CSc 372

Comparative Programming Languages

17 : Prolog — Introduction

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What is Prolog?

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.

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.

Objects & Relationships

Objects & Relationships

Prolog programs deal with

- objects, and
- relationships between objects

English:

"Christian likes the record"

Prolog:

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

Facts

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).
```

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*.

Conditional Relationships

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.
```

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*.

Asking Questions

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
```

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
```

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
```

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
```

Recursive Rules

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
```

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).
```

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
```

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

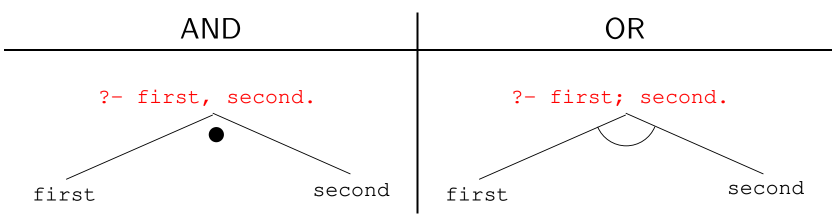
  ```
  person(X) :- X=adam ; X=eve ;
                  has_bellybutton(X).
  ```

  is read as

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

Visualizing Logic. . .

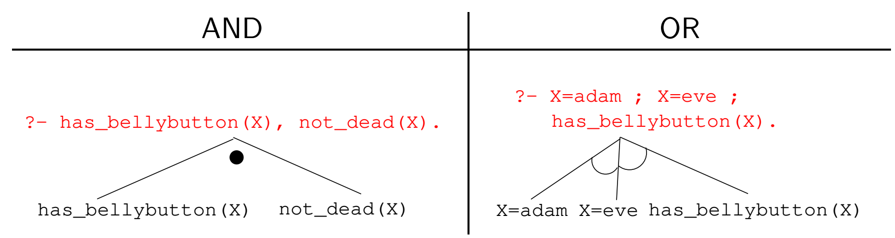
- To visualize what happens when Prolog executes (and this can often be very complicated!) we use the following two notations:



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

Visualizing Logic. . .

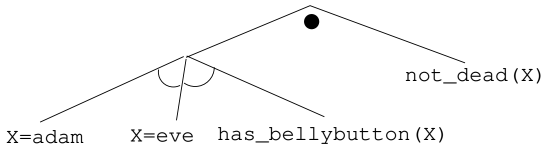
- Here are two examples:



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?"

How does Prolog Answer Questions?

Answering Questions

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

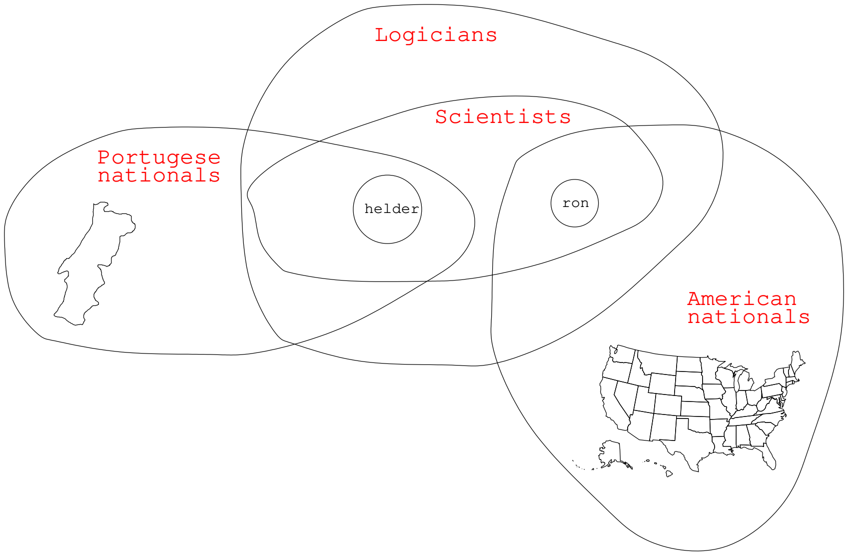
- The rule (5) states that

  "Every scientist is a logician"

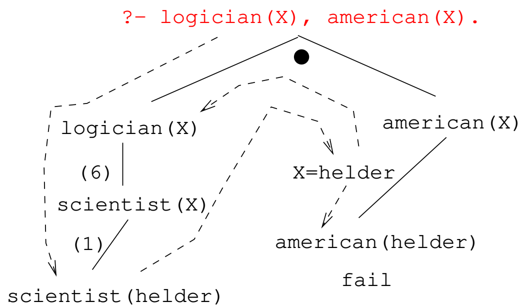
- The question (6) asks

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

Answering Questions...

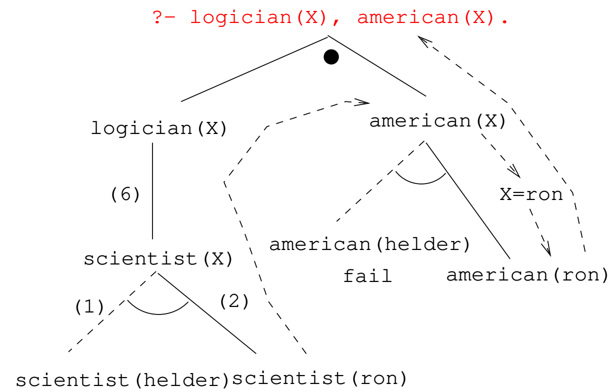


Answering Questions. . .




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

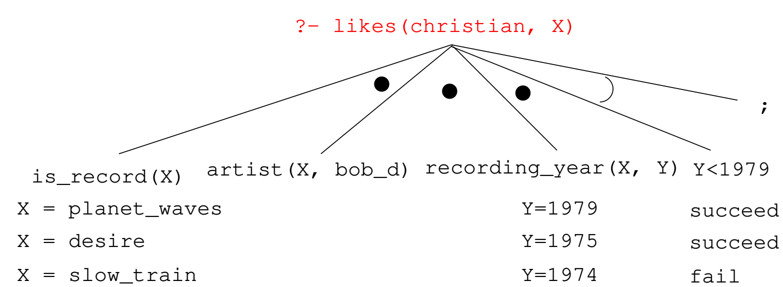
Answering Questions. . .



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.
```

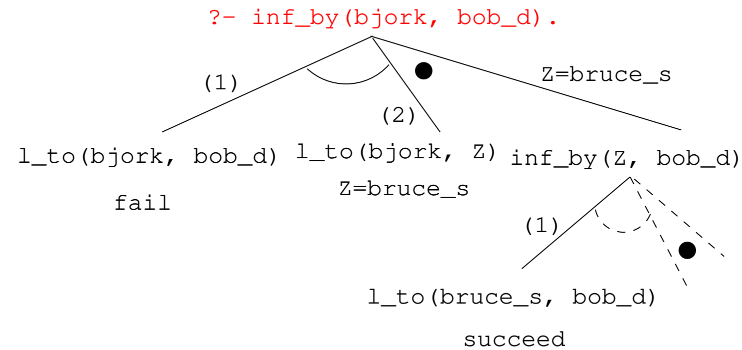
Answering Questions. . .



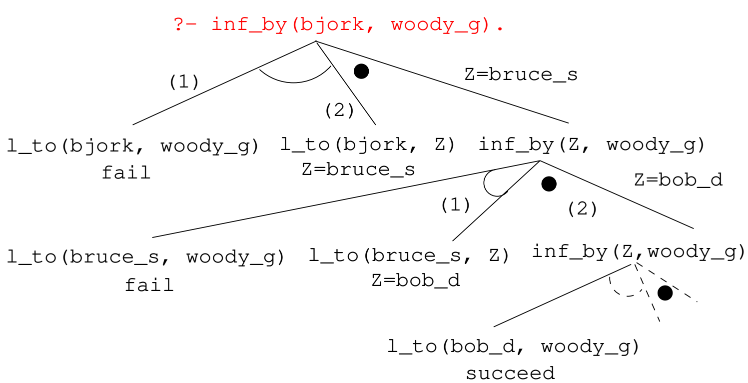
Answering Questions...

```
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).
```

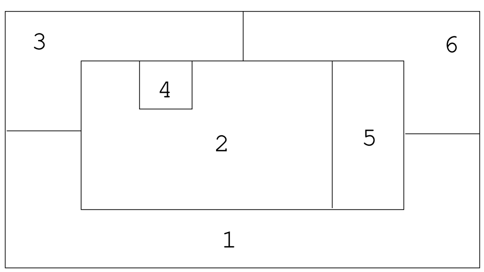
Answering Questions...



Answering Questions...



Map Coloring



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

Map Coloring...

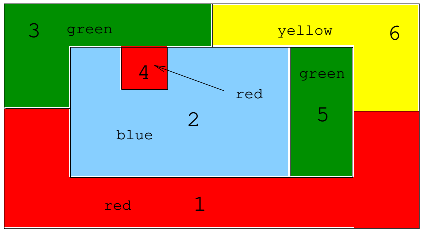
A coloring is OK iff

1. The color of Region 1 ≠ the color of Region 2, and
2. The color of Region 1 ≠ the color of Region 3,...

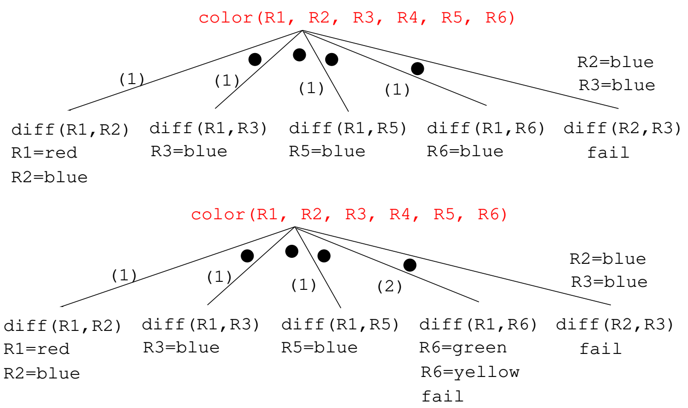
```
color(R1, R2, R3, R4, R5, R6) :-
   diff(R1, R2), diff(R1, R3), diff(R1, R5), diff(R1, R6),
   diff(R2, R3), diff(R2, R4), diff(R2, R5), diff(R2, R6),
   diff(R3, R4), diff(R3, R6), diff(R5, R6).

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).
```

Map Coloring...

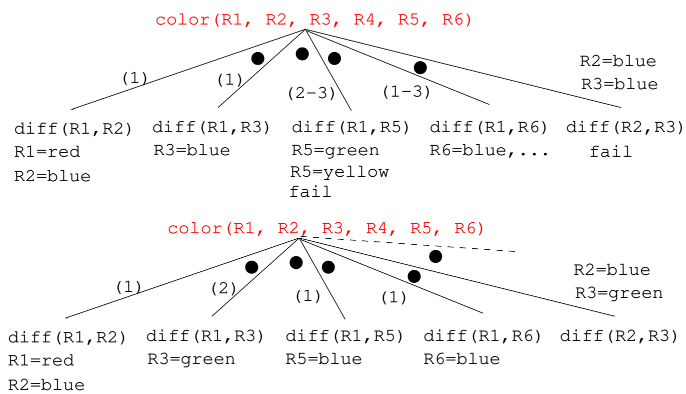
```
?- color(R1, R2, R3, R4, R5, R6).
R1 = R4 = red, R2 = blue,
R3 = R5 = green, R6 = yellow ;

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



Map Coloring – Backtracking



Map Coloring – Backtracking



Working with gprolog

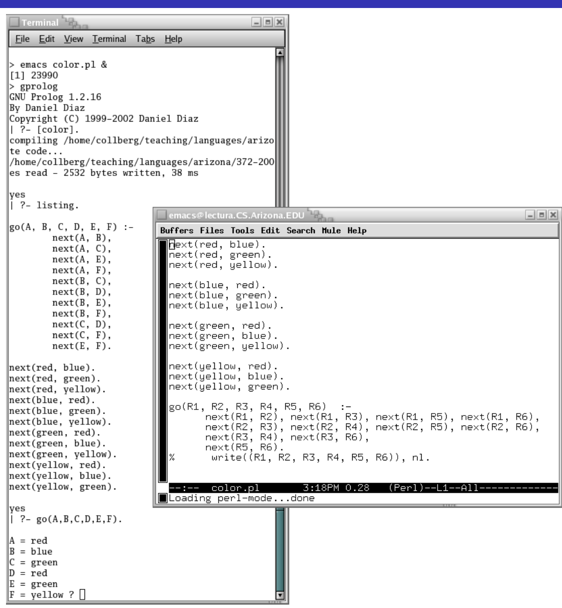
- gprolog can be downloaded from here: http://gprolog.inria.fr/.
- gprolog is installed on lectura (it's also on the Windows machines) and is invoked like this:

```
> 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 ...
```

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.

Working with gprolog...



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

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

Prolog So Far

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

Rules
- Have `head` + `body`:

$$\overbrace{\texttt{likes(chris, X)}}^{\text{head}}\ \texttt{:-}\ \underbrace{\texttt{girl(X), black\_hair(X)}}_{\text{body}}$$

- Can be recursive

Facts
- Head but no body.
- Always true.

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

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