Experiment No.8
Implementation of Unification Algorithm in Prolog.
Date of Performance:
Date of Submission:

Aim: Implementation of unification algorithm in Prolog.

Objective: To study about how to use AI Programming language (Prolog) for developing inferencing engine using Unification process and knowledge declared in Prolog.

Requirement: Turbo Prolog 2.0 or above / Windows Prolog.

Theory:

Unification is a process of making two different logical atomic expressions identical by finding a substitution. It takes two literals as input and makes them identical using substitution. Let
Ψ1 and Ψ2 be two atomic sentences and be a unifier such that, Ψ1 = Ψ2 , then it can be expressed as UNIFY(Ψ1, Ψ2).

For example, if one term is f(X, Y) and the second is f(g(Y, a), h(a)) (where upper case names are variables and lower case are constants) then the two terms can be unified by identifying X with g(h(a), a) and Y with h(a) making both terms look like f(g(h(a), a), h(a)). The unification can be represented by a pair of substitutions {X g(h(a), a)} and {Y
h(a)}.

Unification Algorithm:

```
FUNCTION unify( t1, t2 ) RETURNS (unifiable : BOOLEAN, sigma
: SUBSTITUTION) BEGIN
  IF t1 OR t2 is a variable
    THEN BEGIN
      let x be the variable and let t be the other term
      IF x == t THEN (unifiable, sigma) := (TRUE,
      NULL_SUBSTITUTION); ELSE IF x occurs in t THEN
      unifiable == FALSE;
      ELSE (unifiable, sigma) := (TRUE,
    {x <- t}); END
  ELSE
    BEGIN
      assume t1 == f(x1,    , xn) and t2 == g(y1,
      ... ym) IF f != g OR m != n THEN
      unifiable = FALSE; ELSE
        BEGI
          N k
          := 0;
          unifiable := TRUE;
          sigma := NULL_SUBSTITUTION;
          WHILE k < m AND
            unifiable DO BEGIN
```

```
        k := k + 1;
        (unifiable, tau) := unify( sigma( xk ), sigma(
        yk ) ); IF unifiable THEN sigma := compose(
        tau, sigma );
      EN
    D
    END

  END
 RETURN (unifiable,
sigma); END
```

Implementation Notes

1. To extract the name of a functor and its arguments, you may use the special built-in rules **functor/3**, **arg/3**, and "**=..**" . (Prolog allows overloading of rule names; the notation foo/2 denotes the foo rule that takes two arguments.) They are used as follows:
   1. functor(f(x,y),F,N) ==> F=f
   and N=2 2. arg(1,f(x,y),A) ==>
   A=x 3. f(x,y) =.. L ==> L = [f,x,y]

   Incidentally, an atom is treated as a 0-argument functor.

2. As an option, you may encode functors to be unified as lists in prefix notation. For example, f(x) would be encoded as [f, x]. For a more complicated example, the following function:

   f(3, g(x))

   would be encoded as:
   [f, 3, [g, x]]
   This notation doesn't look as nice, but it might make the implementation simpler.

3. You must choose how to distinguish variables from atoms in the expressions you are matching. For example, if **a** and **b** are constants, then unification of **a** and **b** should fail. However, if **A** and **B** are both variables, then unification should succeed, with the single substitution **A** -> **B**. A reasonable choice is that t, u, v, w, x, y, and z are variables, while all other letters are constants. In any case, please document your choice.

Testing Your Unifier

Here are some tests you should try before stopping work on your unifier. Harder tests are towards the bottom.

1. Two atoms should unify iff both atoms are the same. Two different atoms should fail to unify.
2. A variable should unify with anything that does not contain that variable. For example, x should unify with f(g(y),3,(h(a,z))), but not with f(x).
3. A variable should unify with itself. For example, x should unify with x.
4. Your algorithm should handle cases where a variable appears in multiple locations

   For example, all of the following should unify:
   - f(x,x) = f(a,a)
   - f(x,g(x)) = f(a, g(x))
   - f(x, y) = f(y, x)

   And the following should NOTunify:

   - f(x,x) = f(a,b)
   - f(x,g(x)) = g(a, g(b))
5. When unifying functors, all arguments should unify. For example, g(h(1,2,3,4), 5) does not unify with g(h(1,8,3,4),5).
6. There are plenty of other things to try. These are just some examples to start.

Unification in Prolog:

The way in which Prolog matches two terms is called unification. The idea is similar to that of unification in logic: we have two terms and we want to see if they can be made to represent the same structure. For example, we might have in our database the single Polog clause:

parent(alan,   clive).

and give the query:

|?- parent(X,Y).

We would expect X to be instantiated to alan and Y to be instantiated to clive when the query succeeds. We would say that the term parent(X,Y) unifies with the term parent(alan, clive) with X bound to alan and Y bound to clive. The unification algorithm in Prolog is roughly this:

df:un Given two terms and which are to be unified:

If and are constants (i.e. atoms or numbers) then if they are the same succeed. Otherwise fail.

If is a variable then instantiate to . Otherwise, If is a

variable then instantiate to .

Otherwise, if and are complex terms with the same arity (number of arguments), find the principal functor of and principal functor of . If these are the same, then take the ordered set of arguments of of and the ordered set of arguments of . For each pair of arguments and from the same position in the term, must unify with . Otherwise fail.
For example: applying this procedure to unify foo(a,X) with foo(Y,b) we get:

foo(a,X) and foo(Y,b) are complex terms with the same

arity (2). The principal functor of both terms is foo.

The arguments (in order) of foo(a,X) are a

and X. The arguments (in order) of foo(Y,b)

are Y and b. So a and Y must unify , and X

and b must unify. Y is a variable so we

instantiate Y to a.

X is a variable so we instantiate X to b.

The resulting term, after unification is foo(a,b).

The built in Prolog operator '=' can be used to unify two terms. Below are some examples of its use. Annotations are between ** symbols.

| ?- a = a. ** Two identical atoms

unify ** yes

| ?- a = b. ** Atoms don't unify if they

aren't identical ** no

| ?- X = a. ** Unification instantiates a variable to

an atom ** X=a

yes

| ?- X = Y. ** Unification binds two differently named

variables ** X=_125451 ** to a single, unique

variable name **

Y=_125451

yes

| ?- foo(a,b) = foo(a,b). ** Two identical complex terms

unify ** yes

| ?- foo(a,b) = foo(X,Y).** Two complex terms unify if they

are ** X=a ** of the same arity, have the same

principal**

Y=b ** functor and their

arguments unify ** yes

| ?- foo(a,Y) = foo(X,b).** Instantiation of variables may

occur ** Y=b ** in either of the terms to be unified

** X=

a yes

| ?- foo(a,b) = foo(X,X).** In this case there is no

unification ** no ** because foo(X,X) must have the same

**

** 1st and 2nd arguments **

| ?- 2*3+4 = X+Y. ** The term 2*3+4 has principal

functor + ** X=2*3 ** and therefore unifies

with X+Y with X instantiated** Y=4** to 2*3 and Y instantiated to 4 **

yes

| ?- [a,b,c] = [X,Y,Z]. ** Lists unify just like other

terms ** X=a

Y=

b

Z=

c

yes

| ?- [a,b,c] = [X|Y]. ** Unification using the '|' symbol can

be used ** X=a ** to find the head element, X,

and tail list, Y, ** Y=[b,c] ** of a list **

yes

| ?- [a,b,c] = [X,Y|Z]. ** Unification on lists doesn't have

to be ** X=a ** restricted to finding the first head

element **

Y=b ** In this case we find the 1st and 2nd

elements ** Z=[c] ** (X and Y) and then the

tail list (Z) **

yes

| ?- [a,b,c] = [X,Y,Z|T]. ** This is a similar example but

here ** X=a ** the first 3 elements are unified

with

**

Y=b ** variables X, Y and Z, leaving the **

Z=c ** tail, T, as an empty list

[] ** T=[]

Yes

| ?- [a,b,c] = [a|[b|[c|[]]]]. ** Prolog is quite happy to

unify these ** yes** because they are just notational **

** variants of the same Prolog term **

Conclusion:

In conclusion, the implementation of the Unification Algorithm in Prolog demonstrates Prolog's core strength in logic programming. Unification is a fundamental mechanism that matches terms, variables, and structures during the evaluation of queries. By using unification, Prolog efficiently resolves logical expressions, enabling the development of powerful inference engines. This algorithm is crucial for solving problems in AI and symbolic computation, showcasing how Prolog uses a declarative approach to problem-solving by unifying terms to deduce logical conclusions based on given facts and rules.