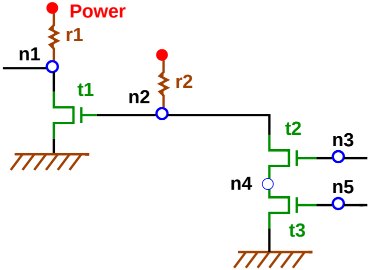

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- But also explain the limits (expectation management):
  - discuss for what logics we have effective deduction procedures,
  - justify the choice of FOL, SLD-resolution, semi-decidability (see pictures later)

  $\rightarrow$ 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.

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

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Show the Beauty: from Specifications to Efficient Programs

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yes
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Or write a more efficient version, also within (pure) Prolog: run▶

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R = s(0) ?
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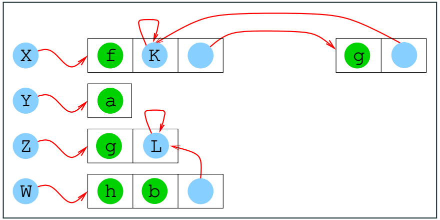
Again, we can also show the *constraints* version.

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"; LP has property-based testing for free!

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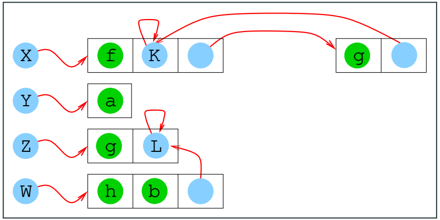

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- Show the (3-line) meta-interpreter + an adorned one.
  - It is a thing of beauty.
  - An excellent demonstrator of the unique powers of Prolog.

- 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, automata, DCGs ... (and run them backwards as generators of course!)

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

How to best teach Prolog: Dispelling Myths and Misconceptions

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

- Explaining termination:

  Non-termination is a fact of life for any powerful 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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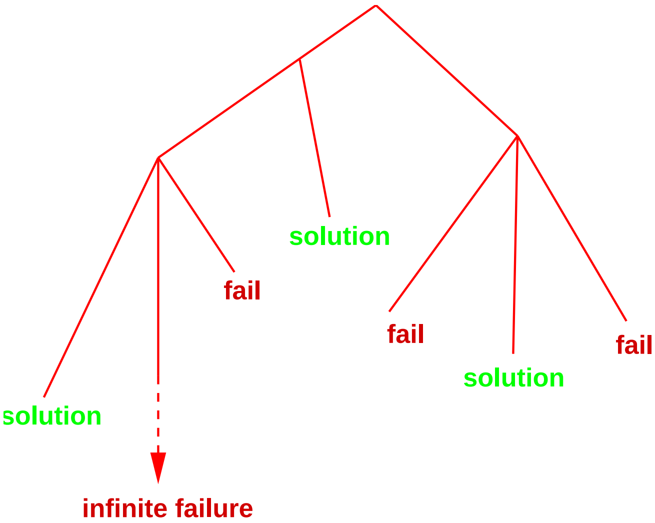
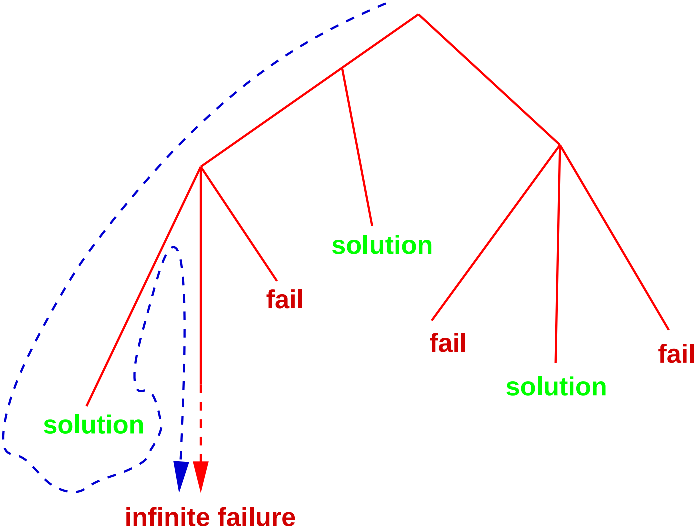
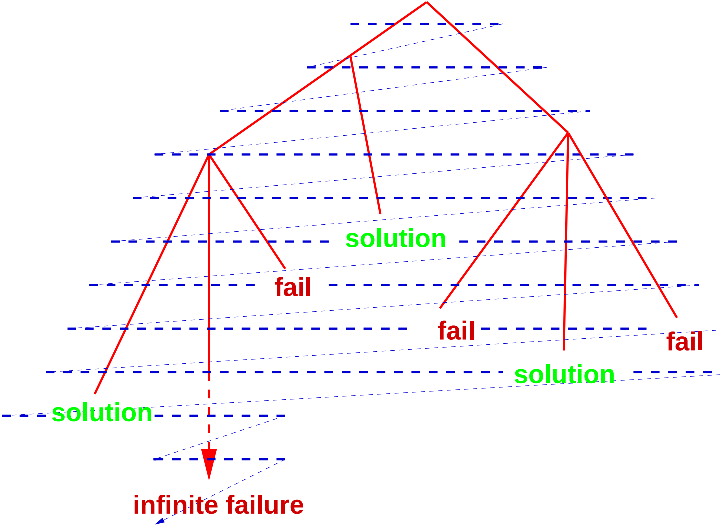
Characterization of the search tree



Depth-First Search



Breadth-First Search



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  - Do relate semi-decidability to the *halting problem*: no-one (Prolog, logic, nor other Turing-complete prog. language) can solve that (but tabling helps: good time to introduce it!).

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

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- Showing that Prolog arithmetic can also be reversible:
  - We show first Peano arithmetic: beautiful and only needs pure LP, but slow.
  - We also show (arithmetic) constraint domains: beautiful and efficient!
  - We justify uses of ISO arithmetic for efficiency.
- The occur check is available (if needed):
  - 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 can be pure (despite cut, assert, etc.):
  - Have a pure mode in the implementation so that impure built-ins are simply not present.
  - Develop pure libraries.
  - Develop purer built-ins that can be loaded alternatively.

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How to best teach Prolog: Dispelling Myths and Misconceptions

- Negation:
  - Explain negation as failure devoting time to discuss limitations.
  - Can also go into other types of negation, s(CASP), etc.
- Prolog has many applications and uses.
  - Show the many examples of impressive applications (cf. Prolog Year/Book).
- Prolog is in many ways as other languages, but adds unique, useful features.
  - Show that Prolog *subsumes* functional and imperative programming (after SSA). It is *simply more*. (Useful for analysis of other languages!)
  - It is "standard" if used in one direction and there is only one definition per procedure.
  - But it can also have several definitions, search, run backwards, etc.
  - In addition to a stack of forward continuations (as in any language, for procedure return), also a stack of *backwards continuations* to go if there is a failure (previous *choice point*).

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  - Can also go into other types of negation, s(CASP), etc.

- Prolog has many applications and uses.
  - Show the many examples of impressive applications (cf. Prolog Year/Book).

- Prolog is in many ways as other languages, but adds unique, useful features.
  - Show that Prolog *subsumes* functional and imperative programming (after SSA). It is *simply more*. (Useful for analysis of other languages!)
  - It is "standard" if used in one direction and there is only one definition per procedure.
  - But it can also have several definitions, search, run backwards, etc.
  - In addition to a stack of forward continuations (as in any language, for procedure return), also a stack of *backwards continuations* to go if there is a failure (previous *choice point*).

How to best teach Prolog: Dispelling Myths and Misconceptions

- Show that Prolog can support functional **syntax** (sometimes more compact):

```
grandparent(X,~parent(~parent(X))). ⇝
grandparent(X,~parent(Z)) :- parent(X,Z). ⇝
grandparent(X,Y) :- parent(X,Z), parent(Z,Y).
```

I.e., read ~ as "last argument of"; ⇝ as "is expanded to."

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

```
list := [] | [_|~list]. ⇝
list([]).
list([_|X]) :- list(X).
```

- Same with loops, mutable variables/assignment, etc.

- Show that Prolog can also have types (and modes, assertions, etc.) *if needed.*

- And of course show that Prolog is fast, can be compiled and generate standard executables, has tests, auto-documenters, linters, and great environments in general.

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