CS344: Introduction to Artificial Intelligence (associated lab: CS386)

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Lecture 27, 28: Prolog

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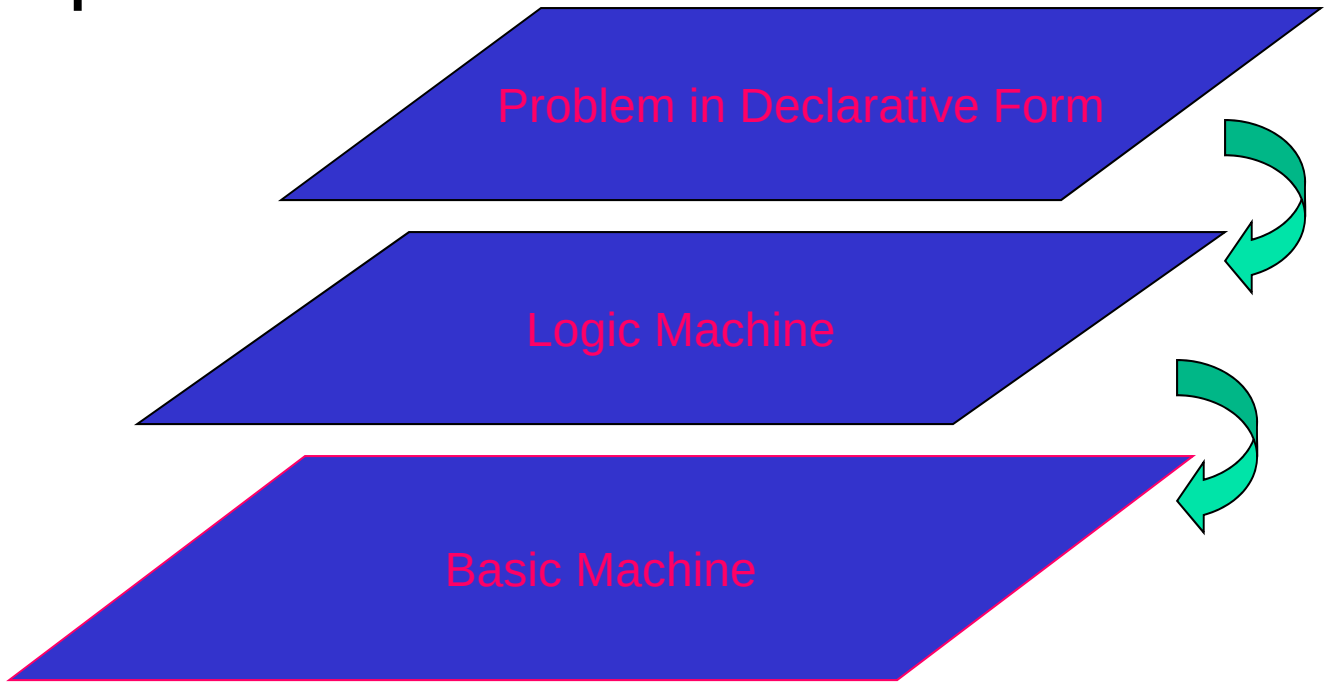
Introduction

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



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:

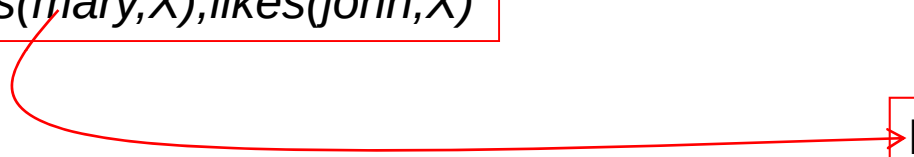
X=flowers and wait
;
mary
;
no

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)

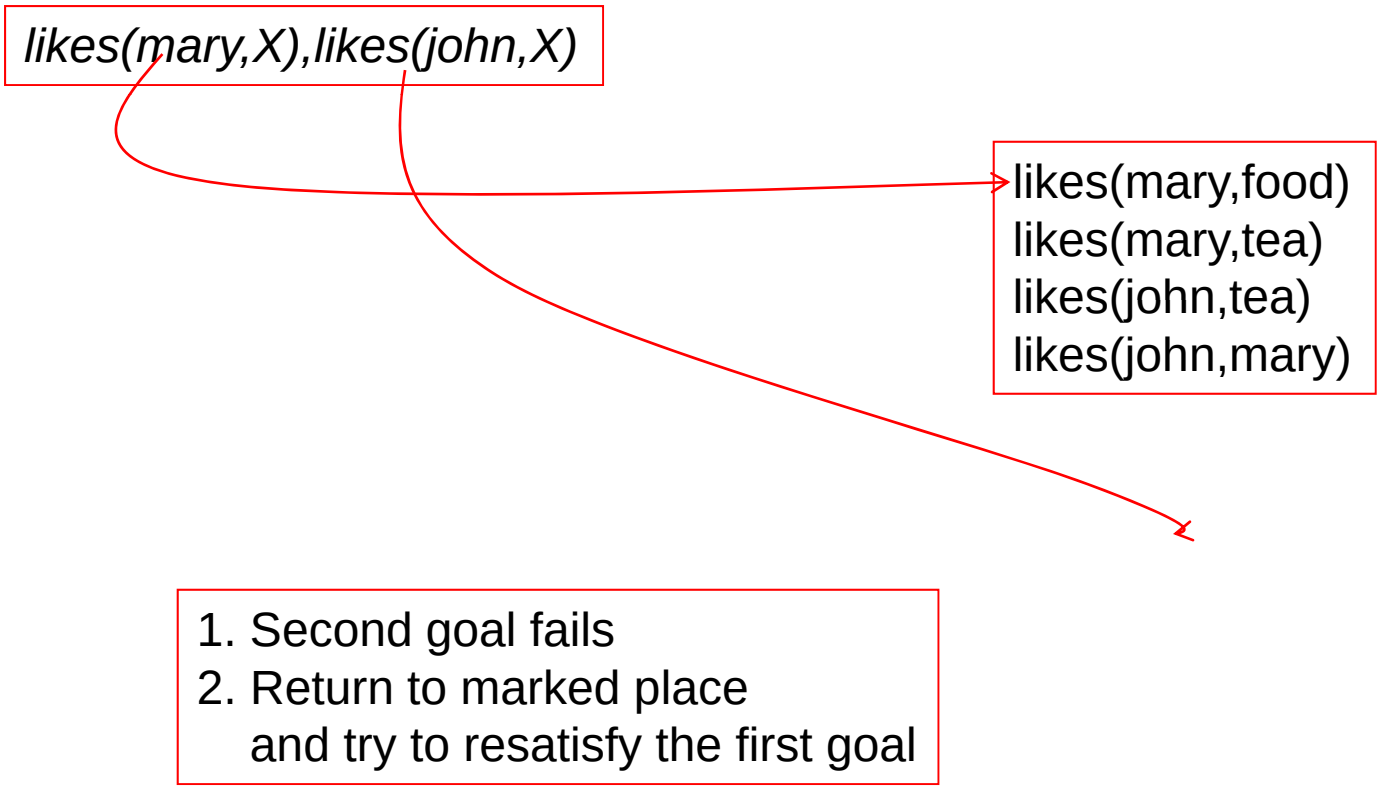


likes(mary,food)
likes(mary,tea)
likes(john,tea)
likes(john,mary)

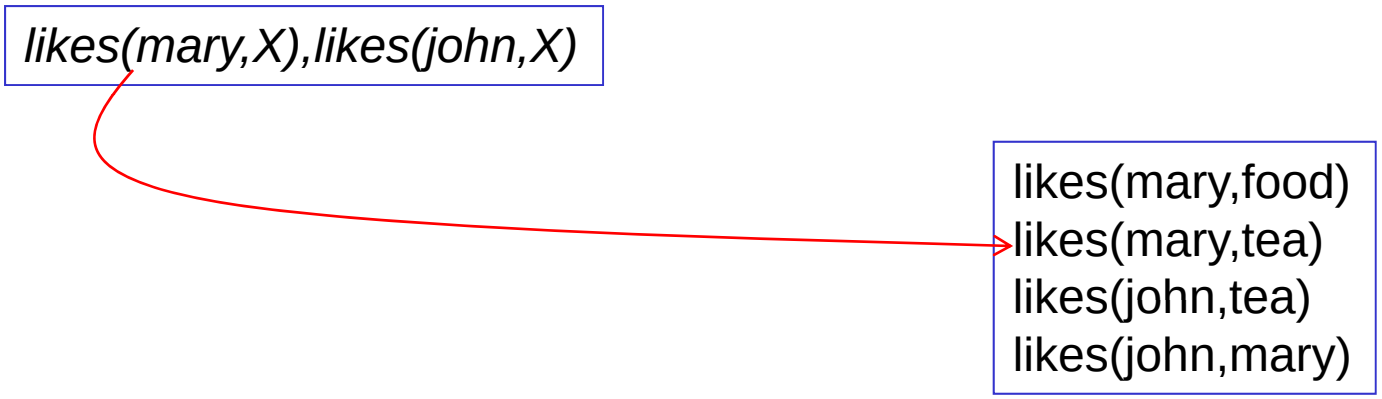
1. First goal succeeds. *X=food*
2. Satisfy *likes(john,food)*

Backtracking *(continued)*

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

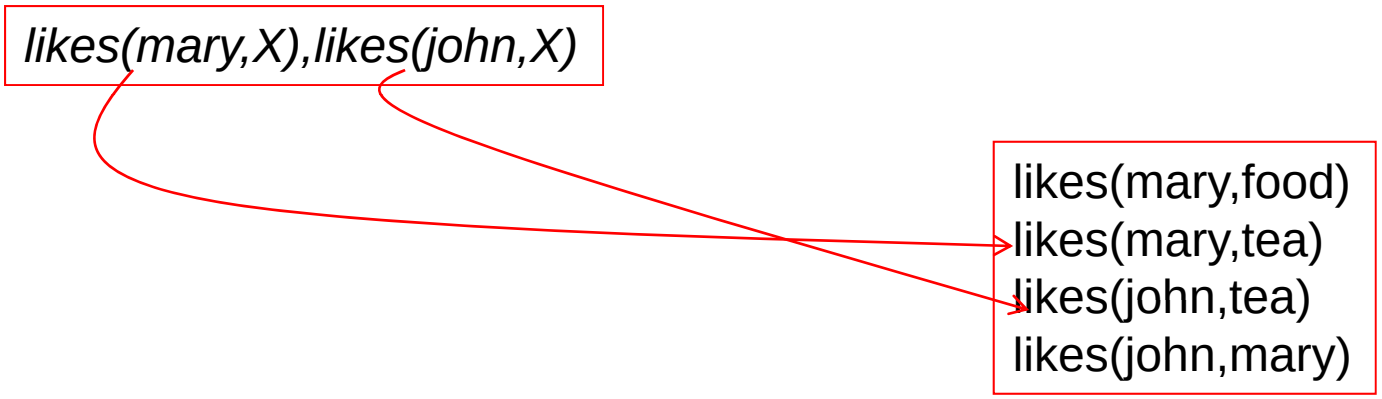


Backtracking *(continued)*



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

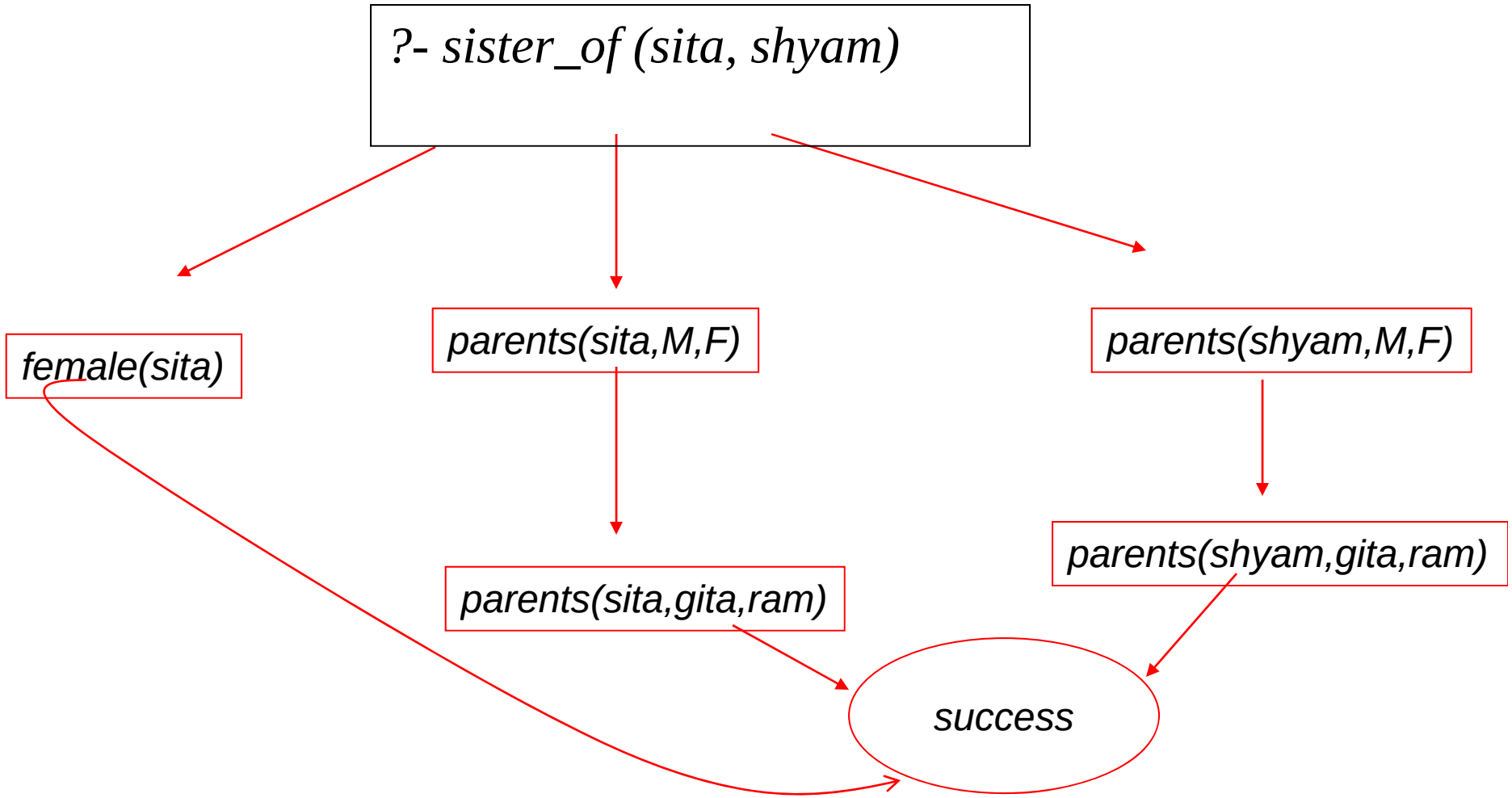
sister_of (X,Y):- female (X),
parents (X, M, F),
parents (Y, M, F).

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

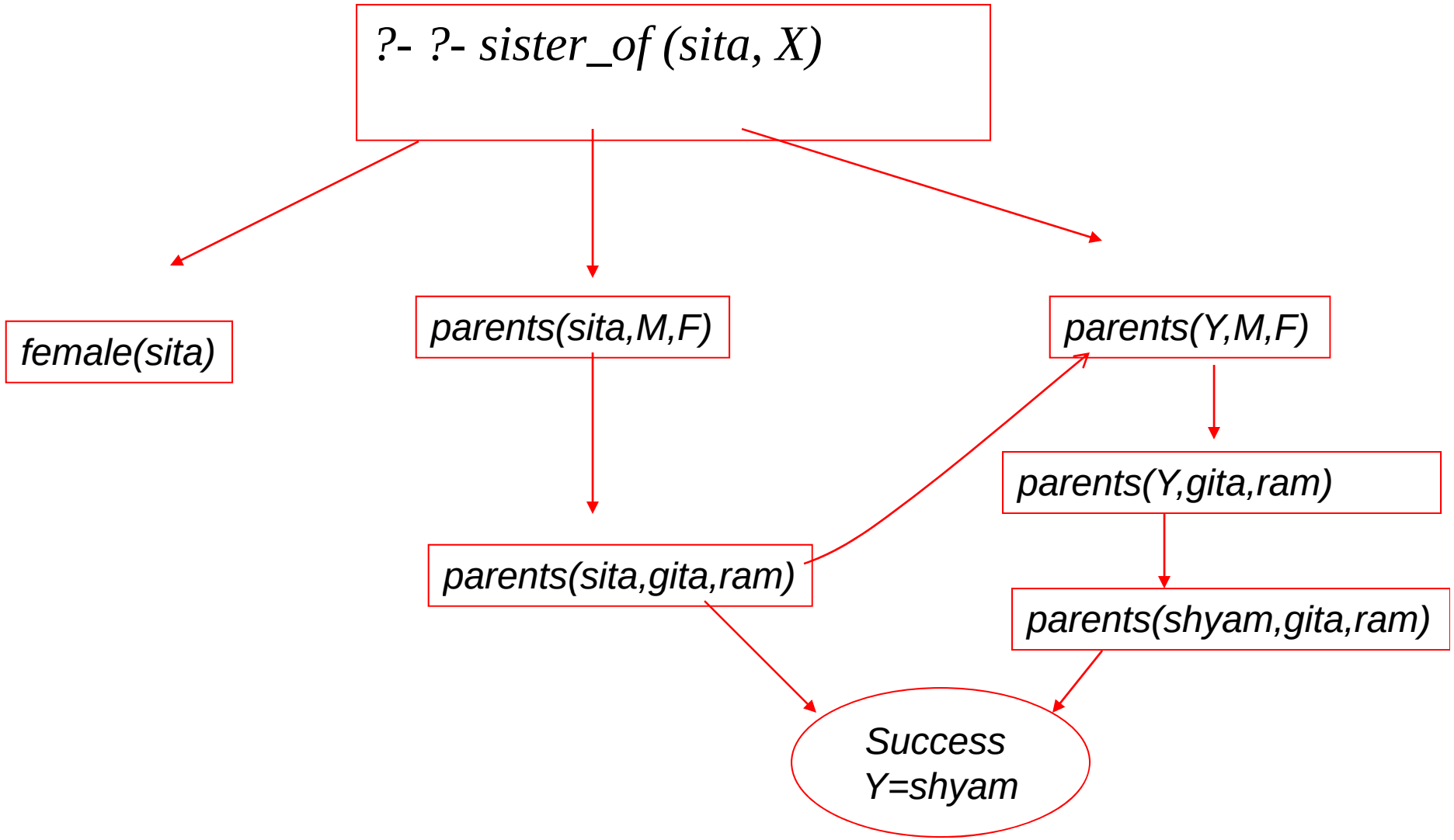
Question Answering in presence of *rules*

- 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?*



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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

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*/
```

Himalayan club problem: working vesion

```
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),!.
```