1st Class

Principles of Artificial Intelligence

مبادئ الذكاء الاصطناعي

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Lecture one:

Contents:
1. Introduction to prolog language
2. Some of prolog language characteristic
3. Prolog language uses
4. Prolog language component
   4.1 fact
   4.2 rule
   4.3 questions
5. Variables

1. Introduction to prolog language

Prolog: is a computer programming language that is used for solving problems involves objects and relationships between objects.

Example:

“John owns the book”

Owens (john,book) relationship(object1,object2)

The relationship has a specific order, johns own the book, but the book dose not owns john, and this relationship and its representation above called fact.

◆ we are using rule to describe relationship between objects.
Example: the rule” two people are sisters if they are both female and have the same parents”

1. Tell us something about what it means to be sisters.
2. Tell us how to find if two people are sisters, simply: check to see if they are both female have the same parents.

Component of computer programming in prolog
Computer programming in prolog consist of:
1. Declaring some facts about objects and their relationships.
2. Defining some rules about objects and their relationships.
3. Asking questions about objects and their relationships.

If we write our rule about sisters, we could then ask the questions whether Mary and Jane are sisters.

Prolog would search through what we told it about Mary and Jane, and come back with the answer Yes or No, depending on what we told it earlier.

So, we can consider prolog as a storehouse of facts and rules, and it uses the facts and rules to answer questions.

Prolog is a conversational language. Which means you and the computer carry out a kind of conversation, typing a letter from keyboard and displaying it at the screen, prolog work like this manner, prolog will wait for you to type in facts and rules that certain to the problem you want to solve? Then if you ask the right kind of questions prolog will work out the answers and show them.

2. Some of prolog language characteristics:
1. We can solve a particular problem using prolog in less no of line of code.
2. It’s an important tool to develop AI application and ES.
3. Prolog program consist of fact and rule to solve the problem and the output is all possible answer to the problem.
4. Prolog language is a descriptive language use the inference depend on fact and rule we submit to get all possible answer while in other language the programmer must tell the computer on how to reach the solution by gives the instruction step by step.
3. **Prolog language uses:**

1. Construct NLI (Natural Language Interface).
2. Translate language.
3. Constructor symbolic manipulation language packages.
4. Implement powerfully database application.
5. Construct expert system programs.

4. **Prolog language component**

4.1 **Facts**

Is the mechanism for representing knowledge in the program.

Syntax of fact:

1. The name of all relationship and objects must begin with a lower-case letter, for example `likes (john, mary)`.
2. The relationship is written first, and the objects are written separated by commas, and enclosed by a pair of round brackets.

Like `(john, mary)`

3. The full stop character ‘.’ Must come at the end of fact.

**Example:**

Gold is valuable `valuable (gold)`.

Jane is female `female (jane)`.

John owns gold `owns (johns, gold)`.

Johns is the father of Mary `father (john, marry)`.

The names of objects that are enclosed within the round brackets are called arguments. And the name of relationship called predicates.

Relationship has arbitrary number of argument. If we want to define predicate called play, were we mention two players and a game they play with each other, it can be:

Play `(john, Mary, football)`.
In prolog the collection of facts is called database.

4.2 Rules

Rules are used when you want to say that a fact depends on a group of other facts, and we use the following syntax:
1. One fact represents the head (conclusion).
2. The word if used after the head and represented as “:-’.
3. One or more fact represents the requirement (condition).

The syntax of if statement
If (condition) then (conclusion)
[Conclusion: - condition]   rule

Example:
I use the umbrella if there is rain
   Conclusion         condition

Represent both as fact like:
Wheatar (rain).
Use (umbrella)
Use (Iam, umbrella):-whether (rain).

4.3 Questions

Question used to ask about facts and rules.

Question look like the fact and written under the goal program section while fact and rule written under clauses section.

Example: for the following fact owns (mary, book).
We can ask: does mary own the book in the following manner:

Goal:
Owens (mary,book)

When Q is asked in prolog, it will search through the database you typed before, it look for facts that match the fact in the question.
Two fact matches if their predicates are the same and their corresponding argument are the same, if prolog finds a fact that matches the question, prolog will respond with Yes, otherwise the answer is No.

5. Variables

If we want to get more interest information about fact or rule, we can use variable to get more than Yes/No answer.

*variables do not name a particular object but stand for object that we cannot name.
*variable name must begin with capital letter.
*using variable we can get all possible answer about a particular fact or rule.
*variable can be either bound or not bound.

Variable is bound when there is an object that the variable stands for. The variable is not bound when what the variable stand for is not yet known.

Example:

Fact
Like (john, mary).
Like (john, flower).
Like (ali, mary).

Question:

1. Like (john, X)
   X= mary
   X = flower
2. like(X, mary)
   X= john
3. Like(X, Y)
There are three type of question in the goal summarized as follow:

1. Asking with constant: prolog matching and return Yes/No answer.
2. Asking with constant and variable: prolog matching and produce result for the Variable.
3. Asking with variable: prolog produce result.

Example:

Age(a,10).
Age(b,20).
Age(c,30).

Goal:
1. Age(a,X). anS: X=10 Type2
2. age(X,20). Ans: X=b Type2
3. age(X,Y). ans: X=a Y=10, X=b Y=20, X=c Y=30. Type3
4. Age(_,X). ans: X=10, X=20, X=30. ‘_’ means don’t care Type3
5. Age(_,__). Ans: Yes Type1
H.W:

Convert the following paragraph into fact or rule:

1. A person may steal something if the person is a thief and he likes the
   thing and the thing is valuable.

2. Bob likes all kind of game. Football is a game. Anything anyone plays
   and not killed by is a game.
Lecture two:

Propositional logic

The Propositional calculus

• Truth symbols: true, false
• Propositional symbols: P, Q, S, ... (Atomic sentences)
• Wrapping parentheses: ( … )
• Sentences are combined by connectives:
  \[ \land \text{...and [conjunction]} \]
  \[ \lor \text{...or [disjunction]} \]
  \[ \Rightarrow \text{...implies [implication / conditional]} \]
  \[ \Leftrightarrow \text{.is equivalent [biconditional]} \]
  \[ \neg \text{...not [negation]} \]

Examples:
Ali is a brave man
This car has 4 wheels
If weather is cold then it is winter

\[
\begin{array}{ccc}
P & Q \\
\hline
P \rightarrow Q \\
\text{Condition evident or conclusion}
\end{array}
\]

Laws:

\[ \neg(\neg P) \equiv P \]
\[ P \rightarrow Q \equiv \neg P \lor Q \]
\[ P \lor Q \equiv Q \lor P \]
\[ P \land Q \equiv Q \land P \]
\[ \neg (P \lor Q) \equiv \neg P \land \neg Q \]
\[ \neg (P \land Q) \equiv \neg P \lor \neg Q \]
### Examples

\[(P \land Q) \lor (\neg Q \lor P)\]

<table>
<thead>
<tr>
<th>P</th>
<th>Q</th>
<th>P\land Q</th>
<th>\neg Q</th>
<th>\neg Q\lor P</th>
<th>(P\land Q)\lor (\neg Q\lor P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>T</td>
<td>T</td>
<td>F</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>T</td>
<td>F</td>
<td>F</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>F</td>
<td>T</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
<td>F</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
</tbody>
</table>

\[A \rightarrow B \equiv \neg A \lor B\]

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>A\rightarrow B</th>
<th>\neg A</th>
<th>\neg A\lor B</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>T</td>
<td>T</td>
<td>F</td>
<td>T</td>
</tr>
</tbody>
</table>
Homework:

1. $a \land (b \lor c) \equiv (a \land b) \lor (a \land c)$

2. $a \lor (b \land c) \equiv (a \lor b) \land (a \lor c)$
**Predicate Logic:**

To solve the limitations in the prepositional calculus, you need to analyze propositions into predicates and arguments, and deal explicitly with quantification. *Predicate Logic* provides formalism for performing this analysis of prepositions and additional methods for reasoning with quantified expressions.

Ali is a man
Man(ali)
is(ali,man)
object(obj1,obj2,.....).

1-Facts
Maha is a girl
Girl(maha)
Is(maha,girl).

I have a book
Have (I) book

Ali is a brave man
Is (ali , man, brave)
Man (ali,brave)
Brave (ali,man).
Man(ali) ^ brave (ali)
Ali have red car
Have (ali, car, red)
Have (ali, car) ^ colour(car, red)

This is sunny day
Is (day, sunny)
Sunny (day).

Maha has 4 books
Have (maha, 4, book)
Have (maha, book) ^ number (book, 4)

Ali going to school now
go (ali, school) ^ time (now)

I have one or two books
Have (I, books) ^ (number (books, 1) V number (books, two))

2- rules
If its winter then it is cold
Is (weather, winter) ⟷ is (weather, cold)
Weather (winter) ⟷ weather (cold)

When I’m sick, I will go to the doctor
Sick (I) ⟷ go (I, doctor)

I f student will read good he will pass
Read(X,good) ⇒ pass(X).
Ahmed got to the school when he is 6 years old
Age (ahmed,6) ⇒ go(ahmed,school).

Example:
Write predicate for book in library
Book(“artificial intelligence”,’gorge lugur”,2009,10)
Book(“c++”,”xt”,2009,9).

Example: write predicate for cars
Car(“BMW”,”black”,”1990”,”full automatic”, “special”).
Car(“Mazda”,”white”,”1995”,”ordinarily”, “special”).
Car(“chery”,”yello”,”2009”,”full automatic”, “Taxi”).

Calling types:-

Goal: book(X,Y,A,b,C).
false  predicate
No

Goal: book(A,B,C,D)
No  arguments
Goa1:book(A,B,C,D,E)
A=Prolod, B=A.I, C=George, D=10, E=2000
A=c++, B=programming, C=printce hill, D=5, E=2001

3/ solution
Yes

A=prolog, C=George, D=10, X=2000

2/SOLUTIONS

X=Expert, Y=A.I, Z=George, W=2000

1/ SOLUTION

A=A.I, C=George, N=10

1/ solution

No Solution
Goal: book(c++,A,B,20,X).
No Solution

 capitalize Variables

Yes

NO

.H.W

Family Relations
Son(ali,ahmed).
Son(ahmed,majed).
Son(mohammed,taha).
Son(Hamza,ahmed).
Son(hussain,majed).
Son (Hassan ,hussain).
Father (X,Y):-son(X,Y).
Brother(X,Y):-father(Z,X),father(Z,Y).
Grandfather(X,Y):-father(X,Z),father(Z,Y).
Cousin(X,Y):-father(Z,X),father(W,Y),brother(Z,W).

Goal
Father(al,ali,B).
B=ahmed. Yes

Goal
Brother(hamza,C)
    Father(Z,hamza) , father(Z,C)
Son(hamza,Z) true son(C,ahmed) true

Z=ahmed C=ali

H.W

Write appropriate predicates for the following family relations:

- Uncle
- Mother
- Sister
Lecture three:

Conjunctions and backtracking

1. Conjunctions
   1. and ‘,’.
   2. or ‘;’.

Used to combine facts in the rule, or to combine fact in the goal to answer questions about more complicated relationship.

Example:

Facts
Like (mary, food).
Like (mary, wine).
Like (john, mary).

Goal
Like (mary, john), like (john, mary).

We can ask does mary like john and does john like mary?

Now, how would prolog answer this complicated question?

Prolog answers the question by attempting to satisfy the first the first goal. If the first goal is in the database, then prolog will mark the place in the database, and attempt to satisfy the second goal.

If the second goal is satisfied, then prolog marks that goal’s place in the database, and we have a solution that satisfy both goals.

♦ It is important to remember that each goal keeps its own place marker. If, however, the second goals are not satisfied, then prolog will attempt to re-satisfy the previous goal.
Prolog searches the database in case it has to re-satisfy the goal at a later time. But when a goal needs to be re-satisfied, prolog will begin the search the database completely for each goal. If a fact in the database happens to match, satisfying the goal, then prolog will mark the place in the database in case it has to re-satisfy the goal at the later time. But when a goal needs to be re-satisfied, prolog will begin the search from the goal’s own place marker, rather than from the start of database and this behavior called “backtracking”.

**Example: about backtracking**

*Facts*

Like(mary,food).
Like(mary,wine).
Like(john,wine).
Like(john,mary).

*Goal:*

Like(mary,X),like(john,X).

```
Like(mary,X)  ,  like(john,X)
```

Like(mary,food).
Like(mary,wine).
Like(john,wine).
Like(john,mary).

1. The first goal succeed, bound X to food.
2. Next, attempt to satisfy the second goal.
3. The second goal fails.
4. Next, backtrack: forget previous value of X and attempt to resatisfy the first goal.

5. The first goal succeeds again, bind X to wine.
6. Next, attempt to satisfy the second goal.

7. The second goal succeeds.
8. Prolog notifies you of success.

H.W
Trace the following goal to find the value of X,Y,W,Z.
Fact
Mark(a,10).
Mark(b,20).
Mark(c,30).

Goal:
Mark(X,Y),Mark(W,Z).
Lecture four:

Content

1. Data type.
2. Program structure.
3. Read and write functions.
4. Arithmetic and logical operation.

1. data type

Prolog supports the following data type to define program entries.

1. **Integer**: to define numerical value like 1, 20, 0,-3,-50, ect.
2. **Real**: to define the decimal value like 2.4, 3.0, 5,-2.67, ect.
3. **Char**: to define single character, the character can be of type small letter or capital letter or even of type integer under one condition it must be surrounded by single quota. For example, ‘a’,’C’,’123’.
4. **string**: to define a sequence of character like “good” i.e define word or statement entries the string must be surrounded by double quota for example “computer”, “134”, “a”. The string can be of any length and type.
5. **Symbol**: another type of data type to define single character or sequence of character but it must begin with small letter and don’t surround with single quota or double quota.

2. program structure

Prolog program structure consists of five segments, not all of them must appear in each program. The following segment must be included in each program predicates, clauses, and goal.

1. **Domains**: define global parameter used in the program.
Domains
  I= integer
  C= char
  S = string
  R = real
2. **Data base**: define internal data base generated by the program
   Database
   Greater (integer)

3. **Predicates**: define rule and fact used in the program.
   Predicates
   Mark(symbol,integer).

4. **Clauses**: define the body of the program. For the above predicates the clauses portion may contain Mark (a, 20).

5. **Goal**: can be internal or external, internal goal written after clauses portion, external goal supported by the prolog compiler if the program syntax is correct
   This portion contains the rule that drive the program execution.

2. **mathematical and logical operation**

   *mathematical operation:*

<table>
<thead>
<tr>
<th>operation</th>
<th>symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>addition</td>
<td>+</td>
</tr>
<tr>
<td>subtraction</td>
<td>-</td>
</tr>
<tr>
<td>multiplication</td>
<td>*</td>
</tr>
<tr>
<td>Integer part of division</td>
<td>div</td>
</tr>
<tr>
<td>Remainder of division</td>
<td>mod</td>
</tr>
</tbody>
</table>
B. Logical operation

<table>
<thead>
<tr>
<th>operation</th>
<th>symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>greater</td>
<td>&gt;</td>
</tr>
<tr>
<td>Less than</td>
<td>&lt;</td>
</tr>
<tr>
<td>Equal</td>
<td>=</td>
</tr>
<tr>
<td>Not equal</td>
<td>&lt;&gt;</td>
</tr>
<tr>
<td>Greater or equal</td>
<td>&gt;=</td>
</tr>
<tr>
<td>Less than or equal</td>
<td>&lt;=</td>
</tr>
</tbody>
</table>

3. Other mathematical function

<table>
<thead>
<tr>
<th>Function name</th>
<th>operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cos(X)</td>
<td>Return the cosine of its argument</td>
</tr>
<tr>
<td>Sine(X)</td>
<td>Return the sine of its argument</td>
</tr>
<tr>
<td>Tan(X)</td>
<td>Return the tangent of its argument</td>
</tr>
<tr>
<td>Exp(X)</td>
<td>Return $e$ raised to the value to which X is bound</td>
</tr>
<tr>
<td>Ln(X)</td>
<td>Return the natural logarithm of X (base e)</td>
</tr>
<tr>
<td>Log(X)</td>
<td>Return the base 10 logarithm of $\log_{10} x$</td>
</tr>
<tr>
<td>Sqrt(X)</td>
<td>Return the positive square of X</td>
</tr>
<tr>
<td>Round(X)</td>
<td>Return the rounded value of X. Rounds X up or down to the nearest integer</td>
</tr>
<tr>
<td>Trunc(X)</td>
<td>Truncates X to the right of the decimal point</td>
</tr>
<tr>
<td>Abs(X)</td>
<td>Return the absolute value of X</td>
</tr>
</tbody>
</table>

4. Read and write function

Read function:
- readint(Var) : read integer variable.
- Readchar(Var) : read character variable.
- Readreal(Var) : read read (decimal) variable.
- Readln(Var) : read string.

Write function
- Write(Var) : write variable of any type.

Example 1: write prolog program to read integer value and print it.
Domains
I = integer
Predicates
print.
Clauses
Print:- write ("please read integer number"), readint(X),
write("you read",X).

Goal
Print.

Output:
Please read integer number 4
You read 4

Example2: write prolog program that take two integer input us integer and print the greater.

Domains
I = integer
Predicates
Greater ( i,i)
Clauses
Greater(X,Y):- X>Y,write("the greater is",X).
Greater(X,Y):- write (" the greater is ",Y).
Goal
Greater(4,3).

Output:
The greater is 4

H.W:
1. write prolog program that read any phrase then print it.
2. write prolog program that read an integer number then print it after multiplying it by any other integer like 5.
Lecture five: More examples

This lecture present several example that intended to display various way to write prolog program, how to write if–else program, divide problem into several parts then combine them in a single rule and how to write program describe specific problem.

Example 1: write prolog program to check if the given number is positive or negative.

Basic rule to check the number

If \( X \geq 0 \) then
   X is positive
Else
   X is negative

Domains
   I= integer
Predicates
   Pos_neg(i)
Clauses
   Pos_neg(X): -X \geq 0, write(“positive number”),nl.
   Pos_neg(_): -write(“negative number”),nl.

Goal
   Pos_neg(4)

Output:
   Positive number

Note: nl mean new line.

Example 2: write prolog program to check if a given number is odd or even.

Basic rule to check number
If $X \mod 2 = 0$ then
   $X$ is even number
Else
   $X$ is odd number

Predicates
   Odd_even(integer)

Clauses
   Odd_even(X):- $X \mod 2 = 0$, write(“even number”), NL.
   Odd_even(X):- write(“odd number”), nl.

Goal
   Odd_even(5)

Output
   Odd number

Example 3: write prolog program to combine both rule in example 1 and example 2.

Domains
   I= integer
Predicates
   Pos_neg(i)
   Odd_even(i)
   Oe_pn(i)

Clauses
   Oe_pn(X):- pos_neg(X),odd_even(X).
   Odd_even(X):- $X \mod 2 = 0$, write(“even number”),nl.
   Odd_even(X):- write(“odd number”),nl.
   Pos_neg(X):- $X \geq 0$, write(“positive number”),nl.
   Pos_neg(_):- write(“negative number”),nl.

Goal
   Oe_pn(3)

Output:
   Odd number
   Positive number
Note: the rule of same type must be gathering with each other.

Example 4: write prolog program to describe the behavior of the logical And gate.

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Sol 1:

Domains
I = integer
Predicates
And1(I, I, I)

Clauses
And1(0,0,0).
And1(0,1,0).
And1(1,0,0).
And1(1,1,1).

Goal
And1(0,1,Z)

Output:
Z = 0

Sol 2:
From the truth table we can infer the following rule:

If X = Y then
    Z = X
Else
    Z = 0
Domains
   I= integer
Predicates
   And1 (I ,I, I )
Clauses
   And1 (X,Y,Z):- X=Y, Z=X.
   And1(X,Y,Z):- X<> Y, Z=0.

Goal
   And1(0,0,Z)

Output
   Z=0

H.W
1. Write prolog program that read character and check if it’s a capital letter, small letter, digit or special character.
2. Modify prolog program in example 3 such that the value of X is read inside the program.
3. Write prolog program that describe the operation of logical Or gate.
Lecture six:
1. Cut and fail function
2. Negation

1. cut

Represented as “!” is a built-in function that is always True, used to stop backtracking and can be placed anywhere in the rule. We list the cases where “!” can be inserted in the rule:

1. R:-f1, f2, !. “f1, f2 will be deterministic to one solution.
2. R:-f1, !, f2. “f1 will be deterministic to one solution while f2 to all.
3. R:- !, f1, f2. “R will be deterministic to one solution.

Example 1: program without use cut.
Domains
I= integer
Predicates
No( I )
Clauses
No (5).
No (7).
No (10).

Goal
No (X).

Output:
X=5
X=7
X=10

Example 2: program using cut.
Domains
I= integer
Predicates
No( I )
Clauses
No (5):-!.
No (7).
No (10).
Goal
No (X).

Output:
X=5.

Example 3: program without using cut.

Domains
 I =integer
 S = symbol
Predicates
 a (I )
 b (s )
 c ( I, s )
Clauses
 a(10).
 a(20)
 b(a)
 b(c)
c (X, Y):- a (X), b (Y).

Goal
c(X,Y).

Output:
X= 10  Y=a
X=10   Y=c
X=20   Y=a
X=20   Y=c

Example 4: using cut in the end of the rule.

Domains
 I =integer
 S = symbol
Predicates
 a(I )
b ( s )
c (I, s )
Clauses
a(10).
 a(20)
 b(a)
 b(c)
 c (X, Y):- a (X), b (Y),!.

Goal
c(X,Y).

Output:
X= 10  Y=a

Example 5: using cut in the middle of the rule.

Domains
 I =integer
 S = symbol
Predicates
 a(I )
 b (s )
 c ( I, s )
Clauses
a(10).
a(20)
b(a)
b(c)
c (X, Y):- a (X),!, b (Y).

Goal
c(X,Y).

Output:
X= 10  Y=a
 Y=c
2. Fail

Built in function written as word “fail” used to enforce backtracking, place always in the end of rule, produce false and can be used with internal goal to produce all possible solution.

Example 6:

Predicates
   Student ( symbol , integer)
   Printout.
Clauses
   Student (aymen,95).
   Student(zainab,44).
   Student(ahmed,60).

Printout:-student(N,M),write(N,”,”,M),nl,fail.

Goal
   Printout.

Output:
   aymen   95
   zainab   44
   ahmed   60
   No

Example 7:

Predicates
   Student ( symbol , integer)
   Printout.
Clauses
   Student (aymen,95).
   Student(zainab,44).
   Student(ahmed,60).

Printout:-student(N,M),write(N,”,”,M),nl,fail.
3. Negation

Exceptions and return false in specific situation. Can be implemented using:
2. Not.

1. Cut-fail

Example 8:
Ahmed likes swimming and he want to visit all middle east seas accept the dead sea. Write prolog program to describe this situation.

A: using fail.

Predicates
Visit (symbol)
Middle_east (symbol)

Clauses
Visit (Sea) :- middle_east (Sea).
Middle_east (deadsea):- fail.
Middle_east( redsea).
Middle_east(arabsea).

Goal
1. Visit (deadsea)  
2. Visit (W).

Output:  
1. No  
2. W= red_sea  
   W=arab_sea

**B: using cut- fail**

Predicates  
Visit (symbol)  
Clauses  
Visit (Sea) :- Sea=deadsea,!.,fail.  
Visit (X):-middle_east(X).  
Middle_east(redsea).  
Middle_east(arabsea).

Example 9: ban like all animals but snake, write prolog program for this case.

Predicates  
Like( symbol, symbol)  
Snake(symbol)  
Animal(symbol)  

Clauses  
Like(ban ,X):- animal(X),X=snake,!.,fail.  
Like(ban,X):- animal(X).  
Animal(cat).  
Animal(bird).  
Animal(dog).

**2. using not**

For example 8: we can write it using not as follow.

Predicates  
Visit ( symbol)  
Middle_east(symbol).  

Clauses  
Visit ( X):- middle_east(X),not (X = deadsea).
Middle_east(redsea).
Middle_east(arabsea).

H.w:
1. Trace the following clauses and find the output:
   a. clauses
      reading:- readchar(Ch),writ(Ch),Ch=‘#’.
      Reading.

   b. clauses
      Go.
      Go:-go.
      Reading:- go,readchar(Ch),write(Ch),Ch=‘#,!.

3. Use negation to define the different relation: diff(X,Y) which is true when X and Y are different numbers.
Lecture seven: repetition and recursion

1. Repetition
   In prolog there is a constant formula to generate repetition; this technique can generate repetition for some operation until the stopping condition become true.
   Example: prolog program read and write a number of characters continue until the input character equal to ‘#’.

   Predicates
   Repeat.
   Typewriter.

   Clauses
   Repeat.
   Repeat:-repeat.
   Typewriter:-repeat,readchar(C),write(C ),nl,C=’#’,!.

2. Recursion
   In addition to have rules that use other rules as part of their requirements, we can have rules that use themselves as part of their requirements.
   This kind of rule called “recursive “because the relation ship in the conclusion appears again in the body of the rule, where the requirements are specified.
   A recursive rule is a way of generating a chain of relationship for a recursive rule to be effective. However, there must be some place in the chain of relationship where the recursion stops.
This stopping condition must be answerable in the database like any other rule.

2.1 Tail Recursion

We place the predicate that cause the recursion in the tail of the rule as shown below:

**Head :- p1,p2,p3, head.**

Example 1: program to print number from n to 1.

Predicates
- A (integer)

Clauses

Output result

Setup variables

32
A(1) :- write (1), nl ,!.
A(M):- write (M) , nl, M1 = M -1, A( M1).

Goal
A(4)

Output:
4
3
2
1
Yes

Example 2: program to find factorial.

5! = 5*4*3*2*1

Predicates
    Fact ( integer, integer, integer)
Clauses
    Fact(1, F, F):-!.
    Fact(N,F,R):- F1=F*N , N1=N-1, fact(N1,F1,R).

Goal
Fact (5,1,F).

Output:
    F = 120.

Example 3: program to find power .

3 ^ 4 = 3*3*3*3
Domains
I= integer

Predicates
Power ( I,I,I, I ).

Clauses
Power ( X,Y,P,R):- P1= P*X, Y1 =Y-1, power(X,Y1,P1,R).
Power (_,0,P,P):-!.

Goal
Power(3,2,1,P)

Output
P= 9

2.2 Non –Tail Recursion ( Stack Recursion )
This type of recursion us the stack to hold the value of the variables till the recursion is complete. The statement is self – repeated as many times as the number of items in the stack.. Below a simple comparison between tail and non-tail recursion.

<table>
<thead>
<tr>
<th>Tail recursion</th>
<th>Non-tail recursion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Call for rule place in the end of the rule.</td>
<td>1. Call for the rule place in the middle in the rule.</td>
</tr>
<tr>
<td>2. It is not fast as much as stack recursion.</td>
<td>2. Stack recursion is fast to implement.</td>
</tr>
<tr>
<td>3. Use more variable than stack recursion.</td>
<td>3. Few parameters are used.</td>
</tr>
</tbody>
</table>

Example 4: factorial program using non-tail recursion.
Predicates
    fact(integer,integer).
Clauses
    fact(1,1).
    fact(N,F) :- N > 1, N1 = N - 1, fact(N1, F1), F = N * F1.

Goal
Fact (4,Y)

Output:
Y = 24.

Example 5: power program using non-tail recursion.

Predicates
    Power (integer, integer, integer)
Clauses
    Power (_,0,1):-!.
    Power (X,Y,P) :- Y > 0, Y1 = Y - 1, power (X, Y1, P1), PZ = X * P1.
Goal
    Power (3,2,Z)

Output
    Z = 9.
H.W

1. Write prolog program to find the sum of 10 integer element using tail and non tail recursion.
2. Write prolog program to find the maximum value between 10 elements.
3. Write prolog program to find the minimum value between 10 elements.
4. Find the sum $S = 1+2+3+...+N$
Lecture eight:

String standard predicates

1. Isname(string) test if the content of the string is name or not

   Isname("abc") yes
   Isname("123"). No

2. char_int(char,integer) convert the character to its integer value and the opposit

   Char_int('A',X)
   X=65
   Char_int(X,65)
   X='A'

3. Str_char(string,char) convert the string (of one char) to char and the opposit

   Str_char("A",X)
   X='A'
   Str_char(X,'A')
   X="A"

4. str_real(string,real) convert the string (ofreal) to real and the opposit

   Str_real("0.5",X)
   X=0.5
   Str_real(X,0.5)
   X="0.5"

5. Fronttoken(string,string,string).
   Take token of word from the string and return the reminder of the string.
   Fronttoken(string,token,rem).
   Fronttoken("ab cd ef",X,Y).
   X="ab"   y="cd ef"
   Fronttoken("c def",X,Y)
   X="cd"   Y="ef"

6. Frontstring(integer,string,string,string)
Take a string(str) with length specified by the integer value and return the reminder

Frontstring(integer,string,str,rem)

Frontstr(3,"ahmed",X,Y)
  X="ahm"   Y="ed"
Frontstr(2,"abcde",X,Y).
  X="ab"   Y="cde"
Frontstr(3,S,"ahm","ed").
  S="ahmed"

7. Frontchar(string,char,string).
Take one char from a specific string and return the reminder

Frontchar(string,char,rem).

Frontchar("ahmed",X,Y)
  X='a'   Y="hmed"
Frontchar(X,'a','hmed')
  X="ahmed"

8. Str_len(string,length)
Return the length of specific string

Str_len("ahmed",X)
  X=5
Str_len("ab",X)
  X=2
Str_len("ab",3)    no
Str_len(X,3)    X="---"

9. Concat(string,string,string).
Concat two string together to produce one string

Concat("ab","cd",X)
  X="abcd"

10. Upper_lower(string,string)
Convert the string in upper case(in capital letter) to the lower case (small letter) and the opposite.

Upper_lower(capital_letter,small_letter)
Upper_lower("ABC",X)
  X="abc"
Prolog Programs that deal with string

Ex1: Program that read two string and concat them in one string as upper case.

predicates
start(string).
clauses
start(X):-readln(S),readln(S1),concat(S,S1,S2),upper_lower(X,S2).

Goal
Start(X)

Output:
Ahmed
Ali
X=AHMEDALI  yes

Ex2: program that read string of one character then return the integer value of this char.

predicates
start(integer).
clauses
start(X):-readln(S),str_char(S,X).

goal
start(X)

Output:
a
X=97
yes
**Ex3:** Program that take a string of words and print each word in a line as upper case.

predicates
start(string).

clauses

start(S):-fronttoken(S,S3,S2), upper_lower(S1,S3), write(S1), nl,start(S2).
start("").

*Goal*

*Start("ali is a good boy").*

*Output:*

ALI
IS
A
GOOD
BOY
yes

**Ex4:** program that take a string and convert each character it contain to its corresponding integer value.

Predicates
start(string).

clauses

start(S):-fronttoken(S,S3,S2), char_int(S1,I), write(I), nl , start(S2).
start(" ").

*Goal*

*Start("abc")*. 

*Output:*

97
98
99
Yes
**Ex5: program that return the number of names in a specific string.**

predicates
start(string,INTEGER).

clauses

start(S,X):-fronttoken(S,S1,S2),isname(S1),X1=X+1,start(S2,X1).
start(S,X):-fronttoken(S,_,S2),start(S2,X).
start("",X):-write("the number of names is",X).

goal
start("ali has 2 cars").

Output:
The no. of names is 3
Yes

**Ex6: program that split a specific string to small string with length 3 char.**

predicates
start(string).

clauses

start("").
start(S):-str_len(S,I), I MOD 3=0, frontstr(3,S,S1,S2), write(S1), nl,start(S2).
start(S):-concat(S," ",S1),start(S1).

Goal
Start("abcdefg").

Output:
abc
def
g
yes

**H.W**
1- Write a prolog program that do the following: convert the string such as "abcdef" to 65 66 67 68 69 70.
2- Program to find the number of tokens and the number of character in a specific string such as: "ab c def" the output is tokens and 6 character.
Lecture nine:
1. list in prolog
2. syntax of list
3. head and tail

1. list in prolog
   In prolog, a list is an object that contains an arbitrary number of other objects within it. Lists correspond roughly to array in other languages but unlike array, a list does not require you to how big it will be before use it.

2. syntax of list
   List always defined in the domains section of the program as follow:

   Domains
   list = integer* 
   • ‘*’ refer to list object which can be of length zero or undefined.
   • The type of element list can be of any standard defined data type like integer, char and user defined data type explained later.
   • List element surrounded with square brackets and separated by comma as follow: l = [1, 2, 3, 4].
   • List consist of two parts head and tail, the head represent the first element in the list and the tail represent the remainder (i.e. head is an element but tail is a list). For the following list:
     L = [1,2,3]
     H = 1 T = [2,3]
     H = 2 T = [3]
     H = 3 T = [ ]

     [ ] refer to empty list.
   List can be written as [H|T] in the program, if the list is nonempty then this statement decomposes the list into Head and tail otherwise (if the list is empty) this statement add element to the list.
4. list and recursion

As maintained previous list consist of many element, therefore to manipulate each element in the list we need recursive call to the list until it become empty.

Example 1: program to print list element in one line.

Domains
  L = integer*
Predicates
  Print (L)
Clauses
  Print ([ ]):-!.
  Print ([ H|T]):- write (H), print (T).

Goal
  Print ([1,4,6,8]).
Output:
  1468

Example 2: program to find sum of integer list.

Domains
  I = integer
  L = i*
Predicates
  Sum ( L I, I)
Clauses
  Sum ([ ], S, S):-!.
  Sum([H|T], S1, S):- S2 = S1+H, Sum(T, S2, S).

Goal
  Sum ([ 1,4,6,9], 0, S).
Output
  S = 20
Example 3: prolog program to split list into list positive and negative list.

Domains
L = integer*

Predicates
Spilt (L,L,L)

Clauses
Spilt ([ ],[ ],[ ]):-!.
Spilt ([H|T],[H|T1],L2):- H>= 0,!,spilt (T, T1,L2).
Spilt ([H|T],L1,[H|T2]) :- spilt (T,L1,L2).

Goal
Spilt([-1,4,-9,8,0],L1,L2).
L1 = [4,9,0]
L2 = [-1,-9]

H.W
1. Write prolog program to find the union of two lists.
2. Write prolog program to find the intersection between two lists.
3. Write prolog program to find the difference between two lists.
4. Write prolog program that check the equality between two lists.
5. Write prolog program to find the last element in a list.
6. Write prolog program to find the union of two lists.
7. Write prolog program to find the length of a list.
8. Write prolog program to find the index of specified element in a list.
9. Write prolog program to get the element at nth index lists.
10. Write prolog program that replace specified element in a list with value 0.
11. Write prolog program that delete a specified element in a list.
12. Write prolog program that take two lists as input and produce a third list as output, this list is the sum of the two lists.
13. Write prolog program that multiply each element in the list by 5.
14. Write prolog program that sort a list descending.
15. Write prolog program that convert any given decimal number to its binary representation and store it in a list.
Lecture ten:

1) Data – Driven and Goal Driven Search (Reasoning Search):

In data –driven search , sometimes called Forward Chaining (F.W) , the problem solver begins with the give facts and a set of rules for changing the state. Search proceeds by apply rules to facts to produce new facts. This process continues until it generates a path that satisfies the goal.

In Goal-Driven search , sometimes called Backward Chaining (B.W) , the problem solver begins with the goal to be used to generate this goal and determine what conditions must be true to use them. These conditions become the new goals, sub goals , for the search. This process continues , working backward through successive sub goals, until a path is generated that lead back to facts of the problem.

Example of Data Driven Search (F.W)

Using (F.W) to find if the goal w is true or false

```
 a.  b.  c.  d.
w:-r,z.
r:-a,b.
z:-c,d.
```

```
sol/
 a.  b.  c.  d.  r.  z.  w.  the goal is true
1) w:-r,z.    ___  6
2) r:-a,b.    ___  4
3) z:-c,d.    ___  5
4)r:-b.     ______  
5) z:-d.   ______   
6)w:-z. _____________________
```


Example of Goal Driven Search (B.W)
Try the previous facts & rules to prove if (w) is true or false.

1) w:-r,z.  6
2)z:-a,b.  4
3)r:-c,d.  5
4)r:-b.   
5) r:-d.   
6)w:-r.   

Example: Try the following facts & Rules with (F.W) & (B.W)
Chaining.

W:-r(x),z(x).
R(w):-a(w),b.
Z(v),c.
Sol/ B.W Chaining

a(1). B. c. d(1). r(1). Z(1). W. the goal is true
1) w:-r(x),z(x). ___6
2) r (w):-a(w),b. ______ 4
3) z (v):d(v),c. ______ 5
4) r (1):-b.  
5) z(v):-d(v).  
6) w:-z(1).  

H.W/ Using B.W & F.W chaining to reasoning that the goal (Z) is true or not.

a(1). b(2). c(3). d(1). e.
r:-a(x),b(y).
z:-e, not (f), not (b(3)), w.
w:-c(z), d(l), not (a(3)), r.
Lecture eleven:

Knowledge Representation

There are many methods can be used for knowledge representation and they can be described as follows:-

1- Semantic net.
2- Conceptual graph.
3- Frames
4- Predicates logic.
5- Clause forms

1) Semantic Net

It is consist of a set of nodes and arcs, each node is represented as a rectangle to describe the objects, the concepts and the events. The arcs are used to connect the nodes and they divided to three parts:-

Is a: → for objects & types
Is → To define the object or describe it
Has a

can
**(Example 1):** Computer has many parts like a CPU and the computer divided into two types, the first one is the mainframe and the second is the personal computer. Mainframe has a line printer with a large sheet but the personal computer has a laser printer. IBM is an example of the mainframe, and PIII and PIV are examples of the personal computer.

**Diagram:**
- Computer
  - Has a CPU
  - Is a PC
    - Has a Laser printer
    - Has a Mainframe
    - Has a Line printer
      - Has a PIV
      - Has a PII
      - Has an IBM

**(Example 2):** Layla gave Selma a book

**Diagram:**
- Layla
  - agent
  - Past
  - book
- gave
- Selma
  - receiver
  - object
Example 3: Layla told Suha that she gave Selma a book

Example 4: Ali gave Ban a disk which is Zaki bought
2) The Conceptual Graph

وهي طريقة لتمثيل المعرفة مشابهة لطريقة Semantic Net وتتكون من جزئين:

- يستخدم لتمثيل الأسماء والصفات والأفعال والثوابت
- يستخدم لتمثيل أدوات التعريف والعلاقات

Example 1: Ahmed read a letter Yesterday
Example 2: The dog Scratch it ear with is paw

Example 3: Ahmed tell Saad that he saw Suha
3) Frame:

Frame-list( node-name, parent, [child]).
Slot-list(node-name, parent).

Example:

Frame –list( computer, _, [Internal structure, monitor, keyboard, plotters]).
Frame-list(Internal structure, computer, [disk controller, mother board]).
Frame- list(printer, peripheral, [speed, ports]).
Slot-list(motherboard, Internal structure).
Slot-list(mouse, peripheral).
Homework 1: **solve with Semantic net**

Ships are divided in two types, the first is “Ocean lines” and the second is “Oil tank”, the ships has an engine, the oil tank are specified to transfer oil therefore it has “fire tools”, the ocean lines are specified to transfer the traveler therefore it has “swimming poot”, Ibnkaldon as an example to oil tank and ship b and ship n as an example to ocean line.

Homework 2: Using Semantic Net and Conceptual graph to solve the following statement:

1) Suha send a book to Tom.
2) Tom believe that Mustafa like cheese.
3) Monkey ema grasp the banana with hand.
**Lecture twelve:**

**Search Algorithms:**
To successfully design and implement search algorithms, a programmer must be able to analyze and predict their behavior. Many questions needed to be answered by the algorithm these include:
- Is the problem solver guaranteed to find a solution?
- Will the problem solver always terminate, or can it become caught in an infinite loop?
- When a solution is found, is it guaranteed to be optimal?
- What is the complexity of the search process in terms of time usage? space search?
- How can the interpreter be designed to most effectively utilize a representation language?

**-State Space Search**
The theory of state space search is our primary tool for answering these questions, by representing a problem as state space graph, we can use graph theory to analyze the structure and complexity of both the problem and procedures used to solve it.

**Graph Theory:**
A graph consists of a set of nodes and a set of arcs or links connecting pairs of nodes. The domain of state space search, the nodes are interpreted to be states in problem-solving process, and the arcs are taken to be transitions between states.

**Graph theory** is our best tool for reasoning about the structure of objects and relations.

Nodes={a,b,c,d,e}
Arcs={(a,b), (a,d),(b,c),(c,b),(d,e),(e,c),(e,d)}
Nodes==\{a,b,c,d,e,f,g,h,i\}
Arcs={\{(a,b),(a,c),(a,d),(b,e),(b,f),(c,f),(c,g),(c,h),(c,i),(d,j)\}}

State Space Representation of Problems:

A state space is represented by four_tuple \([N,A,S,G,D]\),
where:

- \(N\) is a set of nodes or states of the graph. These correspond to the
  states in a problem – solving process.
- \(A\) is the set of arcs between the nodes. These correspond to the
  steps in a problem – solving process.
- \(S\) a nonempty subset of \(N\), contains the start state of the problem.

- \(GD\) a nonempty subset of \(N\) contains the goal state of the problem.

A solution path:- Is a path through this graph from a node \(S\) to a node in \(GD\).
State Space Searches examples:-

1) **Monkey and Banana Problem**

There is a monkey at the door in to a room. In the middle of the room a banana is hanging from the ceiling. The monkey is hungry and wants to get the banana, but he cannot stretch high enough from the floor. At the window of the room there is a box the monkey may use.

**The monkey can perform the following actions:-**

- walk on the floor
- Climb the box
- Push the box a round (if it is already at the box).
- Grasp the banana if standing on the box directly under the banana.

The question is (Can the monkey get the banana?), the initial state of the world is setermind by:-

1- Monkey is at door.
2- Monkey is on floor.
3- Box is at Window.
4- Monkey does not have banana

Initial state :- State (at door, on floor, at window, has not).

At door  ➔  horizontal position of monkey
On floor  ➔  vertical position of monkey
At window ➔  Position of box
Has not ➔  monkey has not banana

Goal state:-State (_,_,_,has).

State1 ➔ state2
Move (state1, move, state2).
State1: is the state before the move.
Move: is the move executed.
State2: is the state after the move.
To answer the question :- Can the monkey in some initial state (state) get the banana?
This can be formulated as a predicate canget(state). The program canget can be based on two observation:-
1) The program:- for any state in which the monkey already has the banana. The predicate canget must certainly be true, no move is needed in this case:
Canget(state( state(_,_,_,has)).
2) In other cases one or more moves are necessary.
Canget (state):-move (state1,move,state2), canget (state2).

**A program of monkey and banana problem:-**
Move (state (at door, on floor, at window, has not), walk, state (at box, on floor, at window, has not)).
Move (state (at box, on floor, at window, has not), push, state (middle, on floor, middle, has not)).
Move (state (middle, on floor, middle, has not), climb, state (middle, on box, middle, has not)).
Move (state (middle, on box, middle, has not), grasp, state (middle, on box, middle, has not)).
Canget( state(_,_,_,has)).
Canget (State1):- move (state1,move,state2), canget (state2).
Goal= canget (state(at door, on floor, at window , has not)).

- The monkey and banana problem can be represented by the following state space:-

State (at door, on floor, at window, has not)

Walk (at door, at box)

State (at box, on floor, at window, has not)

climb

Push (at box, middle)

State(at window, on box, at window, has not).

No move possible

, state (middle, on floor, middle, has not)

State (middle, on box, middle, has not)

state (middle, on box, middle, has not)

state (middle, on box, middle, has not)
2) Water Jug Problem

You are given two jugs, a 4-gallon one and a 3-gallon one. Neither has any measuring markers on it. There is a pump that can be used to fill the jugs with water. How can you get exactly 2 gallons of water into the 4-gallon jug?

The state space for this problem can be described as the set of ordered pairs of integers \((x,y)\), such that \(x=0,1,2,3\) or 4 and \(y=0,1,2,\) or 3; \(x\) represents the number of gallons of water in the 4-gallon jug, and \(y\) represents the quantity of water in 3-gallon jug. The start state is \((0,0)\). The goal state is \((2,n)\) for any value of \(n\) (since the problem does not specify how many gallons need to be in the 3-gallon jug).

1) \((X,Y: X<4)\) \(\rightarrow\) \((4,Y)\) Fill the 4-gallon jug
2) \((X,Y: Y<3)\) \(\rightarrow\) \((X,3)\) Fill the 3-gallon jug
3) \((X,Y: X>0)\) \(\rightarrow\) \((X-D,Y)\) Pour some water out of the 4-gallon jug
4) \((X,Y: Y>0)\) \(\rightarrow\) \((X,Y-D)\) Pour some water out of the 3-gallon jug
5) \((X,Y: X>0)\) \(\rightarrow\) \((0,Y)\) Empty the 4-gallon jug on the ground
6) \((X,Y: Y>0)\) \(\rightarrow\) \((X,Y)\) Empty the 3-gallon jug on the ground
7) \((X,Y: X+Y>=4 \land Y>0)\) \(\rightarrow\) \((4,Y-(4-X))\) Pour water from the 3-gallon jug into the 4-gallon jug until the 4-gallon jug is full.
8) \((X,Y: X+Y<=4 \land X>0)\) \(\rightarrow\) \((X-(3-Y),3)\) Pour water from the 4-gallon jug into the 3-gallon jug until the 3-gallon jug is full.
9) \((X,Y: X+Y<=4 \land Y>0)\) \(\rightarrow\) \((X+Y,0)\) Pour all the water from 3-gallon jug into the 4-gallon jug.
10) \((X,Y: X+Y<=3 \land X>0)\) \(\rightarrow\) \((0,X+Y)\) Pour all the water from 4-gallon jug into the 3-gallon jug.
The solutions of water jug problem

3) **Tower of Hanoi Problem**

- Is a mathematical puzzle. It consists of three rods, and a number of disks of different sizes.
- The objective of the puzzle is to move the entire stack to another rod, the middle rod, with regard the following rules:
  - Only one disk can be moved at a time.
✓ Disk can only be moved if it is the uppermost disk on a stack.
✓ No disk may be placed on top of a smaller disk.
The prolog program of Tower of Hanoi problem:

domains
loc=symbol
predicates
hanoi(integer)
move(integer,loc,loc,loc)
print(loc,loc)
clauses
hanoi(N) :- move(N, left, middle, right).
move(0, _, _, _) :- !.
move(N, Left, Middle, Right) :-
    M = N-1,
    move(M, Left, Right, Middle),
    print (Left, Middle),
    move(M, Right, Middle, Left).
print(Loc1,Loc2):-
    write("\n move disc from ",Loc1," to ",Loc2).
**goal:** \textit{hanoi}(3).

- move disc from left to middle
- move disc from left to right
- move disc from middle to right
- move disc from left to middle
- move disc from right to left
- move disc from right to middle
- move disc from left to middle
- yes