CSc 372 — Comparative Programming Languages

16 : Prolog — Introduction

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1 What is Prolog?

- Prolog is a language which approaches problem-solving in a *declarative* manner. The idea is to define *what* the problem is, rather than *how* it should be solved.
- In practice, most Prolog programs have a procedural as well as a declarative component — the procedural aspects are often necessary in order to make the programs execute efficiently.

2 What is Prolog?

Algorithm = Logic + Control Robert A. Kowalski

Prescriptive Languages:

- Describe *how* to solve problem
- Pascal, C, Ada,...
- Also: Imperative, Procedural

Descriptive Languages:

- Describe *what* should be done
- Also: Declarative

Kowalski's equation says that

- Logic – is the specification (what the program should do)
- Control – what we need to do in order to make our logic execute efficiently. This usually includes imposing an execution order on the rules that make up our program.

3 Objects & Relationships

Prolog programs deal with

- objects, and
- relationships between objects

English:

"Christian likes the record"

Prolog:

```
likes(christian, record).
```

4 Record Database

- Here's an excerpt from Christian's record database:

```
is_record(planet_waves).
is_record(desire).
is_record(slow_train).

recorded_by(planet_waves, bob_dylan).
recorded_by(desire, bob_dylan).
recorded_by(slow_train, bob_dylan).

recording_year(planet_waves, 1974).
recording_year(desire, 1975).
recording_year(slow_train, 1979).
```

5 Record Database...

- The data base contains *unary facts* (`is_record`) and *binary facts* (`recorded_by, recording_year`).
- The fact

  `is_record(slow_train)`

  can be interpreted as

  `slow_train` *`is-a-record`*

- The fact `recording_year(slow_train, 1979)` can be interpreted as *the recording year of slow_train was 1979.*

6 Conditional Relationships

- Prolog programs deal with conditional relationships between objects.

English:

"C. likes Bob Dylan records recorded before 1979"

Prolog:

```
likes(christian, X) :-
      is_record(X),
      recorded_by(X, bob_dylan),
      recording_year(X, Year),
      Year < 1979.
```

7 Conditional Relationships...

- The rule

  ```
  likes(christian, X) :-
        is_record(X),
        recorded_by(X, bob_dylan),
        recording_year(X, Year),
        Year < 1979.
  ```

  can be restated as

  > "Christian likes `X`, if `X` is a record, and `X` is recorded by Bob Dylan, and the recording year is before 1979."

- Variables start with capital letters.
- Comma (",") is read as *and*.

8 Asking Questions

Prolog programs

- solve problems by asking questions.

English:

"Does Christian like the albums *Planet Waves* & *Slow Train*?'

Prolog:

```
?- likes(christian, planet_waves).
yes
?- likes(christian, slow_train).
no
```

9 Asking Questions...

English:

"Was *Planet Waves* recorded by Bob Dylan?"

"When was *Planet Waves* recorded?"

"Which album was recorded in 1974?"

Prolog:

```
?- recorded_by(planet_waves, bob_dylan).
   yes

?- recording_year(planet_waves, X).
   X = 1974

?- recording_year(X, 1974).
   X = planet_waves
```

10 Asking Questions...

In Prolog

- "," (a comma), means "and'

English:

"Did Bob Dylan record an album in 1974?"

Prolog:

```
?- is_record(X),
      recorded_by(X, bob_dylan),
      recording_year(X, 1974).
yes
```

11 Asking Questions...

Sometimes a query has more than one answer:

- Use ";" to get all answers.

English:

"What does Christian like?"

Prolog:

```
?- likes(christian, X).
   X = planet_waves ;

   X = desire ;

no
```

12 Asking Questions...

Sometimes answers have more than one part:

English:

"List the albums and their artists!"

Prolog:

```
?- is_record(X), recorded_by(X, Y).
X = planet_waves,
Y = bob_dylan ;
X = desire,
Y = bob_dylan ;
X = slow_train,
Y = bob_dylan ;
no
```

13 Recursive Rules

"People are influenced by the music they listen to.

People are influenced by the music listened to by the people *they* listen to."

```
listens_to(bob_dylan, woody_guthrie).
listens_to(arlo_guthrie, woody_guthrie).
listens_to(van_morrison, bob_dylan).
listens_to(dire_straits, bob_dylan).
listens_to(bruce_springsteen, bob_dylan).
listens_to(björk, bruce_springsteen).

influenced_by(X, Y) :- listens_to(X, Y).
influenced_by(X, Y) :- listens_to(X,Z),
                       influenced_by(Z,Y).
```

14 Asking Questions...

English:

"Is Björk influenced by Bob Dylan?"

"Is Björk influenced by Woody Guthrie?"

"Is Bob Dylan influenced by Bruce Springsteen?"

Prolog:

```
?- influenced_by(bjork, bob_dylan).
yes
?- influenced_by(bjork, woody_guthrie).
yes
?- influenced_by(bob_dylan, bruce_s).
no
```

15 Visualizing Logic

- *Comma* (`,`) is read as `and` in Prolog. Example: The rule

```
person(X) :- has_bellybutton(X), not_dead(X).
```

  is read as

  "X is a person if X has a bellybutton and X is not dead."

- *Semicolon* (`;`) is read as `or` in Prolog. The rule

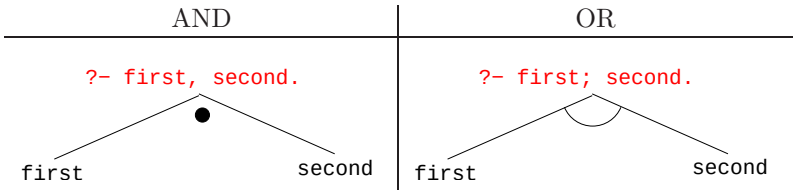
```
person(X) :- X=adam ; X=eve ;
             has_bellybutton(X).
```

  is read as

  "X is a person if X is adam or X is eve or X has a bellybutton."

16 Visualizing Logic...

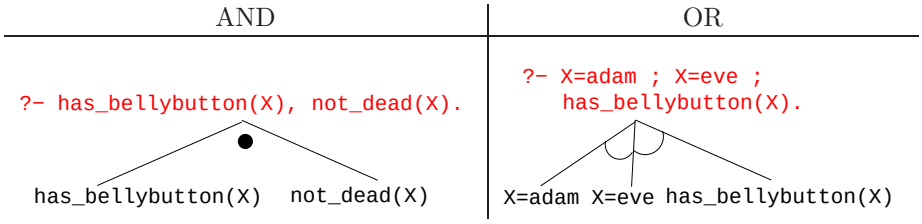
- To visualize what happens when Prolog executes (and this can often be very complicated!) we use the following two notations:



- For `AND`, both legs have to succeed.
- For `OR`, one of the legs has to succeed.

17 Visualizing Logic...

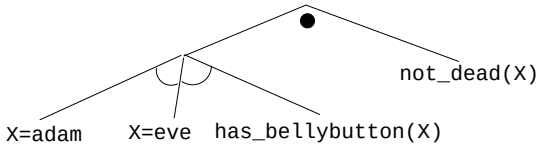
- Here are two examples:



18 Visualizing Logic...

- `and` and `or` can be combined:

```
?- (X=adam ; X=eve ; has_bellybutton(X)), not_dead(X).
```



- This query asks

  "Is there a person X who is adam, eve, or who has a bellybutton, and who is also not dead?"

19 Answering Questions

```
(1)   scientist(helder).
(2)   scientist(ron).
(3)   portuguese(helder).
(4)   american(ron).
(5)   logician(X) :- scientist(X).
(6)   ?- logician(X), american(X).
```

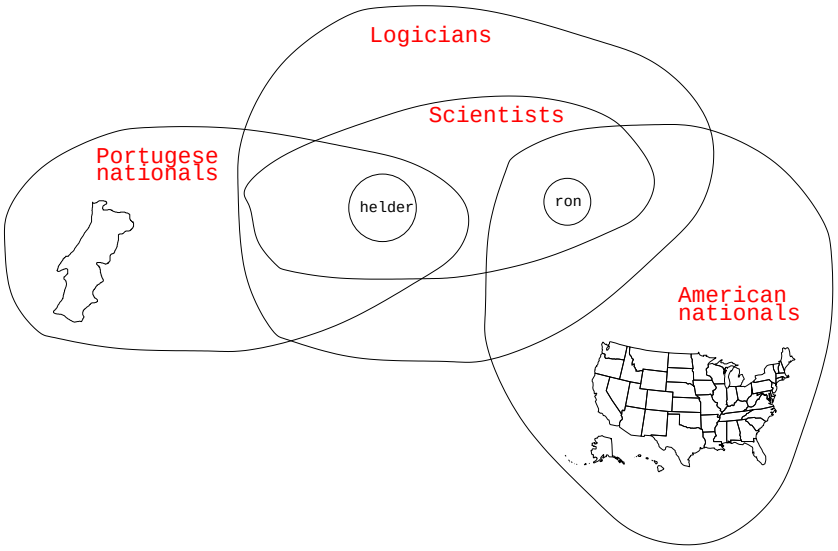
- The rule (5) states that

  "Every scientist is a logician"

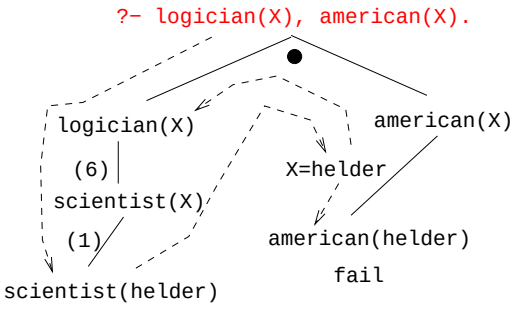
- The question (6) asks

  "Which scientist is a logician *and* an american?"

20 Answering Questions...

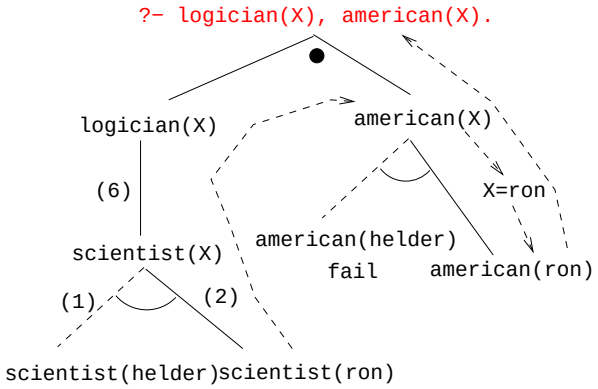


21 Answering Questions...




```
(1)   scientist(helder).
(2)   scientist(ron).
(3)   portuguese(helder).
(4)   american(ron).
(5)   logician(X) :- scientist(X).
(6)   ?- logician(X), american(X).
```

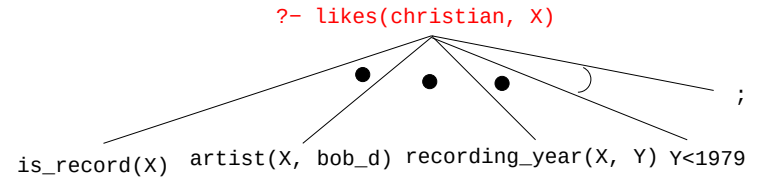
22 Answering Questions...



23 Answering Questions...

```
is_record(planet_waves).  is_record(desire).
is_record(slow_train).

recorded_by(planet_waves, bob_dylan).
recorded_by(desire, bob_dylan).
recorded_by(slow_train, bob_dylan).

recording_year(planet_waves, 1974).
recording_year(desire, 1975).
recording_year(slow_train, 1979).

likes(christian, X) :-
      is_record(X), recorded_by(X, bob_dylan),
      recording_year(X, Year), Year < 1979.
```

24 Answering Questions...

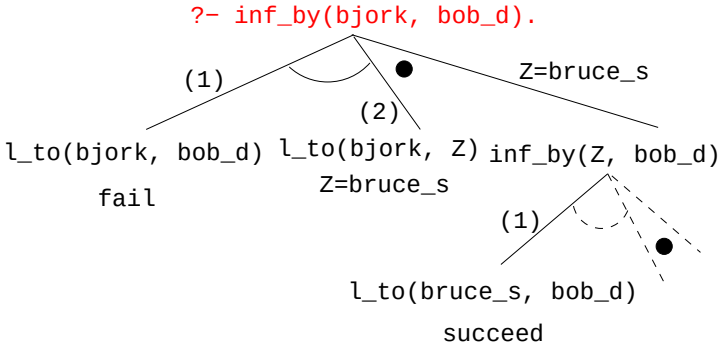


X = planet_waves	Y=1979	succeed
X = desire	Y=1975	succeed
X = slow_train	Y=1974	fail

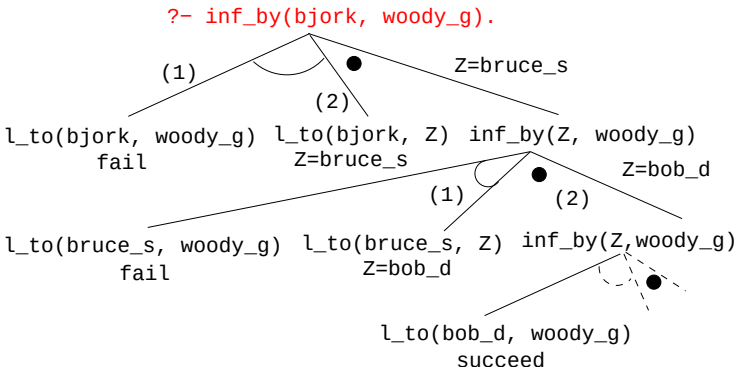
25 Answering Questions...

```
listens_to(bob_dylan, woody_guthrie).
listens_to(arlo_guthrie, woody_guthrie).
listens_to(van_morrison, bob_dylan).
listens_to(dire_straits, bob_dylan).
listens_to(bruce_springsteen, bob_dylan).
listens_to(björk, bruce_springsteen).

(1)   influenced_by(X, Y) :- listens_to(X, Y).
(2)   influenced_by(X, Y) :-
         listens_to(X, Z),
         influenced_by(Z, Y).

?- influenced_by(bjork, bob_dylan).
?- inf_by(bjork, woody_guthrie).
```

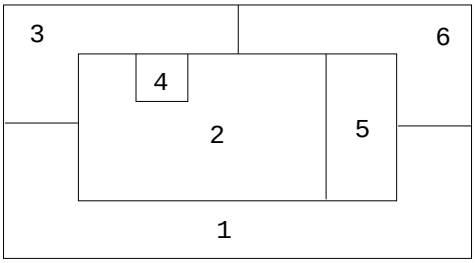
26 Answering Questions...



27 Answering Questions...



28 Map Coloring



"Color a planar map with at most four colors, so that contiguous regions are colored differently."

29 Map Coloring...

A coloring is OK iff

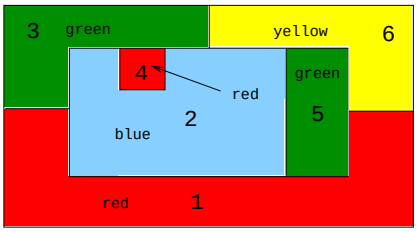
1. The color of Region 1 $\neq$ the color of Region 2, and
2. The color of Region 1 $\neq$ the color of Region 3,...

```
color(R1, R2, R3, R4, R5, R6) :-
   diff(R1, R2), diff(R1, R3), diff(R1, R5), diff(R1, R6),
   diff(R2, R3), diff(R2, R4), diff(R2, R5), diff(R2, R6),
   diff(R3, R4), diff(R3, R6), diff(R5, R6).

diff(red,blue).  diff(red,green).  diff(red,yellow).
diff(blue,red).  diff(blue,green).  diff(blue,yellow).
diff(green,red).  diff(green,blue).  diff(green,yellow).
diff(yellow, red).diff(yellow,blue).  diff(yellow,green).
```

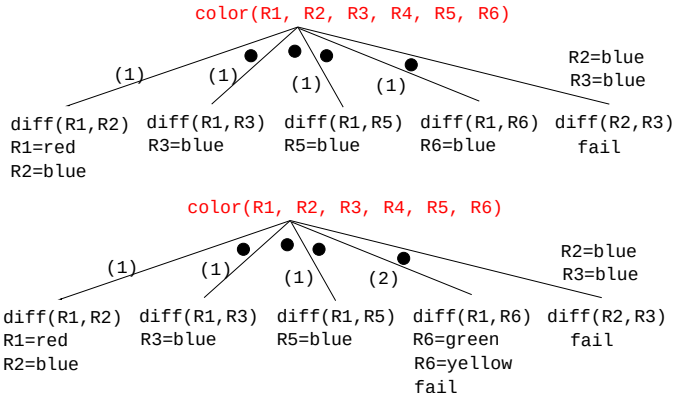
30 Map Coloring...

```
?- color(R1, R2, R3, R4, R5, R6).
R1 = R4 = red, R2 = blue,
R3 = R5 = green, R6 = yellow ;
```

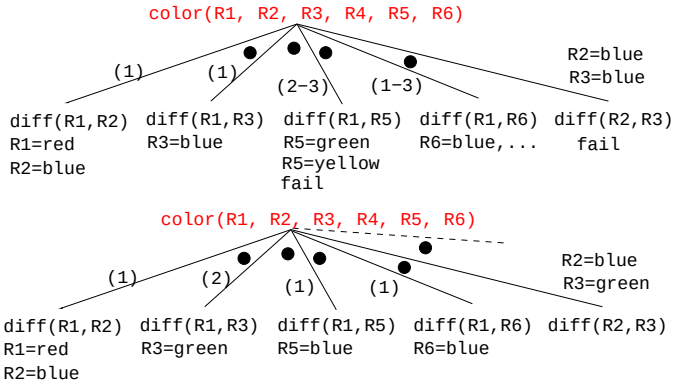
```
R1 = red, R2 = blue,
R3 = R5 = green, R4 = R6 = yellow
```



31 Map Coloring – Backtracking



32 Map Coloring – Backtracking



33 Working with gprolog

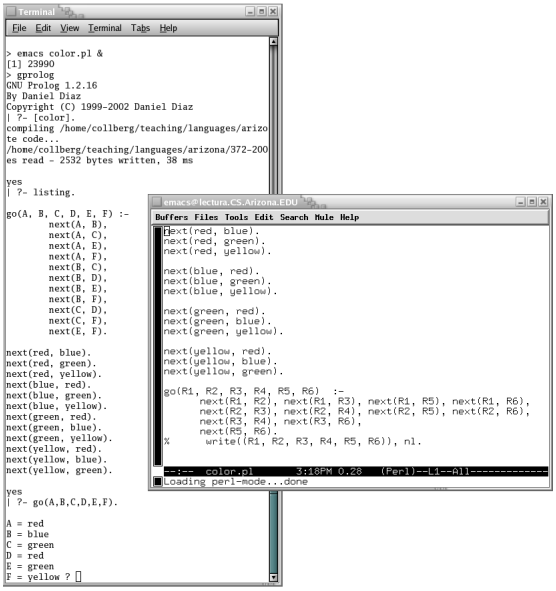
- gprolog can be downloaded from here: http://gprolog.inria.fr/.
- gprolog is installed on lectura (it's also on the Windows machines) and is invoked like this:

```
> gprolog
GNU Prolog 1.2.16
| ?- [color].
| ?- listing.
go(A, B, C, D, E, F) :- next(A, B), ...
| ?- go(A,B,C,D,E,F).
A = red ...
```

34 Working with gprolog...

- The command `[color]` loads the prolog program in the file `color.pl`.
- You should use the texteditor of your choice (`emacs`, `vi`,...) to write your prolog code.
- The command `listing` lists all the prolog predicates you have loaded.

35 Working with gprolog...



36 Readings and References

- Read Clocksin-Mellish, Chapter 1-2.
- http://dmoz.org/Computers/Programming/Languages/Prolog

Prolog by Example	Coelho & Cotta
Prolog: Programming for AI	Bratko
Programming in Prolog	Clocksin & Mellish
The Craft of Prolog	O'Keefe
Prolog for Programmers	Kluzniak & Szpakowicz
Prolog	Alan G. Hamilton
The Art of Prolog	Sterling & Shapiro

37 Readings and References...

Computing with Logic	Maier & Warren
Knowledge Systems Through Prolog	Steven H. Kim
Natural Language Processing in Prolog	Gazdar & Mellish
Language as a Cognitive Process	Winograd
Prolog and Natural Language Analysis	Pereira and Shieber
Computers and Human Language	George W. Smith
Introduction to Logic	Irving M. Copi
Beginning Logic	E.J.Lemmon

38 Prolog So Far

- A Prolog program consists of a number of *clauses*:

  Rules – Have `head` + `body`:

  head

  ```
  likes(chris, X) :-
     girl(X), black_hair(X)
  ```

  body

  – Can be recursive

  Facts – Head but no body.

  – Always true.

39 Prolog So Far...

- A clause consists of

  atoms Start with lower-case letter.

  variables Start with upper-case letter.

- Prolog programs have a
  - Declarative meaning
    - The relations defined by the program
  - Procedural meaning
    - The order in which goals are tried

40 Prolog So Far...

- A question consists of one or more goals:
  - `?- likes(chris, X), smart(X).`
  - `","` means `and`
  - Use `";"` to get all answers
  - Questions are either
    - Satisfiable (the goal succeeds)
    - Unsatisfiable (the goal fails)

- Prolog answers questions (satisfies goals) by:
  - instantiating variables
  - searching the database sequentially
  - backtracking when a goal fails