Logic Programming

Prolog: Arithmetic, Equalities, Operators, I/O, Infinite regression. Knowledge bases: assert, retract. (PLP 11)

Carlos Varela

Rensselaer Polytechnic Institute

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Arithmetic Goals

```
N>M
N<M
N=<M
N>=M
```

- `N` and `M` must be bound to numbers for these tests to *succeed* or *fail*.
- `X is 1+2` is used to *assign* numeric value of right-hand-side to variable in left-hand-side.

Loop Revisited

```
natural(1).
natural(N) :-  natural(M), N is M+1.
my_loop(N) :-  N>0,
               natural(I), %generate
               write(I), nl,
               I=N,        %test
               !.
my_loop(_).
```

Also called *generate-and-test*.

= is not equal to == or =:=

`X=Y` `X\=Y`

test whether `X` and `Y` **can be** or **cannot be** *unified*.

`X==Y` `X\==Y`

test whether `X` and `Y` are currently *co-bound*, i.e., have been bound to, or share the same value.

`X=:=Y` `X=\=Y`

test *arithmetic* equality and inequality.

Can take expressions and evaluates them to a numeric value before testing. Do not bind variables.

More equalities

`X=@=Y` `X\=@=Y`

test whether `X` and `Y` are *structurally identical*.

- `=@=` is weaker than `==` but stronger than `=`.

- Examples:

`a=@=A`	**false**
`A=@=B`	**true**
`x(A,A)=@=x(B,C)`	**false**
`x(A,A)=@=x(B,B)`	**true**
`x(A,B)=@=x(C,D)`	**true**

More on equalities

`X==Y`

$\Rightarrow$ `X=@=Y`

$\Rightarrow$ `X=Y`

but not the other way ($\Leftarrow$).

- If two terms are currently co-bound, they are structurally identical, and therefore they can unify.
- Examples:

`a=@=A`	**false**
`A=@=B`	**true**
`x(A,A)=@=x(B,C)`	**false**
`x(A,A)=@=x(B,B)`	**true**
`x(A,B)=@=x(C,D)`	**true**

Prolog Operators

```
:- op(P,T,O)
```

declares an operator symbol `O` with precedence `P` and type `T`.

- Example:

```
:- op(500,xfx,'has_color')
a has_color red.
b has_color blue.
```

then:

```
?- b has_color C.
C = blue.
?- What has_color red.
What = a.
```

Operator precedence/type

- Precedence `P` is an integer: the larger the number, the less the precedence (*ability to group*).
- Type `T` is one of:

`T`	**Position**	**Associativity**	**Examples**
`xfx`	Infix	Non-associative	`is`
`xfy`	Infix	Right-associative	`, ;`
`yfx`	Infix	Left-associative	`+ - * /`
`fx`	Prefix	Non-associative	`?-`
`fy`	Prefix	Right-associative	
`xf`	Postfix	Non-associative	
`yf`	Postfix	Left-associative	

Testing types

`atom``(X)`

tests whether `X` is an *atom*, e.g., `'foo'`, `bar`.

`integer``(X)`

tests whether `X` is an *integer*; it does not test for complex terms, e.g., `integer(4/2)` fails.

`float``(X)`

tests whether `X` is a *float*; it matches exact type.

`string``(X)`

tests whether `X` is a *string*, enclosed in `` `` ... `` ``.

Prolog Input

`seeing``(X)`

succeeds if `X` is (or can be) bound to *current read port*.

`X = user` is keyboard (standard input.)

`see``(X)`

opens port for input file bound to `X`, and makes it *current*.

`seen`

closes current port for input file, and makes `user` *current*.

`read``(X)`

reads Prolog type expression from *current* port, storing value in `X`.

`end-of-file`

is returned by **read** at <*end-of-file*>.

Prolog Output

`telling``(X)`

succeeds if `X` is (or can be) bound to *current output port*.

`X = user` is screen (standard output.)

`tell``(X)`

opens port for output file bound to `X`, and makes it *current*.

`told`

closes current output port, and reverses to screen output (makes `user` *current*.)

`write``(X)`

writes Prolog expression bound to `X` into *current* output port.

`nl`

new line (line feed).

`tab``(N)`

writes `N` spaces to current output port.

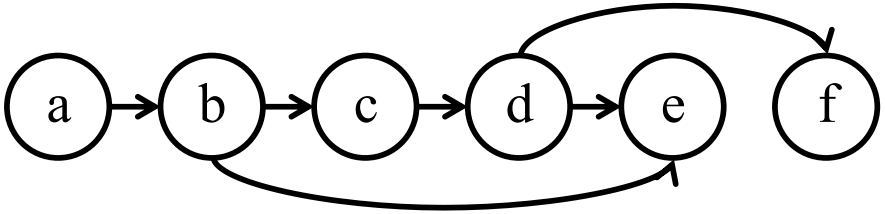
I/O Example

```
browse(File) :-
   seeing(Old),                  /* save for later */
   see(File),                    /* open this file */
   repeat,
   read(Data),                   /* read from File */
   process(Data),
   seen,                         /* close File */
   see(Old),                     /* prev read source */
   !.                            /* stop now */

process(end_of_file) :- !.
process(Data) :-  write(Data), nl, fail.
```

First-Class Terms Revisited

`call(P)`	Invoke predicate as a goal.
`assert(P)`	Adds predicate to database.
`retract(P)`	Removes predicate from database.
`functor(T,F,A)`	Succeeds if `T` is a *term* with *functor* `F` and *arity* `A`.
`findall(F,P,L)`	Returns a list `L` with all elements `F` satisfying predicate `P`
`clause(H,B)`	Succeeds if the clause `H :- B` can be found in the database.

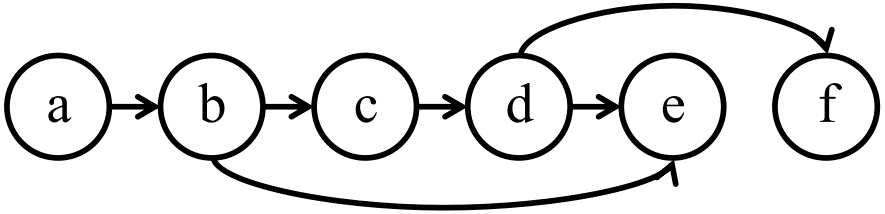
Directed Graph Paths



Finding paths between nodes, following edges in graph.

```
edge(a,b). edge(b,c). edge(c,d). edge(d,e). edge(b,e). edge(d,f).

path(X,X).
path(X,Y) :- edge(X,Z), path(Z,Y).
```

Infinite Regression



Finding paths between nodes, following edges in graph.
Changing the order of the `path` clauses and the order of their inner terms, does not change their logical meaning, but can result in non-termination.

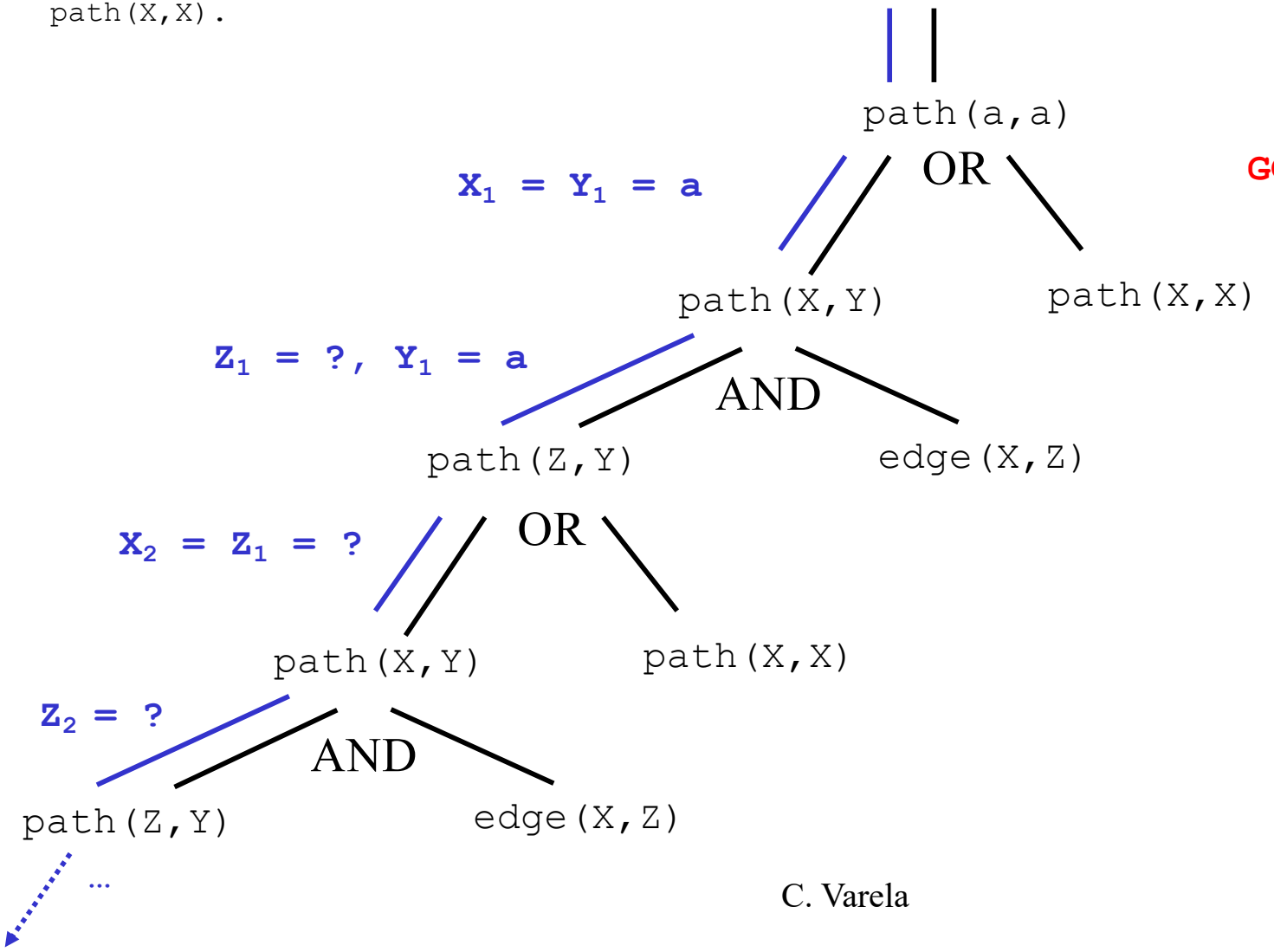
```
edge(a,b). edge(b,c). edge(c,d). edge(d,e). edge(b,e). edge(d,f).

path(X,Y) :- path(Z,Y), edge(X,Z).
path(X,X).
```

Infinite Regression

```
path(X,Y) :- path(Z,Y), edge(X,Z).
path(X,X).
```

Search strategy goes into an infinite path.

GOAL FAILS.



Databases: assert and retract

- Prolog enables direct modification of its knowledge base using assert and retract.
- Let us consider a tic-tac-toe game:

1	2	3
4	5	6
7	8	9

- We can represent a board with facts x(n) and o(n), for n in {1..9} corresponding to each player's moves.
- As a player (or the computer) moves, a fact is dynamically added to Prolog's knowledge base.

Databases: assert and retract

```
% main goal:
play :- clear, repeat, getmove, respond.

getmove :-  repeat,
            write('Please enter a move: '),
            read(X), empty(X),
            assert(o(X)).

respond :- makemove, printboard, done.

makemove :- move(X), !, assert(x(X)).
makemove :- all_full.

clear :- retractall(x(_)), retractall(o(_)).
```

Human move

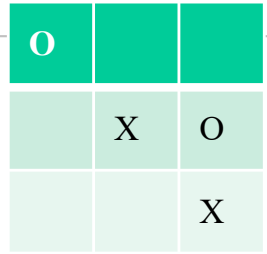
Computer move

Tic-tac-toe: Strategy

The strategy is to first try to win, then try to block a win, then try to create a split (forced win in the next move), then try to prevent opponent from building three in a row, and creating a split, finally choose center, corners, and other empty squares. The order of the rules is key to implementing the strategy.

```
move(A) :- good(A), empty(A), !.

good(A) :- win(A).
good(A) :- block_win(A).
good(A) :- split(A).
good(A) :- strong_build(A).
good(A) :- weak_build(A).

good(5).
good(1).  good(3).  good(7).  good(9).
good(2).  good(4).  good(6).  good(8).
```

Tic-tac-toe: Strategy(2)



- Moving x(8) produces a split: x(2) or x(7) wins in next move.

```
win(A)        :- x(B), x(C), line(A,B,C).
block_win(A):- o(B), o(C), line(A,B,C).
split(A)      :- x(B), x(C), different(B,C),
   line(A,B,D), line(A,C,E), empty(D), empty(E).
strong_build(A) :- x(B), line(A,B,C), empty(C),
                   not(risky(C)).
weak_build(A)   :- x(B), line(A,B,C), empty(C),
                   not(double_risky(C)).

risky(C)      :- o(D), line(C,D,E), empty(E).
double_risky(C) :- o(D), o(E), different(D,E),
   line(C,D,F), line(C,E,G), empty(F), empty(G).
```

Exercises

81. The Prolog predicate my_loop/1 can succeed or fail as a goal. Explain why you may want a predicate to succeed, or to fail, depending on its expected calling context.
82. Create a nested_loop/2 predicate that prints all pairs (I,J) for numbers 1<= I <= N, 1 <= J <= M.
83. CTM Exercise 9.8.1 (page 671). Do it in Prolog.
84. Modify the tic-tac-toe game so that the user can make two moves at each turn.