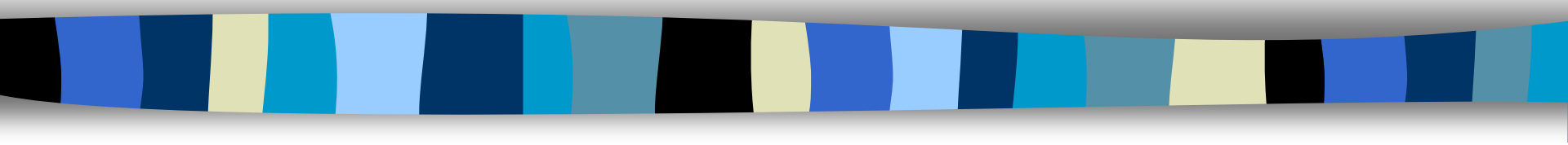
Meta Level Programming in Prolog



Meta Logical Predicates

- Meta predicates are those which are programmed using user's and Prolog system's defined predicates.
- Meta program treats other program as data.
- Meta rules enhance general purpose control structures and are not a control structures by themselves.
- We will describe some of important and useful meta predicates.
- These may be implementation specific

Basic predicates

var(X): succeeds if X is a variable

nonvar(X):succeeds if X is not a variable.

number(X): succeeds if X is integer or real.

atomic(X): succeeds if X is a number, symbol or string.

integer(X): succeeds if X is integer.

compound(X): succeeds if X is a compound term. A compound term is of the form $f(t_1, \ldots, t_n)$, where f is n-place functor and $t_1, \ldots, t_n$ are simple terms. Simple term in Prolog is either a constant or a variable.

Functor and Arg predicates

functor(Term, F, N):succeeds if *Term* is a compound term with name of function as F having arity N.

- Examples
  - **functor(max(4,5), F, N)** succeeds with bindings F = max and N = 2
  - **functor(father(john, mike), father, N)** succeeds with N = 2
  - **functor(T, min, 2)** succeeds and T is unified with min(_, _)
  - **functor (f (4, 5, 6), f, 3)** succeeds & functor(g(4), g, 2) fails.

arg(N, Term, Arg): succeeds by unifying N^{th} argument of *Term* with *Arg*.

- Examples
  - arg(1, f(ram, shyam), ram) succeeds.
  - arg(2, f(ram, shyam), A) succeeds with A = shyam.

Cont…

- Note that predicate *functor* and *arg* fail if goal does not unify with appropriate fact or if the type restrictions are violated.

Term = . . [F|L] *:* succeeds if F is unified with function name of *Term* and L is unified with the list of arguments of F.

- Examples
  - father(ram, shyam) =..[F | L] succeeds with bindings F = father and L = [ram, shyam].
  - father(ram, shyam) =..[father | [ram,shyam]] succeeds.

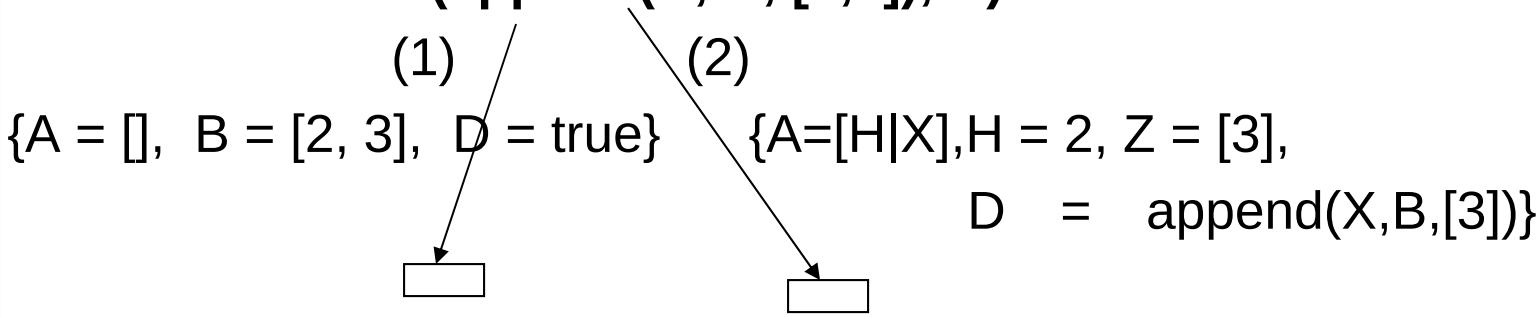
Clause predicate

clause(Head, Body): succeeds, if *Head* and *Body* are matched with the head and body of an existing rule in the Prolog program. It is very important and useful while developing interpreters.

append([], X, X). **(1)**

append([H|X], Y, [H|Z] :- append(X, Y, Z). **(2)**

?- clause(append(A, B, [2,3]), D).



Call predicate

call(X): succeeds if goal X succeeds and fails if goal **X** fails.

- At the first glance, this predicate seems to be redundant because effect of, for example, *call(member(3, L))* and *member(3, L)* is same.
- It is not same.
  - When we have to construct goal X dynamically during execution of a program, then we *call* predicate with variable goal as an argument is used whose value keeps on changing at run time.
- The *call* predicate is also widely used while writing various interpreters.

Findall predicate

findall(X, G, L):succeeds by constructing a list L of all the objects X for which the goal G is satisfied.

- Examples

  ?- findall(X, son(X, john), L) - L is a list of all X such that son(X, john) is satisfied.

  ?- findall(X, son(mike, john), L) -fails

  ?- findall([X,Y], son(X, Y), L) - L is a list of list [X ,Y] such that son(X,Y) is satisfied.

Input / Output predicates

- Input/output predicates are not part of pure prolog.
- *read(X):* succeeds by getting the value of X from terminal.
- *write(X):* succeeds by printing the value of X on terminal.
- *nl :*succeeds by creating a new line.
- *writeln(X):* succeeds after writing X on terminal and creating new line.
- *listing:*succeeds by listing all the predicates in the current database.

Prolog Program

Example: Define a predicate *ground(X)* which succeeds if X is a ground term (i.e., a term without variables).

Solution: We can write program for ground(X) in Prolog using some system defined predicates as:

```
ground(T) :-   nonvar(T), atomic(T),!.

ground(T) :-  nonvar(T), compound(T),
              functor(T,_,N), ground1(T, N).

ground1(T, N) :- N > 0, arg(N, T, A),  ground(A),
              N1 is N –1,ground1(T, N1).

ground1(T, 0).
```

Query: ?- ground(4) and ?- ground(f(2, 3)) succeeds

Interactive Interpreter for Prolog

- One can write interactive meta interpreter that accepts commands from terminal and executes them using Prolog interpreter and terminates its execution when 'exit' command is given.

```
interpreter :- interpreter_prompt, read(Goal),
        interpreter(Goal).                          (1)
interpreter(exit) :- !.                             (2)
interpreter(Goal):- ground(Goal), !,
        solve_ground(Goal), interpreter.            (3)
interpreter(Goal) :- solve(Goal), interpreter.      (4)
interpreter_prompt :- writeln('Next Command').
```

Interpreter – Cont…

```
solve_ground(Goal) :- call(Goal), !, writeln('Yes').      (5)
solve_ground(Goal)  :- writeln('No').                     (6)
solve(Goal) :- call(Goal), writeln(Goal), fail.           (7)
solve(Goal) :- writeln('No more Solutions').              (8)
```

- **Interpretation of the rules:**
  - Rule(1) displays message 'Next Command' and asks user to input the *Goal* to be interpreted. The Goal is passed as an argument of predicate *interpreter*.
  - Rule(2) states that if Goal is *exit*, then quit the program.
  - Rule(3) checks whether *Goal* is ground or not. If *Goal* is ground, then solve ground goal using rules (5) and (6) otherwise rule(4) is tried and *Goal* is solved using rules (7) and (8). The predicate *interpreter* is again initiated and the process repeats interaction with user till 'exit' goal is given.

Meta Interpreter

- *Meta interpreter* for a language is an interpreter or a meta program that is written in a language itself. *Meta program* treats other programs as data.
- Prolog has a powerful features for writing meta programs because Prolog treats program and data both as terms.
- One can write meta interpreters for various applications.

Applications of Interpreter

- Following are various applications for which meta interpreters can be developed.
  - exploring different execution strategies based on breadth first, combination of depth first and breadth first searches etc.
  - generating proof trees
  - developing expert system shell, editor etc.
  - debugging programs i.e., to identifying errors in a program. (Bug may be of any type viz., program is returning false result, fails to return some true solution or fails to terminate etc.)

Meta Interpreter for Prolog Language

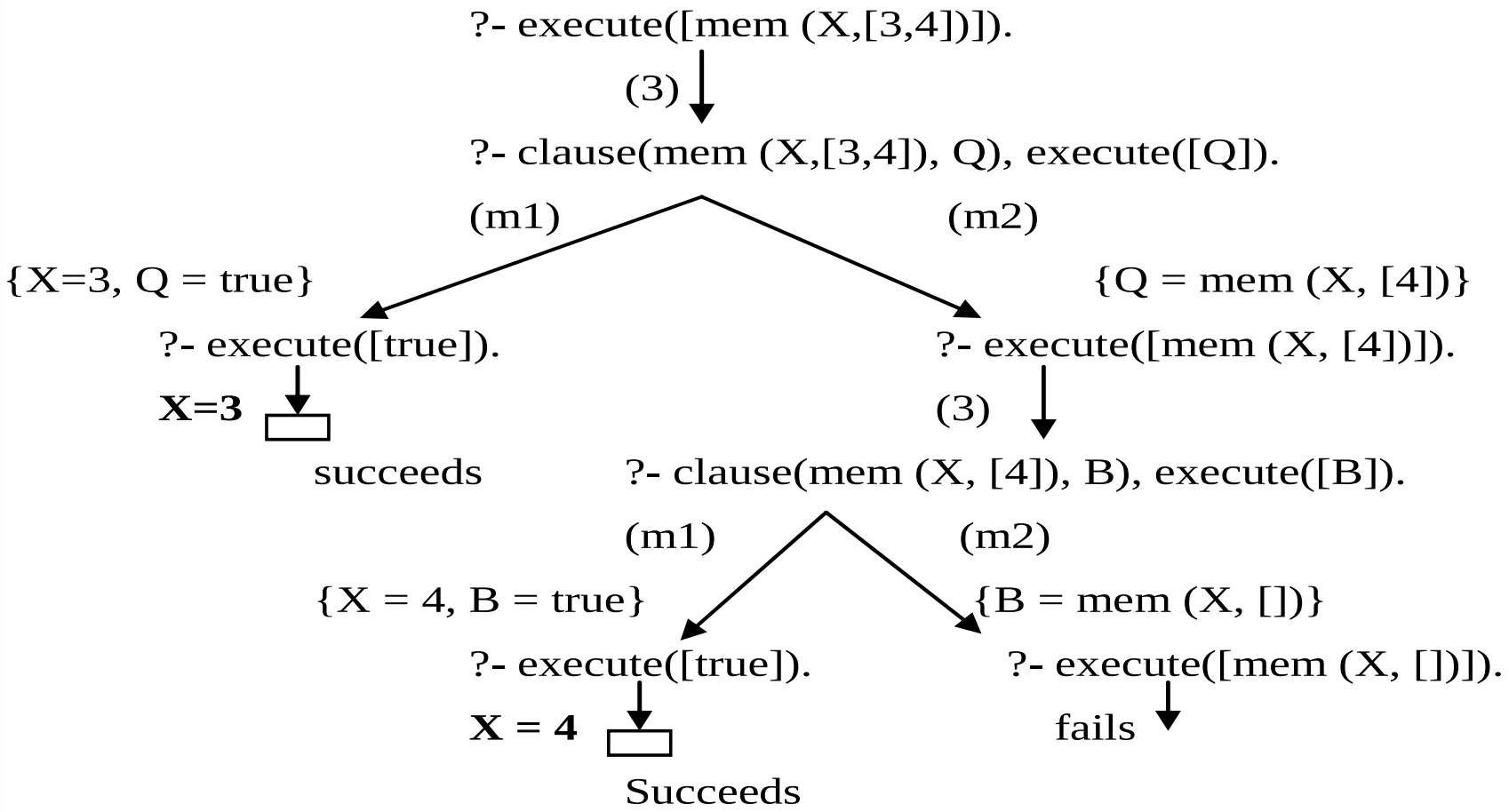
- Let us write simple meta interpreter that simulates the computational model of Prolog program using depth first (DF) control strategy.

  /* execute(G) – succeeds if G succeeds with respect to program being interpreted. */

```
execute([true]) :- !.                                  (1)
execute([P]) :- clause(P, Body), execute([Body]). (2)
execute([P|Q])  :- execute(P), execute(Q).          (3)
```

Query for Meta Interpreter

- Query: **?- execute([mem (X,[3,4])]).**



Answer: X = 3; X = 4

Interpreter for Building Proof Trees

- Add an extra parameter for storing proof tree.
- The basic relation is *gen(G, Proof),* where *Proof* is a proof tree for solving a goal G.
- Let us represent proof trees by a structure *(G $\Rightarrow$ Proof),* where *Proof* is a conjunction of the branches proving the goal G.
- It must be noted that 'G' has to be ground.

Cont…

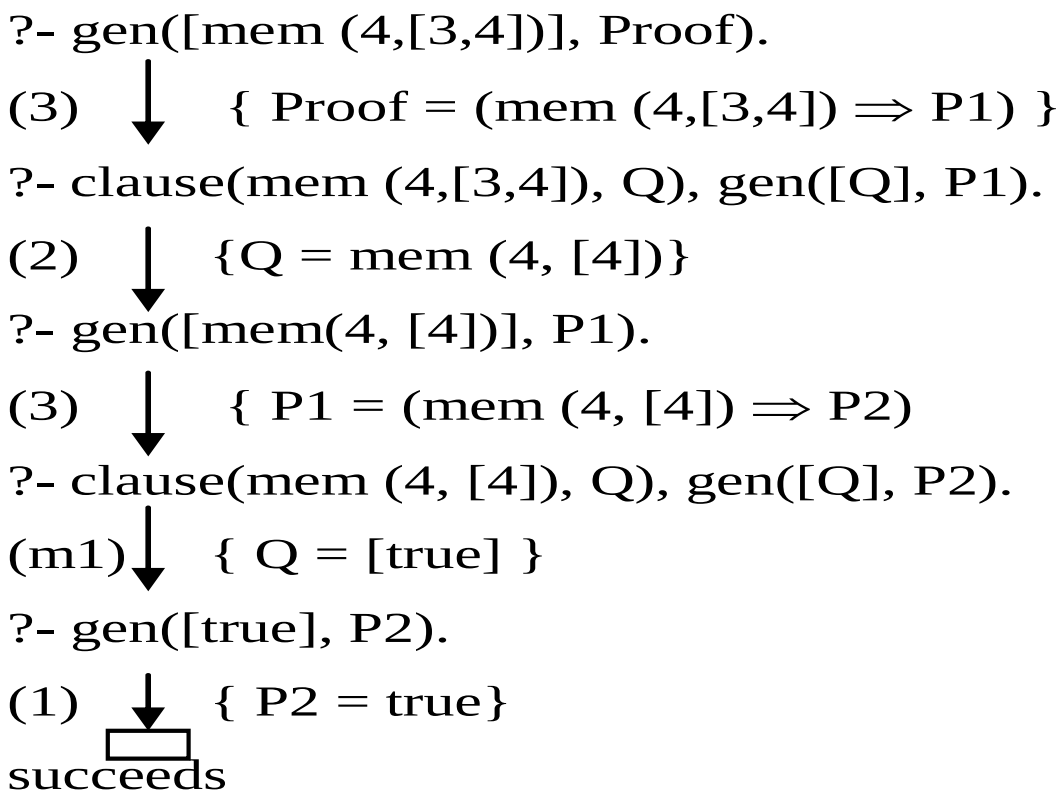
/* gen(G, Proof) - succeeds if G succeeds with respect to program being interpreted and Proof is unified with its proof structure. */

```
gen([true], true).                                          (1)
gen([G], (G ⇒ P)) :- clause(G, Body), gen([Body], P).       (2)
gen([G1|T], (P1, T1))   :- gen(G1, P1), gen(T, T1).         (3)
```

- **Interpretation of above rules:**
  - Rule (1) states that if a goal is true, then proof tree is represented by an atom **true**.
  - Rule (2) builds an actual proof tree structure (G ⇒ P) for the goal G, where **P** is a proof recursively built by solving the body of G.
  - Rule (3) states that a proof tree of a conjunctive goals stored in list [G1|T] is a conjunction of the proof trees of P1 and T1 as (P1, T1).

Cont…

- Goal: ?- gen([mem(4,[3,4])], Proof).
- Proof = (mem(4, [3,4]) ⇒ (mem(4,[4]) ⇒ true))



Proof = (mem (4,[3,4]) ⇒ (mem (4, [4]) ⇒ true))

Iteration Looping

- Iterative loops are important facility and can simulate them in Prolog easily.
- The predicate ***repeat*** (user defined predicate) creates a loop (similar to the loops in imperative programming language)
- Even though it is not a system defined predicate but is quite useful predicate and is defined as follows:

```
repeat.
repeat :- repeat.
```

Login Module – asking password till it is correct

```
login           :-   getdata(_, _), write("You are logged on "), nl.          (1)
login           :-   repeat, write("Sorry, you are not permitted"), nl,       (2)
                     write("Try again:  "), getdata(_, _),
                     write("You are now logged on"), nl.
getdata(N, P)   :-   write("Enter your login name: "),
                     readln(N), nl
                     write("Enter your password:  "),
                     readln(P), nl, user(N, P).                               (3)

user(john, john1).
user(mike, mike1).
user(mary, mary1).
user(jack, jack1).
```

Higher Order Predicate

- Define a predicate which checks whether some predicate S succeeds for all possible variables that satisfy some other predicate R.
- In other words, we want to say that S never fails when R has succeeded previously.

```
for_all(R, S) :- not(failure_exist(R, S)).
failure_exist (R, S) :-  call(R), not(call(S)).
```

- This is basically a universal quantification of S with respect to R i.e., $\forall$(R) S.
  - Predicate defined above is an example of *second order predicate* where quantification is over predicate and not on variables.