CS621: Artificial Intelligence

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Lecture 25, 26, 27–Prolog (with actually tested Himalayan club example)

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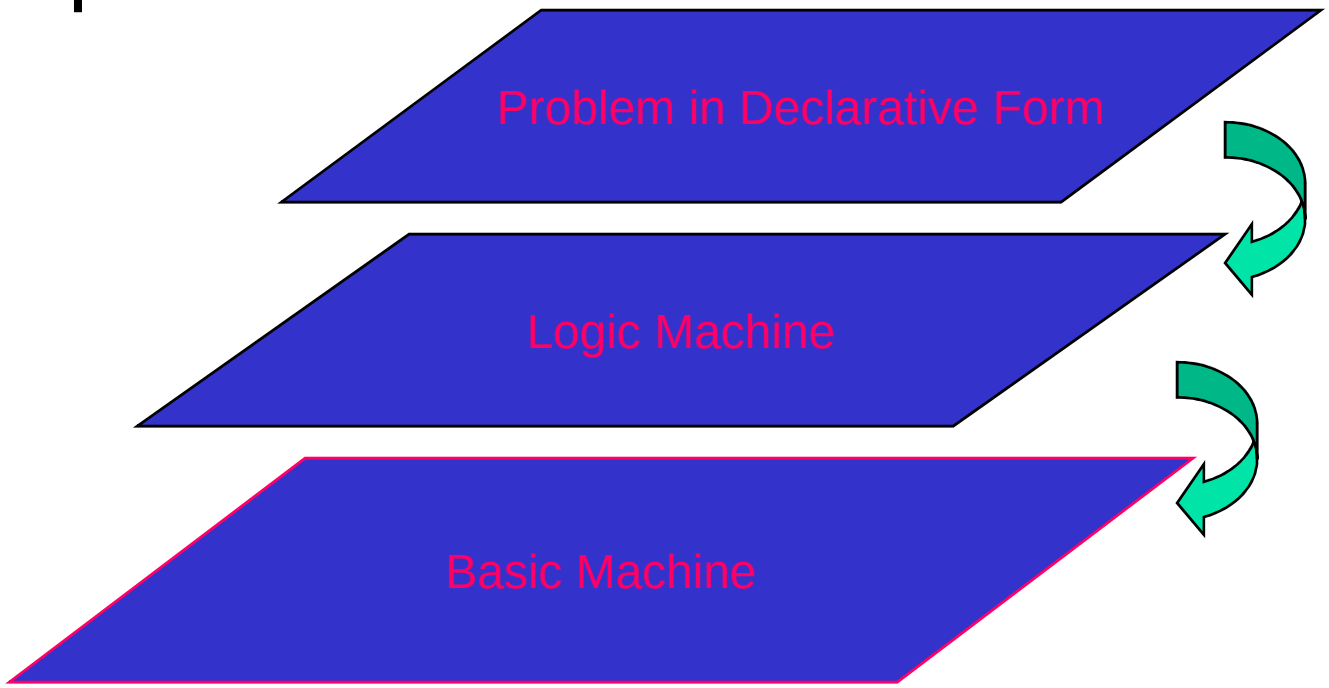
Introduction

- PROgramming in LOGic
- Emphasis on *what* rather than *how*



Prolog's strong and weak points

- Assists thinking in terms of *objects* and *entities*
- Not good for *number crunching*
- Useful applications of Prolog in
  - *Expert Systems* (Knowledge Representation and Inferencing)
  - *Natural Language Processing*
  - *Relational Databases*

A Typical Prolog program

Compute_length ([],0).

Compute_length ([Head|Tail], Length):-

Compute_length (Tail,Tail_length),

Length is Tail_length+1.

High level explanation:

The length of a list is 1 plus the length of the tail of the list, obtained by removing the first element of the list.

This is a declarative description of the computation.

Fundamentals

(absolute basics for writing Prolog Programs)

Facts

- *John likes Mary*
  - *like(john,mary)*
- Names of relationship and objects must begin with a lower-case letter.
- Relationship is written *first* (typically the *predicate* of the sentence).
- *Objects* are written separated by commas and are enclosed by a pair of round brackets.
- The full stop character '.' must come at the end of a fact.

More facts

Predicate	**Interpretation**
valuable(gold)	Gold is valuable.
owns(john,gold)	John owns gold.
father(john,mary)	John is the father of Mary
gives (john,book,mary)	John gives the book to Mary

Questions

- *Questions* based on facts
- Answered by *matching*

Two facts *match* if their predicates are same (spelt the same way) and the arguments each are same.

- If matched, prolog answers *yes*, else *no*.
- *No* does not mean falsity.

Prolog does *theorem proving*

- When a question is asked, prolog tries to match *transitively.*
- When no match is found, answer is *no.*
- This means *not provable* from the given facts.

Variables

- Always begin with a capital letter
  - *?- likes (john,X).*
  - *?- likes (john, Something).*
- But *not*
  - *?- likes (john,something)*

Example of usage of variable

Facts:

likes(john,flowers).
likes(john,mary).
likes(paul,mary).

Question:

?- likes(john,X)

Answer:

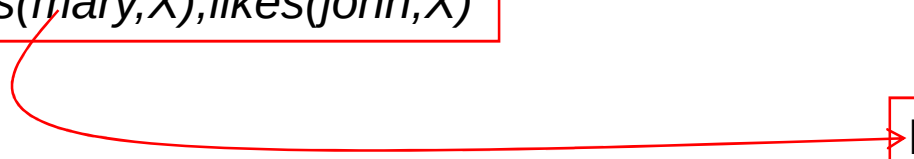
X=flowers and wait
;
mary
;
no

Conjunctions

- Use ‘,’ and pronounce it as *and*.
- Example
  - Facts:
    - likes(mary,food).
    - likes(mary,tea).
    - likes(john,tea).
    - likes(john,mary)
- ?-
    - likes(mary,X),likes(john,X).
    - Meaning *is anything liked by Mary also liked by John?*

Backtracking *(an inherent property of prolog programming)*

likes(mary,X),likes(john,X)

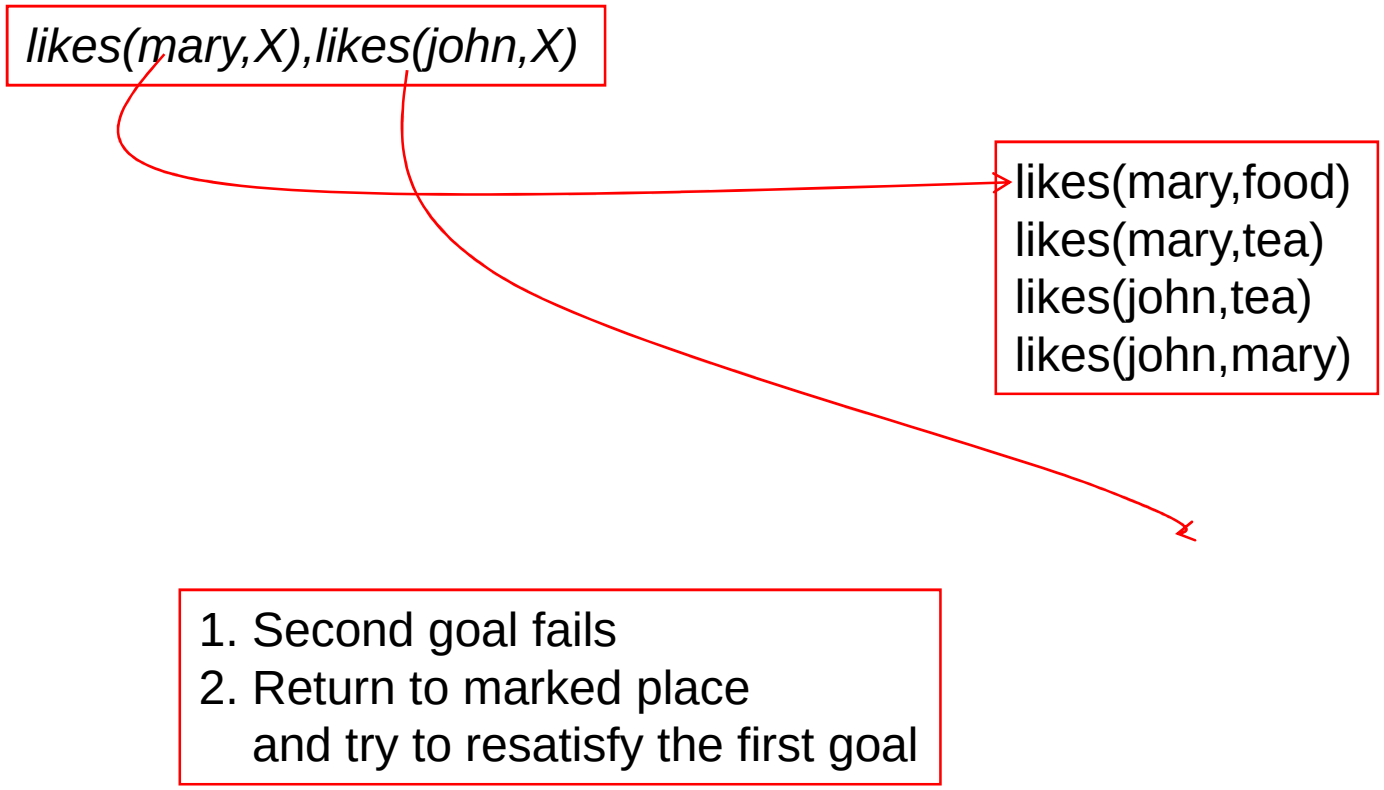


likes(mary,food)
likes(mary,tea)
likes(john,tea)
likes(john,mary)

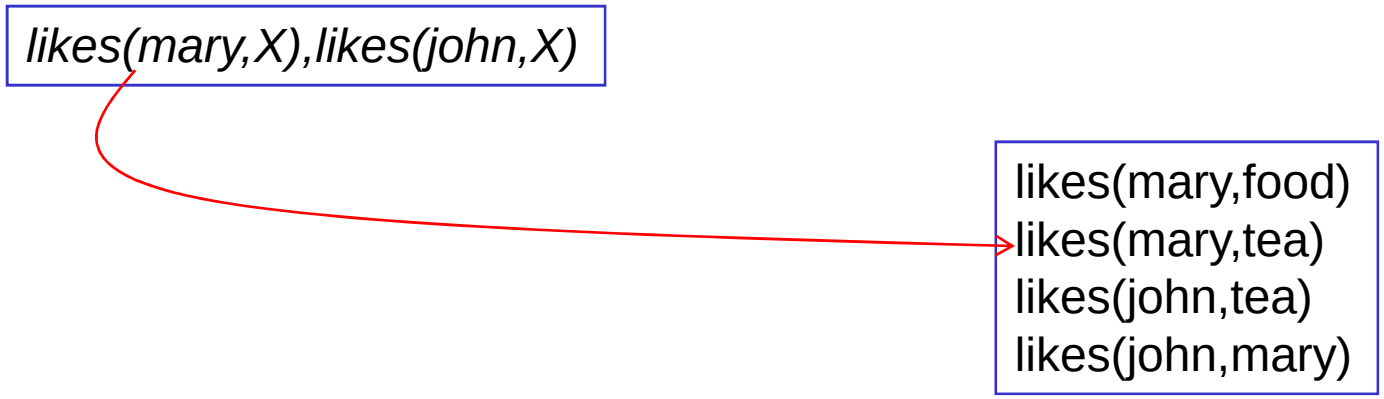
1. First goal succeeds. *X=food*
2. Satisfy *likes(john,food)*

Backtracking *(continued)*

Returning to a marked place and trying to resatisfy is called *Backtracking*

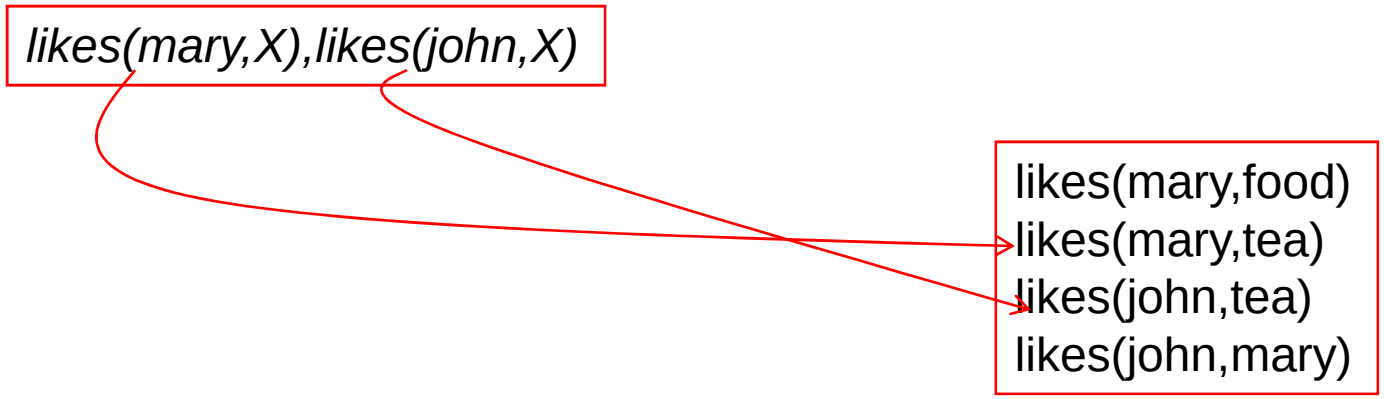


Backtracking *(continued)*



1. First goal succeeds again, *X=tea*
2. Attempt to satisfy the *likes(john,tea)*

Backtracking *(continued)*



1. Second goal also suceeds
2. Prolog notifies success and waits for a reply

Rules

- Statements about *objects* and their *relationships*
- Expess
  - *If-then conditions*
    - *I use an umbrella if there is a rain*
    - *use(i, umbrella) :- occur(rain).*
  - *Generalizations*
    - *All men are mortal*
    - *mortal(X) :- man(X).*
  - *Definitions*
    - *An animal is a bird if it has feathers*
    - *bird(X) :- animal(X), has_feather(X).*

Syntax

- **<head> :- <body>**
- Read **‘:-’ as ‘if’.**
- E.G.
  - *likes(john,X) :- likes(X,cricket).*
  - *"John likes X if X likes cricket".*
  - *i.e., "John likes anyone who likes cricket".*
- Rules always end with ‘.’.

Another Example

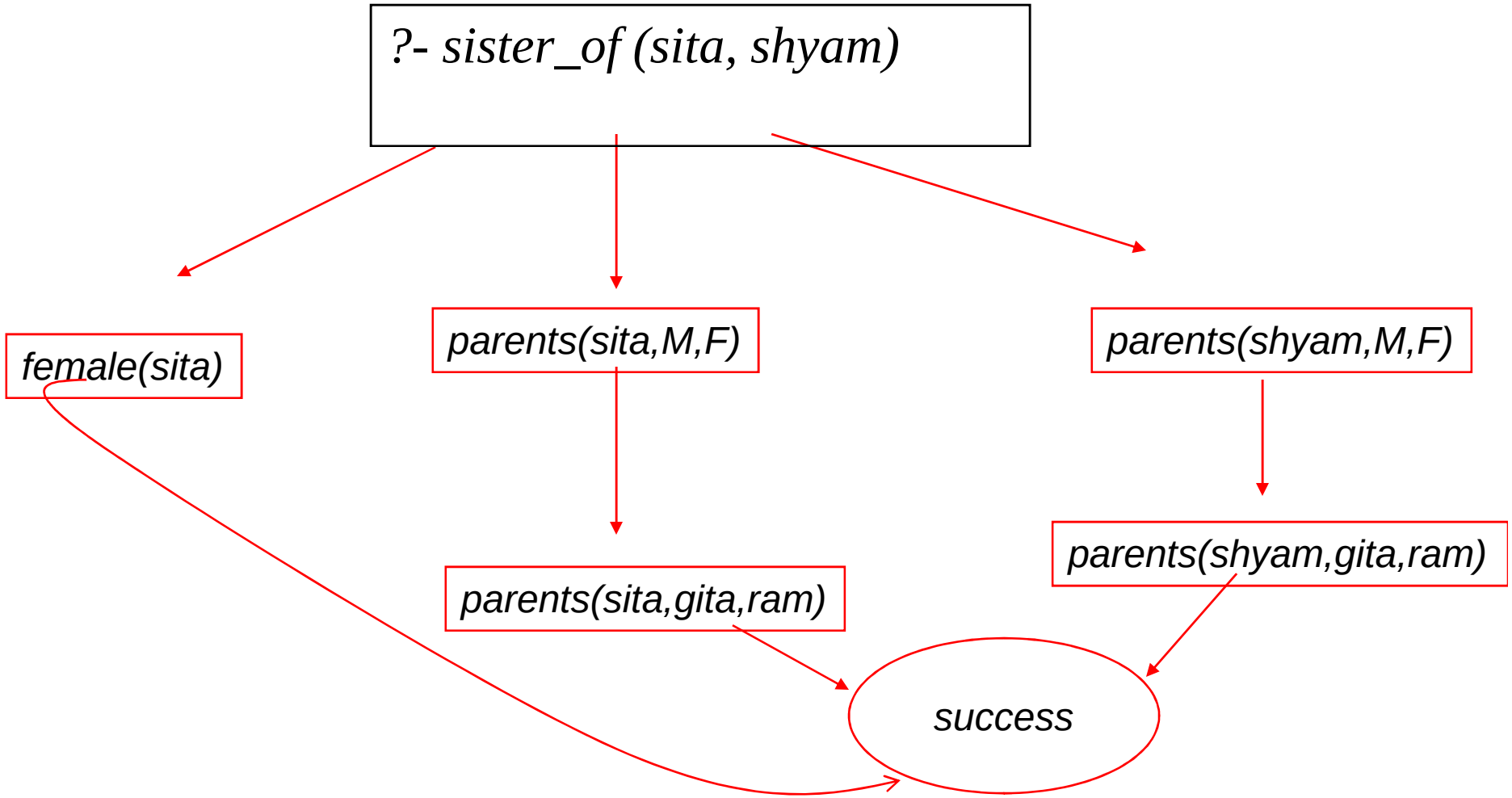
sister_of (X,Y):- female (X),
parents (X, M, F),
parents (Y, M, F).

X is a sister of Y is
X is a female and
X and Y have same parents

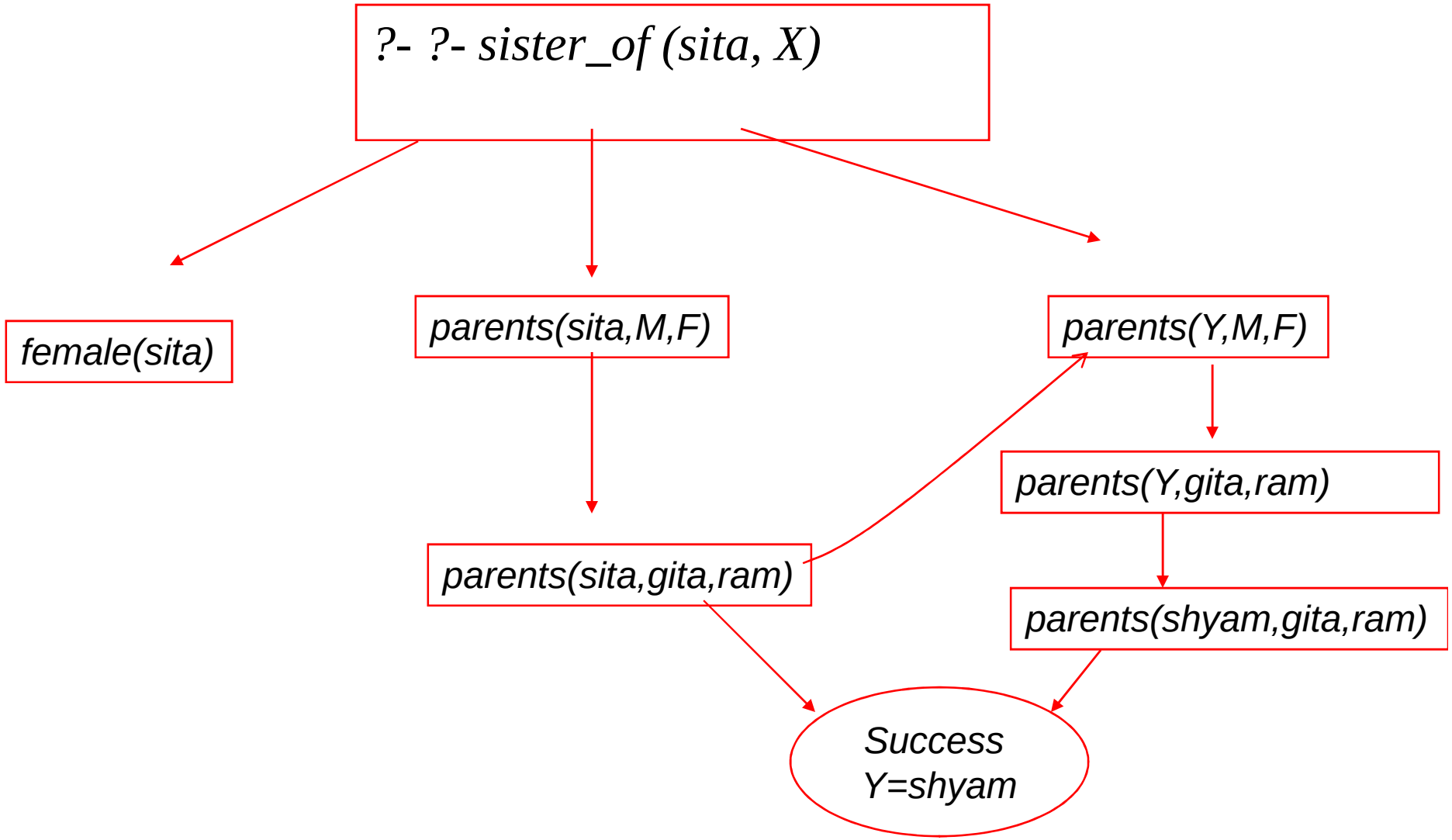
Question Answering in presence of *rules*

- Facts
  - male (ram).
  - male (shyam).
  - female (sita).
  - female (gita).
  - parents (shyam, gita, ram).
  - parents (sita, gita, ram).

Question Answering: Y/N type: *is sita the sister of shyam?*



Question Answering: wh-type: *whose sister is sita?*



Exercise

1. From the above it is possible for somebody to be her own sister. How can this be prevented?

An example Prolog Program

Shows path with mode of conveyeance from city C_1 to city C_2

- :-use_module(library(lists)).

- byCar(auckland,hamilton).
- byCar(hamilton,raglan).
- byCar(valmont,saarbruecken).
- byCar(valmont,metz).

- byTrain(metz,frankfurt).
- byTrain(saarbruecken,frankfurt).
- byTrain(metz,paris).
- byTrain(saarbruecken,paris).

- byPlane(frankfurt,bangkok).
- byPlane(frankfurt,singapore).
- byPlane(paris,losAngeles).
- byPlane(bangkok,auckland).
- byPlane(losAngeles,auckland).

- go(C1,C2) :- travel(C1,C2,L), show_path(L).

- travel(C1,C2,L) :- direct_path(C1,C2,L).

- travel(C1,C2,L) :- direct_path(C1,C3,L1),travel(C3,C2,L2),append(L1,L2,L).

- direct_path(C1,C2,[C1,C2,' by car']):- byCar(C1,C2).
- direct_path(C1,C2,[C1,C2,' by train']):- byTrain(C1,C2).
- direct_path(C1,C2,[C1,C2,' by plane']):- byPlane(C1,C2).

- show_path([C1,C2,M|T]) :- write(C1),write(' to '),write(C2),write(M),nl,show_path(T).

Rules

- Statements about *objects* and their *relationships*
- Expess
  - *If-then conditions*
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  - *Generalizations*
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Prolog Program Flow, BackTracking and Cut

Controlling the program flow

Prolog's computation

- **Depth First Search**
  - **Pursues a goal till the end**
- **Conditional AND; *falsity* of any goal prevents satisfaction of further clauses.**
- **Conditional OR; *satisfaction* of any goal prevents further clauses being evaluated.**

Control flow (top level)

Given

g:- a, b, c. (1)

g:- d, e, f; g. (2)

If prolog cannot satisfy (1), control will automatically fall through to (2).

Control Flow within a rule

Taking (1),

g:- a, b, c.

If *a* succeeds, prolog will try to satisfy *b,* succeding which *c* will be tried.

For ANDed clauses, control flows forward till the '.', iff the current clause is *true.*

For ORed clauses, control flows forward till the '.', iff the current clause evaluates to *false.*

What happens on failure

- **REDO the immediately preceding goal.**

Fundamental Principle of prolog programming

- **Always place the more general rule AFTER a specific rule.**

CUT

- **Cut tells the system that**

  IF YOU HAVE COME THIS FAR

  DO NOT BACKTRACK

  EVEN IF YOU FAIL SUBSEQUENTLY.

  'CUT' WRITTEN AS '!' ALWAYS SUCCEEDS.

Fail

- This predicate always fails.
- *Cut* and *Fail* combination is used to produce negation.
- Since the LHS of the neck cannot contain any operator, *A → ~B* is implemented as

B :- A, !, Fail.

Prolog and Himalayan Club example

- *(Zohar Manna, 1974):*
  - Problem: A, B and C belong to the Himalayan club. Every member in the club is either a mountain climber or a skier or both. A likes whatever B dislikes and dislikes whatever B likes. A likes rain and snow. No mountain climber likes rain. Every skier likes snow. *Is there a member who is a mountain climber and not a skier?*
- Given knowledge has:
  - Facts
  - Rules

A syntactically wrong prolog program!

1. belong(a).
2. belong(b).
3. belong(c).
4. mc(X);sk(X) :- belong(X) /* X is a mountain climber or skier or both if X is a member; operators NOT allowed in the head of a horn clause; hence wrong*/
5. like(X, snow) :- sk(X). /*all skiers like snow*/
6. \+like(X, rain) :- mc(X). /*no mountain climber likes rain; \+ is the not operator; negation by failure; wrong clause*/
7. \+like(a, X) :- like(b,X). /* a dislikes whatever b likes*/
8. like(a, X) :- \+like(b,X). /* a dislikes whatever b likes*/
9. like(a,rain).
10. like(a,snow).

?- belong(X),mc(X),\+sk(X).

Correct (?) Prolog Program

```
belong(a).
belong(b).
belong(c).
belong(X):-\+mc(X),\+sk(X), !, fail.
belong(X).
like(a,rain).
like(a,snow).
like(a,X) :- \+ like(b,X).
like(b,X) :- like(a,X),!,fail.
like(b,X).
mc(X):-like(X,rain),!,fail.
mc(X).
sk(X):- \+like(X,snow),!,fail.
sk(X).
g(X):-belong(X),mc(X),\+sk(X),!. /*without this cut, Prolog will look for next answer
    on being given ';' and return 'c' which is wrong*/
```

Make and Break

Fundamental to Prolog

Prolog examples using making and breaking lists

```
%incrementing the elements of a list to produce another list
incr1([],[]).
incr1([H1|T1],[H2|T2]) :- H2 is H1+1, incr1(T1,T2).

%appending two lists; (append(L1,L2,L3) is a built is
function in Prolog)
append1([],L,L).
append1([H|L1],L2,[H|L3]):- append1(L1,L2,L3).


%reverse of a list (reverse(L1,L2) is a built in function
reverse1([],[]).
reverse1([H|T],L):- reverse1(T,L1),append1(L1,[H],L).
```

Remove duplicates

Problem: to remove duplicates from a list

```
rem_dup([],[]).
rem_dup([H|T],L) :- member(H,T), !, rem_dup(T,L).
rem_dup([H|T],[H|L1]) :- rem_dup(T,L1).
```

Note: The cut ! in the second clause needed, since after succeeding at member(H,T), the 3rd clause should not be tried even if rem_dup(T,L) fails, which prolog will otherwise do.

Member (membership in a list)

```
member(X,[X|_]).
member(X,[_|L]):- member(X,L).
```

Union (lists contain unique elements)

```
union([],Z,Z).
union([X|Y],Z,W):-
   member(X,Z),!,union(Y,Z,W).
union([X|Y],Z,[X|W]):- union(Y,Z,W).
```

Intersection (lists contain unique elements)

```
intersection([],Z,[]).
intersection([X|Y],Z,[X|W]):-
   member(X,Z),!,intersection(Y,Z,W).
intersection([X|Y],Z,W):-
   intersection(Y,Z,W).
```

Prolog Programs are close to Natural Language

Important Prolog Predicate:

member(e, L) / true if e is an element of list L*

member(e,[e|L1). / e is member of any list which it starts*

*member(e,[_|L1]):- member(e,L1) /*otherwise e is member of a list if the tail of the list contains e*

Contrast this with:

P.T.O.

Prolog Programs are close to Natural Language, C programs are not

```
For (i=0;i<length(L);i++){
    if (e==a[i])
        break(); /*e found in a[]
}
If (i<length(L){
    success(e,a); /*print location where e appears in
        a[]/*
else
    failure();
}
```

What is *i* doing here? Is it natural to our thinking?

Machine should ascend to the level of man

- A prolog program is an example of reduced man-machine gap, unlike a C program
- That said, a very large number of programs far outnumbering prolog programs gets written in C
- The demand of practicality many times incompatible with the elegance of ideality
- But the ideal should nevertheless be striven for

The “working” Himalayan club problem

Himalayan club

```
belong(a).
belong(b).
belong(c).

belong(X):-notmc(X),notsk(X),!, fail. /*contraposition to have horn clause
belong(X).

like(a,rain).
like(a,snow).
like(a,X) :- dislike(b,X).
like(b,X) :- like(a,X),!,fail.
like(b,X).

mc(X):-like(X,rain),!,fail.
mc(X).
notsk(X):- dislike(X,snow). /*contraposition to have horn clause
notmc(X):- mc(X),!,fail.
notmc(X).

dislike(P,Q):- like(P,Q),!,fail.
dislike(P,Q).

g(X):-belong(X),mc(X),notsk(X),!.
```