**B.M.S COLLEGE OF ENGINEERING**
**BENGALURU** Autonomous Institute, Affiliated to VTU

Lab Record

# Artificial Intelligence

**(22CS5PCAIN)**

*Submitted in partial fulfilment for the 5th Semester Laboratory*

Bachelor of Technology
in
Computer Science and Engineering

*Submitted by:*

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**B.M.S COLLEGE OF ENGINEERING**

**DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING**

***CERTIFICATE***

This is to certify that the Artificial Intelligence (22CS5PCAIN) laboratory has been carried out by VIBHA HUGAR (1BM21CS255) during the 5th Semester November 2023-January 2024.

Signature of the Faculty In charge:

Dr Kayarvizhy N
Associate Professor
Department of Computer Science and Engineering
B.M.S. College of Engineering, Bangalore

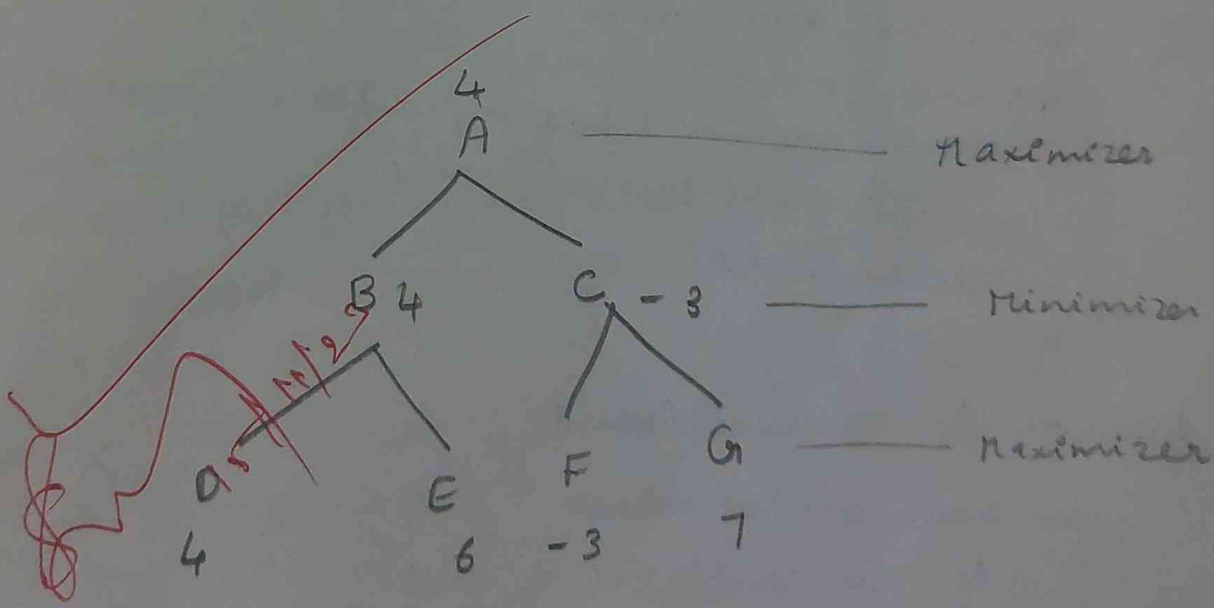
## Observation Screenshots

# Min - Max Algorithm

function minimax(node, depth, maximizingPlayer) is
if depth == 0 or node is a terminal node then
return static evaluation of node

if MaximizingPlayer then
maxEva = - infinity
for each child of node do
eva = minimax( child, depth - 1, false)
maxEva = max (maxEva, eva)
return maxEva

else
minEva = + infinity
for each child of node do
eva = minimax (child, depth - 1, true)
minEva = min ( minEva, eva)
return minEva




Rule Based AI - if else condition is used
Algorithm : DFS
Data Structure: List

15.11

Tic Tac Toe

```
function findBestMove(board):
    bestmove = -ve
  for each move in board
    if current move is better:
      bestmove = current
    return bestmove

function minimax(board, depth, isMaxiPlayer)
    # all possible winning solutions
      if current board state is terminal:
       return value of board

  if isMaxiPlayer:
          bestVal = - INFINITY
          for each move in board;
          value = minimax (board, depth +1, not is maxiplayer

          bestval = max (best Val, value)
          return bestVal

  else:
     bestValue = + INFINITY
     for each move in board:
       value = minimal (board, depth +1, not is maxiplayer)
      bestval = min( best Val, value)
       return bestVal

function is MovesLeft(board):
    for each cell in board:
        if current cell is empty
              return true
        return false
```

```
X _ _
_ O _
_ _ _
```

# Vacuum Cleaner Agent



function REFLEX-VACUUM-AGENT([location, status]) returns action

    if status = Dirty then return Suck
    else if location = A then return Right
    else if location = B then return Left

## CODE

```
def vacuum_world():
    goal_state = {'A': '0', 'B': '0'}
    cost = 0

  location_input = input("Enter location of vacuum")
  status_input = input ("Enter status of" + location_input)
  status_input_complement = input (" Enter other room's status")
  print ("Initial location condition" + str (goal_state))

  if location_input == 'A':
    print ("vacuum is placed in location A")
    if status_input == '1':
    print ("Location A is dirty")

      goal_state ['A'] = '0'.
      cost += 1
      print ("COST for moving RIGHT" + str(cost))

       goal_state ['B'] = '0'
       cost += 1

    print ("COST for SUCK" + str (cost))
    print ("Location B has been cleaned.")

  else :
       print (" No action + str (cost))
       print ("Location B is already clean")
```

```
else:

    print ("vacuum is placed in location B")
    if status_input == '1':
        print ("Location B is dirty")
        goal_state ['B'] = '0'
        cost += 1
        print ("COST for CLEANING" + str (cost))
        print ("Location B has been cleaned")

        if status_input_complement == '1':
            print ("Location A is dirty")
            print ("moving LEFT to the location A")
            cost += 1
            print ("COST for moving LEFT" + str (cost))
            goal_state ['A'] = '0'
            cost += 1
            print ("COST for SUCK" + str (cost))
            print ("Location A has been cleaned")

    else:
        print (cost)
        print ("Location B is already clean")

        if status_input_complement == '1':
            print ("Location A is dirty")
            print ("Moving LEFT to the location A")
            cost += 1
            print ("COST for moving LEFT" + str (cost))

            goal_state ['A'] = '0'
            cost += 1
            print ("Cost for SUCK" + str (cost))
            print ("Location A has been cleaned")

        else:
            print ("No action" + str (cost))
            print ("Location A is already clean")

print ("GOAL STATE:")
print (goal_state)
print ("Performance Measurement:" + str (cost))
vacuum_world ()
```

# 8 puzzle Problem



```
def bfs (src, target):
        queue = []
        queue.append (src)

        exp = []

    while len (queue) > 0:
          source = queue .pop(0)
            exp.append (source)
         print (source)
        if source == target:
             print ("success")
           return

  poss_moves_to_do = []
  poss_moves_to_do = possible moves (source, exp)

 for move in poss_moves to do:
   if move not in exp and move not in queue:

def possible_moves (state, visited_states):
  b = state.index(0)

   d = []

   if b not in [0, 1, 2]:
             d.append ('u')
     if b not in [6, 7, 8]:
              d. append ('d')
       if b not in [0, 3, 6]:
              d.append ('l')
        if b not in [2, 5, 8]:
               d.append ('r')


      poss_moves_it_can = []
```

```
for i in d:
    pos_moves_it_can.append(gen(state, i, b))

return [move_it_can for move_it_can in pos_moves_it_can
    if move_it_can not in visited_states]

def gen(state, m, b):
    temp = state.copy()

    if m == 'd':
        temp[b+3], temp[b] = temp[b], temp[b+3]
    if m == 'u':
        temp[b-3], temp[b] = temp[b], temp[b-3]
    if m == 'l':
        temp[b-1], temp[b] = temp[b], temp[b-1]
    if m == 'r':
        temp[b+1], temp[b] = temp[b], temp[b+1]

    return temp

src = [1, 2, 3, 0, 4, 5, 6, 7, 8]
target = [1, 2, 3, 4, 5, 0, 6, 7, 8]

src = [2, 0, 3, 1, 8, 4, 7, 6, 5]
target = [1, 2, 3, 8, 0, 4, 7, 6, 5]

bfs(src, target)
```

1 2 3 4 5 0 6 7 8

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 0 | 4 | 5 |
| 6 | 7 | 8 |

| | | |
|---|---|---|
| 0 | 2 | 3 |
| 1 | 4 | 5 |
| 6 | 7 | 8 |

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 6 | 4 | 5 |
| 0 | 7 | 8 |

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 0 | 5 |
| 6 | 7 | 8 |

| | | |
|---|---|---|
| 2 | 0 | 3 |
| 1 | 4 | 5 |
| 6 | 7 | 8 |

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 6 | 4 | 5 |
| 7 | 0 | 8 |

| | | |
|---|---|---|
| 1 | 0 | 3 |
| 4 | 2 | 5 |
| 6 | 7 | 8 |

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 7 | 5 |
| 6 | 0 | 8 |

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 5 | 0 |
| 6 | 7 | 8 |

success

# 8 puzzle using Iterative Deepening DFS

-1 => Blank Space

## I

sr

| | | |
|---|---|---|
| 1 | 2 | 3 |
| -1 | 4 | 5 |
| 6 | 7 | 8 |

goal

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 6 | 4 | 5 |
| -1 | 7 | 8 |

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 6 | 4 | 5 |
| -1 | 7 | 8 |

if depth = 1 limit

TRUE

## II

| | | |
|---|---|---|
| 1 | 2 | 3 |
| -1 | 4 | 5 |
| 6 | 7 | 8 |

goal

| | | |
|---|---|---|
| 2 | -1 | 3 |
| 1 | 4 | 5 |
| 6 | 7 | 8 |

| | | |
|---|---|---|
| -1 | 2 | 3 |
| 1 | 4 | 5 |
| 6 | 7 | 8 |

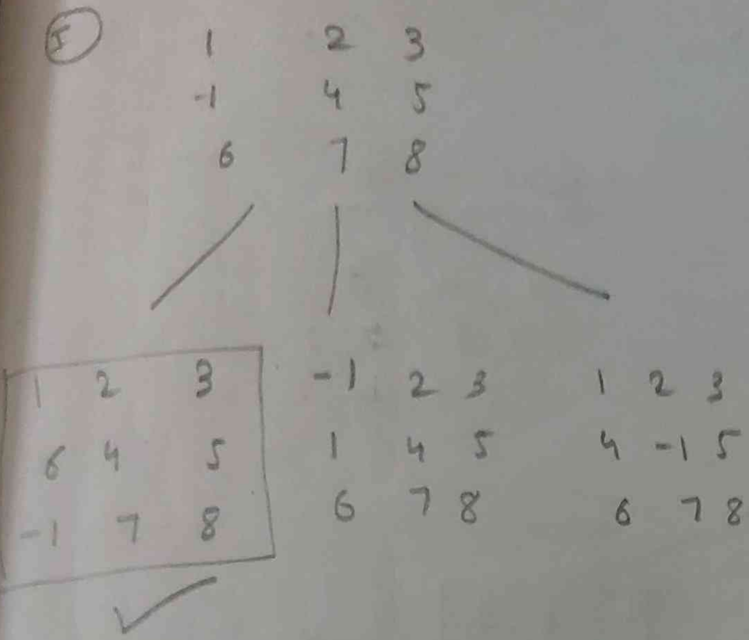
if depth limit = 1

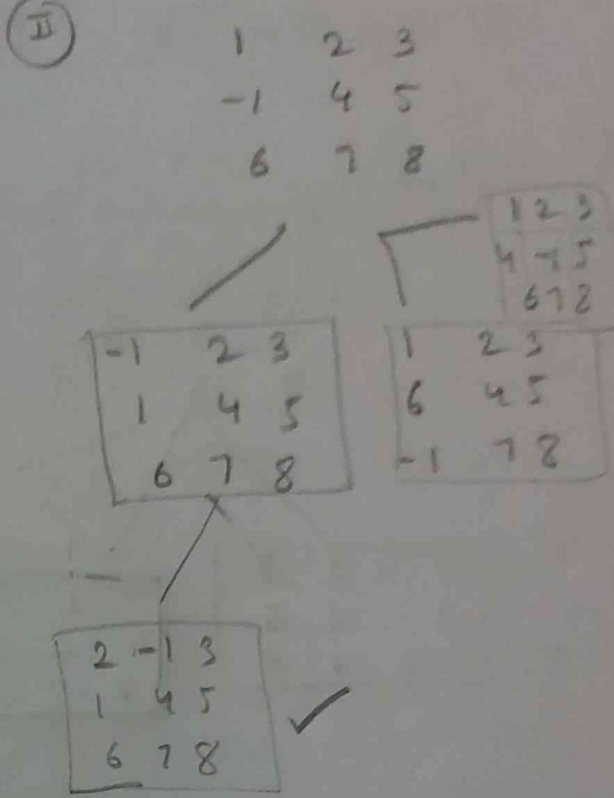
FALSE

if depth limit = 2

TRUE

| | | |
|---|---|---|
| 2 | -1 | 3 |
| 1 | 4 | 5 |
| 6 | 7 | 8 |



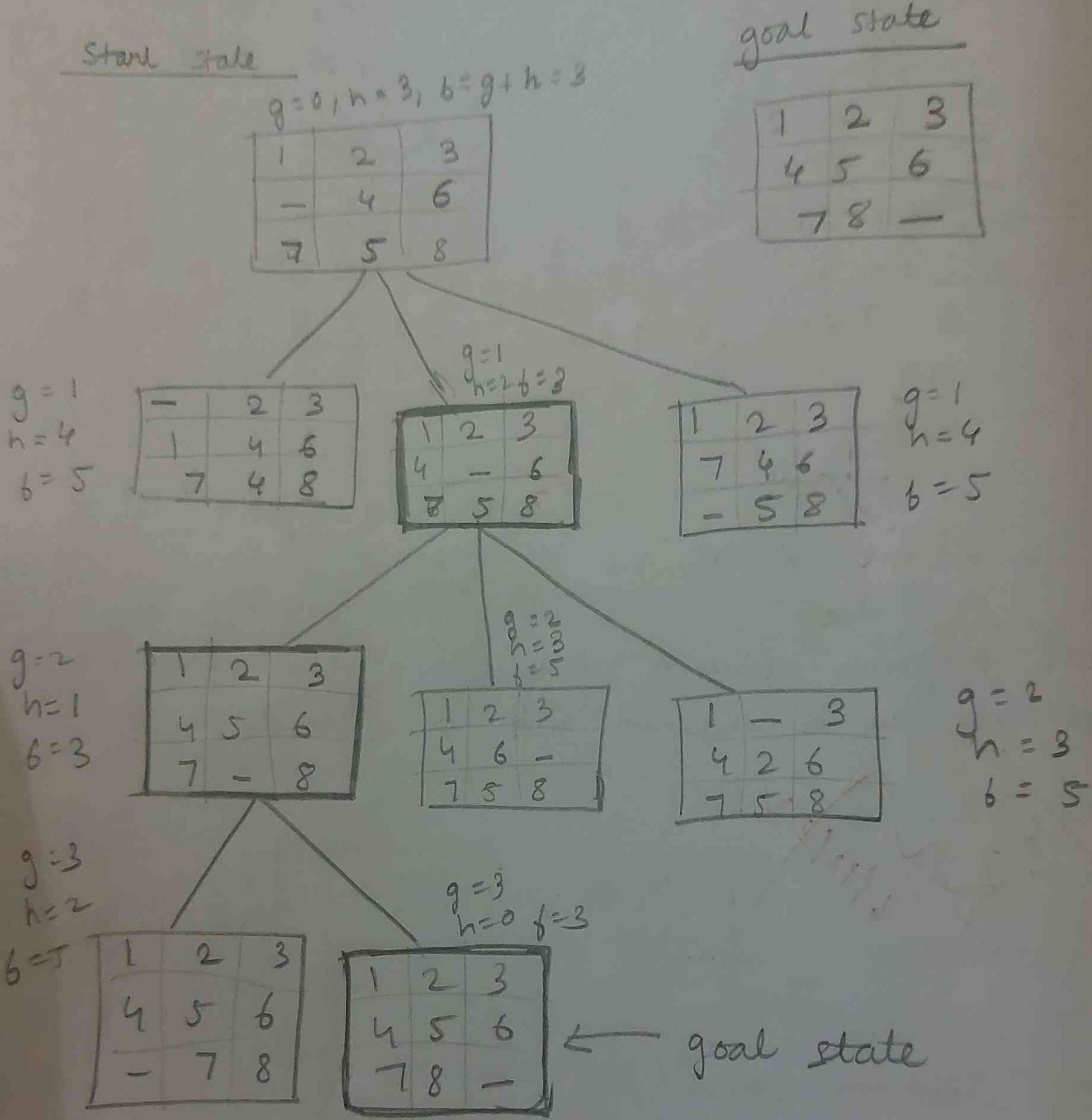




The IDDFS program gives a true/false output whether the goal state can be reached with the given depth.

10/10

6/12/23

# A* Algorithm for 8 puzzle




- A* algorithm makes use of cost as well as heuristic function to calculate $f(n) = g(n) + h(n)$.
- Based on the f value, the move is made towards the goal state (minimum f value is chosen)

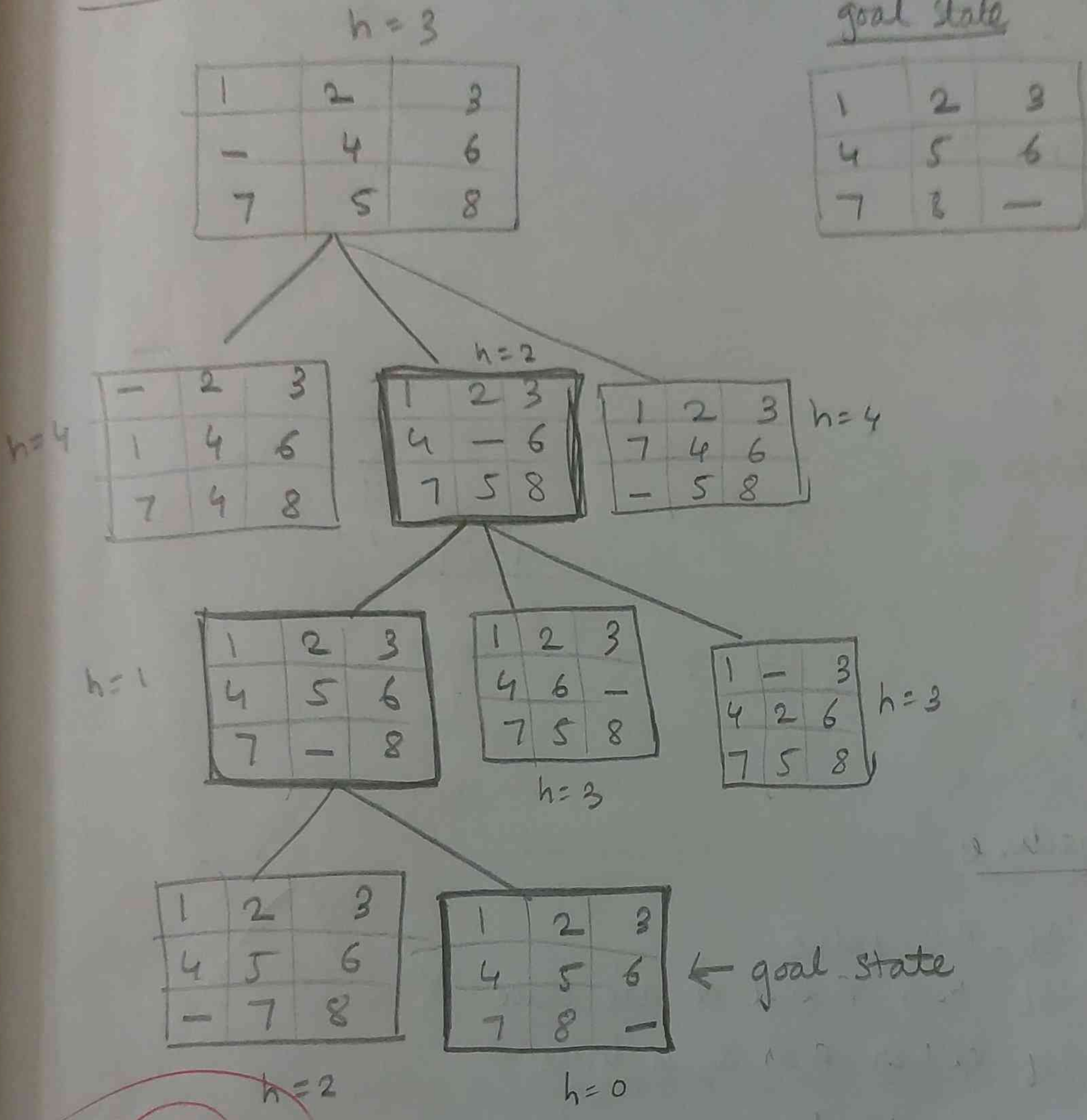
13.12.23

# Best-First Search Algorithm for 8 puzzle

11

Start State

goal State




10/10

- Best-First search algorithm is used to arrive at the goal state making use of the heuristic function
- Heuristic value of 8 puzzle is the number of ~~missing~~ ~~tile~~ misplaced tiles.
- Based on minimum heuristic value, the move is made towards goal state.

13/12/23

20.12.23

# Knowledge Base : Propositional Logic

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① $(\sim q \vee \sim p \vee r) \wedge (\sim q \wedge p) \wedge q$

query : r

② $(p \vee q) \wedge (\sim r \vee p)$

query : $p \wedge r$

$\sim$ - negation

$\wedge$ - and

$\vee$ - or

$\rightarrow$ - implies

$\leftrightarrow$ - biconditional

p - x[0]

q - x[1]

r - x[2]

## Logical connectives

$\sim P$ is true iff P is false

$P \wedge Q$ is true iff both P and Q are true

$P \vee Q$ is true iff either P or Q is true

$P \rightarrow Q$ is true unless P is true and Q is false $\sim P \vee Q$

$P \leftrightarrow Q$ is true iff P and Q are both true or both false (x

$P \leftrightarrow Q$

| P | Q | Output |
|---|---|---|
| T | T | T |
| T | F | F |
| F | T | F |
| T | T | T |

① rule: lambda x: (not x[1] or not x[0] or x[2]) and (not x[1] and x[0]) and x[1]

query: lamba x: x[2]

answer:

| kb | alpha |
| --- | --- |
| False | True |
| False | False |
| False | True |
| False | False |
| False | True |
| False | False |
| False | True |
| False | False |

10/10

Entails

② rule: lambda x: (x[0] or x[1]) and (not x[2] or x[0])

query: lambda x: (x[0] and x[2])

answer:

| kb | alpha |
| --- | --- |
| True | True |
| True | False |

Does not entail

20/12/23

14

27.12.23
Wednesday

# Knowledge Base: PL and proving query using resolution

(1)

$(P \wedge Q) \leftrightarrow R$ : $(R \vee \neg P) \vee (R \vee \neg Q) \wedge (\neg R \vee P) \wedge (\neg R \vee Q)$

KB: $R \vee \neg P$ $\quad R \vee \neg Q$ $\quad \neg R \vee P$ $\quad \neg R \vee Q$

query: R
↓
goal

$R \vee \neg P$ $\quad \neg R \vee Q$

→ $R \vee \neg P$
$R \vee \neg Q$
→ $\neg R \vee P$
$\neg R \vee Q$
| given

$R \vee \neg R$ → null

10/10

$R \vee \neg R$

$\neg R$ → contradiction (negation of goal)

$R$ → true

27/12/23

(2) KB: $R \vee Q$ | $P \vee R$ | $\neg P \vee R$ | $R \vee S$ | $R \vee \neg Q$ | $\neg S \vee \neg Q$

query: R

$P \vee Q$
$P \vee R$
$\neg P \vee R$
$R \vee S$
$R \vee \neg Q$
$\neg S \vee \neg Q$
| given

$\neg P \vee R$
$\neg R$

$\neg R$
$Q \vee R$
$P \vee \neg S$
$P$
$\neg P$
$R \vee \neg S$
$R$
$S$
$\neg Q$
$Q$
$\neg S$

$\neg R$ $\quad R$
$\neg R \vee R$ → null

$\neg R$ → contradiction

$R$ → true

# Unification : First Order Logic

10.1.24
Wednesday

15

unify(A1, A2)

- if A1 = A2
  true
- if A1 occurs in A2
  fail
  else
  A2/A1
- if A2 occurs in A1
  fail
  else
  A1/A2
- if diff predicates
- if diff arguments } fails

uppercase char → constant
lowercase char → variable

constants replace variable

eg: prime(11), prime(y)
same predicate
11 in place of y [11/y]
{constant in place of variable}
prime(11), prime(11)

① knows (f(x), y) knows (J, John)
knows (J, John)

substitutions : ['J / f(x)', 'John/y']

① knows = knows
f(x), J new = J
J → constant old = f(x)
[J / f(x)]

y, John
John → constant
[John / y] new = John
old = y

② student (x)
teacher (Rose)

student ≠ teacher
fails {different predicates}

10/1/24

③ knows (John, x) knows (John, Mother(y))
knows (y, Mother(y))

sub : ['John / y', 'Mother(y)/x']

③ knows = knows

John, y new = John
old = y
John → constant
[John / y]
x, Mother(y)
Mother(y) → constant
[Mother(y) / x]
New = Mother(y)
Old = x

④ like (A, y)
like (K, g(x))
A & K are both constants
fails.

17.1.24
Wednesday

## First Order Logic to Conjunctive Normal Form Conversion

{FOL to CNF}

### Test 1

Q: $\forall x$ food(x) $\Rightarrow$ likes(John, x)

$\sim \forall x$ food(x) V likes(John, x)

$\exists \sim$ food(x) V likes(John, x)

$\sim$food(A) V likes(John, A)

A: $\sim$ food(A) V likes(John, A)

### Test 2

Q: $\forall x$ [$\exists z$ [loves(x, z)]]

$\forall x$ [loves(x, B(x))] Skolem

[loves(x, B(x))]

A: [loves(x, B(x))]

### Test 3

Q: [american(x) ^ weapon(y) ^ sells(x, y, z) ^ hostile(z)] $\rightarrow$ Criminal(x)

A: [$\sim$american(x) V $\sim$weapon(y) V $\sim$sells(x, y, z) V $\sim$hostile(z)] V Criminal(x)

$\sim$[american(x) ^ weapon(y) ^ sells(x, y, z) ^ hostile(z)] V Criminal(x)

[$\sim$american(x) V $\sim$weapon(y) V $\sim$sells(x, y, z) V $\sim$hostile(z)] V Criminal(x)

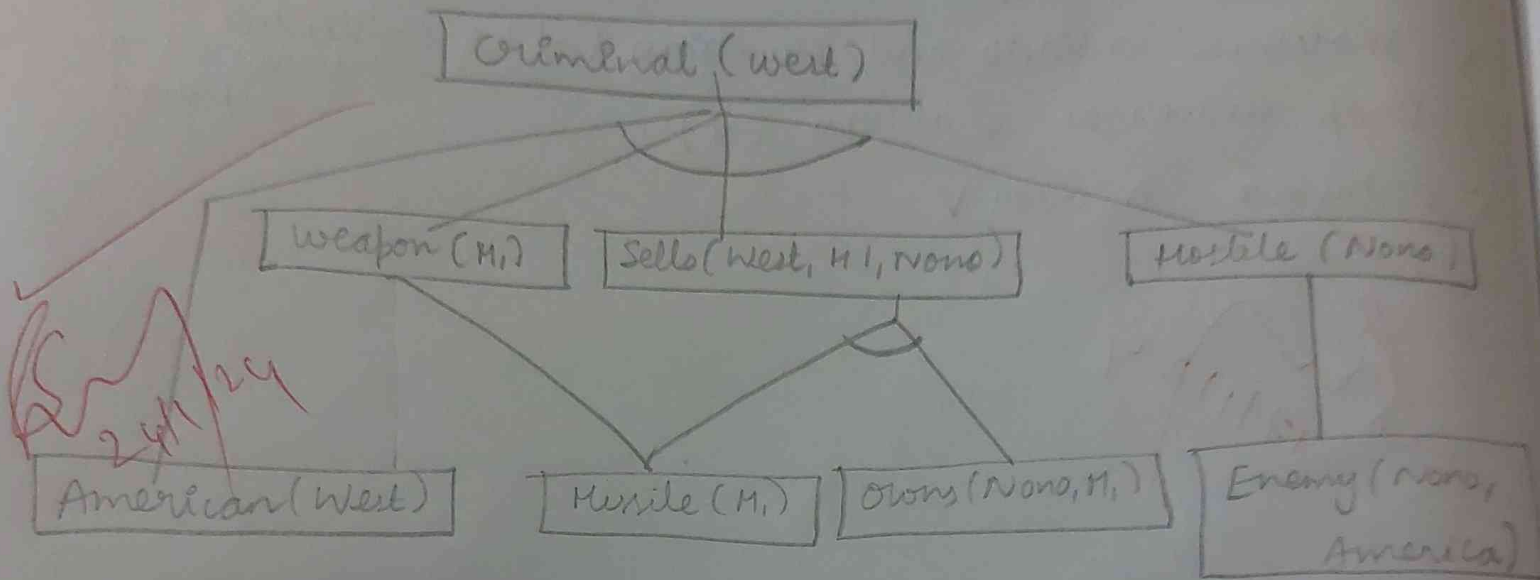
Steps to convert FOL to CNF

1. Eliminate biimplication and implication
2. Move negation (~) inwards
3. Standardize variables
4. Skolemize constants and functions (∃) → existential qualifiers are replaced
5. Drop universal qualifiers (∀)
6. Distribute ∧ over ∨

17/11/24

26.1.24
Wednesday

# Forward Reasoning




missile (x) ⇒ weapon (x)

missile (M1)

enemy (x, America) ⇒ hostile (x)

american (west)

enemy (nono, America)

owns (nono, M1)

missile (x) & owns (Nono, x) → sells (west, x, Nono)

american (x) & weapon (y) & sells (x, y, z) & hostile (z) → criminal (x)

Query: criminal (x)

## Table of Contents

1. **Implement TIC-TAC-TOE Game**

```
def printBoard(board):
print(board[1] + '|' + board[2] + '|' + board[3])
print('-+-+-')
print(board[4] + '|' + board[5] + '|' + board[6])
print('-+-+-')
print(board[7] + '|' + board[8] + '|' + board[9])
print("\n")
def spaceIsFree(position):
if board[position] == ' ':
return True
else:
return False
def insertLetter(letter, position):
if spaceIsFree(position):
board[position] = letter
printBoard(board)
if (checkDraw()):
print("Draw!")
exit()
if checkForWin():
if letter == 'X':
print("Bot wins!")
exit()
else:
print("Player wins!")
exit()
return
else:
```

```
print("Can't insert there!")
position = int(input("Please enter new position: "))
insertLetter(letter, position)
return
def checkForWin():
if (board[1] == board[2] and board[1] == board[3] and board[1] != ' '):
return True
elif (board[4] == board[5] and board[4] == board[6] and board[4] != ' '):
return True
elif (board[7] == board[8] and board[7] == board[9] and board[7] != ' '):
return True
elif (board[1] == board[4] and board[1] == board[7] and board[1] != ' '):
return True
elif (board[2] == board[5] and board[2] == board[8] and board[2] != ' '):
return True
elif (board[3] == board[6] and board[3] == board[9] and board[3] != ' '):
return True
elif (board[1] == board[5] and board[1] == board[9] and board[1] != ' '):
return True
elif (board[7] == board[5] and board[7] == board[3] and board[7] != ' '):
return True
else:
return False
def checkWhichMarkWon(mark):
if board[1] == board[2] and board[1] == board[3] and board[1] == mark:
return True
elif (board[4] == board[5] and board[4] == board[6] and board[4] == mark):
return True
elif (board[7] == board[8] and board[7] == board[9] and board[7] == mark):
return True
```

```
elif (board[1] == board[4] and board[1] == board[7] and board[1] == mark):
return True
elif (board[2] == board[5] and board[2] == board[8] and board[2] == mark):
return True
elif (board[3] == board[6] and board[3] == board[9] and board[3] == mark):
return True
elif (board[1] == board[5] and board[1] == board[9] and board[1] == mark):
return True
elif (board[7] == board[5] and board[7] == board[3] and board[7] == mark):
return True
else:
return False
def checkDraw():
for key in board.keys():
if (board[key] == ' '):
return False
return True
def playerMove():
position = int(input("Enter the position for 'O': "))
insertLetter(player, position)
return
def compMove():
bestScore = -800
bestMove = 0
for key in board.keys():
if (board[key] == ' '):
board[key] = bot
score = minimax(board, 0, False)
board[key] = ' '
if (score > bestScore):
```

```
bestScore = score
bestMove = key
insertLetter(bot, bestMove)
return
def minimax(board, depth, isMaximizing):
if (checkWhichMarkWon(bot)):
return 1
elif (checkWhichMarkWon(player)):
return -1
elif (checkDraw()):
return 0
if (isMaximizing):
bestScore = -800
for key in board.keys():
if (board[key] == ' '):
board[key] = bot
score = minimax(board, depth + 1, False)
board[key] = ' '
if (score > bestScore):
bestScore = score
return bestScore
else:
bestScore = 800
for key in board.keys():
if (board[key] == ' '):
board[key] = player
score = minimax(board, depth + 1, True)
board[key] = ' '
if (score < bestScore):
bestScore = score
```

```
return bestScore
board = {1: ' ', 2: ' ', 3: ' ',
4: ' ', 5: ' ', 6: ' ',
7: ' ', 8: ' ', 9: ' '}
printBoard(board)
print("Computer goes first! Good luck.")
print("Positions are as follow:")
print("1, 2, 3 ")
print("4, 5, 6 ")
print("7, 8, 9 ")
print("\n")
player = 'O'
bot = 'X'
global firstComputerMove
firstComputerMove = True
while not checkForWin():
compMove()
playerMove()
```

**OUTPUT**

```
 | |
-+-+-
 | |
-+-+-
 | |


Computer goes first! Good luck.
Positions are as follow:
1, 2, 3
4, 5, 6
7, 8, 9


X| |
-+-+-
 | |
-+-+-
 | |


Enter the position for 'O':  7
X| |
-+-+-
 | |
-+-+-
O| |


X|X|
-+-+-
 | |
-+-+-
O| |
```

```
Enter the position for 'O':  3
X|X|O
-+-+-
 | |
-+-+-
O| |


X|X|O
-+-+-
 |X|
-+-+-
O| |


Enter the position for 'O':  8
X|X|O
-+-+-
 |X|
-+-+-
O|O|


X|X|O
-+-+-
 |X|
-+-+-
O|O|X


Bot wins!
```

**2. Solve 8 Puzzle Problem**
**(using breadth first search)**

```
import numpy as np

import pandas as pd

import os


def bfs(src,target):
    queue = []
    queue.append(src)

    exp = []

    while len(queue) > 0:
        source = queue.pop(0)
        exp.append(source)

        print(source)

        if source==target:
            print("success")
            return

        poss_moves_to_do = []
        poss_moves_to_do = possible_moves(source,exp)

        for move in poss_moves_to_do:

            if move not in exp and move not in queue:
                queue.append(move)

def possible_moves(state,visited_states):
```

```
    #index of empty spot
    b = state.index(-1)

    #directions array
    d = []
    #Add all the possible directions

    if b not in [-1,1,2]:
        d.append('u')
    if b not in [6,7,8]:
        d.append('d')
    if b not in [-1,3,6]:
        d.append('l')
    if b not in [2,5,8]:
        d.append('r')


    # If direction is possible then add state to move
    pos_moves_it_can = []

    # for all possible directions find the state if that move is played
    ### Jump to gen function to generate all possible moves in the given
directions

    for i in d:
        pos_moves_it_can.append(gen(state,i,b))

    return [move_it_can for move_it_can in pos_moves_it_can if move_it_can
not in visited_states]

def gen(state, m, b):
    temp = state.copy()
```

```
    if m=='d':
        temp[b+3],temp[b] = temp[b],temp[b+3]

    if m=='u':
        temp[b-3],temp[b] = temp[b],temp[b-3]

    if m=='l':
        temp[b-1],temp[b] = temp[b],temp[b-1]

    if m=='r':
        temp[b+1],temp[b] = temp[b],temp[b+1]


    # return new state with tested move to later check if "src == target"
    return temp
```

**OUTPUT**

```
src = [1,2,3,-1,4,5,6,7,8]
target = [1,2,3,4,5,-1,6,7,8]
bfs(src, target)
```

```
[1, 2, 3, -1, 4, 5, 6, 7, 8]
[-1, 2, 3, 1, 4, 5, 6, 7, 8]
[1, 2, 3, 6, 4, 5, -1, 7, 8]
[1, 2, 3, 4, -1, 5, 6, 7, 8]
[6, 2, 3, 1, 4, 5, -1, 7, 8]
[8, 2, 3, 1, 4, 5, 6, 7, -1]
[2, -1, 3, 1, 4, 5, 6, 7, 8]
[1, 2, 3, 6, 4, 5, 7, -1, 8]
[1, -1, 3, 4, 2, 5, 6, 7, 8]
[1, 2, 3, 4, 7, 5, 6, -1, 8]
[1, 2, 3, 4, 5, -1, 6, 7, 8]
success
```

```
src = [2,-1,3,1,8,4,7,6,5]
target = [1,2,3,8,-1,4,7,6,5]
bfs(src, target)
```

```
[2, -1, 3, 1, 8, 4, 7, 6, 5]
[2, 8, 3, 1, -1, 4, 7, 6, 5]
[-1, 2, 3, 1, 8, 4, 7, 6, 5]
[2, 3, -1, 1, 8, 4, 7, 6, 5]
[2, 8, 3, 1, 6, 4, 7, -1, 5]
[2, 8, 3, -1, 1, 4, 7, 6, 5]
[2, 8, 3, 1, 4, -1, 7, 6, 5]
[7, 2, 3, 1, 8, 4, -1, 6, 5]
[1, 2, 3, -1, 8, 4, 7, 6, 5]
[5, 2, 3, 1, 8, 4, 7, 6, -1]
[2, 3, 4, 1, 8, -1, 7, 6, 5]
[2, 8, 3, 1, 6, 4, -1, 7, 5]
[2, 8, 3, 1, 6, 4, 7, 5, -1]
[-1, 8, 3, 2, 1, 4, 7, 6, 5]
[2, 8, 3, 7, 1, 4, -1, 6, 5]
[2, 8, -1, 1, 4, 3, 7, 6, 5]
[2, 8, 3, 1, 4, 5, 7, 6, -1]
[7, 2, 3, -1, 8, 4, 1, 6, 5]
[7, 2, 3, 1, 8, 4, 6, -1, 5]
[1, 2, 3, 7, 8, 4, -1, 6, 5]
[1, 2, 3, 8, -1, 4, 7, 6, 5]
success
```

**3. Implement Iterative deepening search algorithm**

```
def dfs(src,target,limit,visited_states):
    if src == target:
        return True
    if limit <= 0:
        return False
    visited_states.append(src)
    moves = possible_moves(src,visited_states)
    for move in moves:
        if dfs(move, target, limit-1, visited_states):
            return True
    return False

def possible_moves(state,visited_states):
    b = state.index(-1)
    d = []
    if b not in [0,1,2]:
        d += 'u'
    if b not in [6,7,8]:
        d += 'd'
    if b not in [2,5,8]:
        d += 'r'
    if b not in [0,3,6]:
        d += 'l'
    pos_moves = []
    for move in d:
        pos_moves.append(gen(state,move,b))
    return [move for move in pos_moves if move not in visited_states]

def gen(state, move, blank):
```

```
    temp = state.copy()
    if move == 'u':
        temp[blank-3], temp[blank] = temp[blank], temp[blank-3]
    if move == 'd':
        temp[blank+3], temp[blank] = temp[blank], temp[blank+3]
    if move == 'r':
        temp[blank+1], temp[blank] = temp[blank], temp[blank+1]
    if move == 'l':
        temp[blank-1], temp[blank] = temp[blank], temp[blank-1]
    return temp

def iddfs(src,target,depth):
     for i in range(depth):
        visited_states = []
        if dfs(src,target,i+1,visited_states):
            return True
     return False

src = []
target=[]
n = int(input("Enter number of elements : "))
print("Enter source elements")
for i in range(0, n):
    ele = int(input())
    src.append(ele)
print("Enter target elements")
for i in range(0, n):
    ele = int(input())
    target.append(ele)
depth=8
```

```
iddfs(src, target,depth)
```

**OUTPUT**

```
Enter number of elements : 9
Enter source elements
1
2
3
-1
4
5
6
7
8
Enter target elements
1
2
3
4
5
-1
6
7
8
True
```

**4. 8 Puzzle: Implement A* Search Algorithm**

```
class Node:
    def __init__(self, data, level, fval):
        # Initialize the node with the data ,level of the node and the calculated fvalue
        self.data = data
        self.level = level
        self.fval = fval

    def generate_child(self):
        # Generate hild nodes from the given node by moving the blank space
        # either in the four direction {up,down,left,right}
        x, y = self.find(self.data, '_')
        # val_list contains position values for moving the blank space in either of
        # the 4 direction [up,down,left,right] respectively.
        val_list = [[x, y - 1], [x, y + 1], [x - 1, y], [x + 1, y]]
        children = []
        for i in val_list:
            child = self.shuffle(self.data, x, y, i[0], i[1])
            if child is not None:
                child_node = Node(child, self.level + 1, 0)
                children.append(child_node)
        return children

    def shuffle(self, puz, x1, y1, x2, y2):
        # Move the blank space in the given direction and if the position value are out
        # of limits the return None
        if x2 >= 0 and x2 < len(self.data) and y2 >= 0 and y2 < len(self.data):
            temp_puz = []
            temp_puz = self.copy(puz)
            temp = temp_puz[x2][y2]
```

```
            temp_puz[x2][y2] = temp_puz[x1][y1]
            temp_puz[x1][y1] = temp
            return temp_puz
        else:
            return None

    def copy(self, root):
        # copy function to create a similar matrix of the given node
        temp = []
        for i in root:
            t = []
            for j in i:
                t.append(j)
            temp.append(t)
        return temp

    def find(self, puz, x):
        # Specifically used to find the position of the blank space
        for i in range(0, len(self.data)):
            for j in range(0, len(self.data)):
                if puz[i][j] == x:
                    return i, j


class Puzzle:
    def __init__(self, size):
        # Initialize the puzzle size by the the specified size,open and closed lists to empty
        self.n = size
        self.open = []
        self.closed = []
```

```
def accept(self):
    # Accepts the puzzle from the user
    puz = []
    for i in range(0, self.n):
        temp = input().split(" ")
        puz.append(temp)
    return puz

def f(self, start, goal):
    # Heuristic function to calculate Heuristic value f(x) = h(x) + g(x)
    return self.h(start.data, goal) + start.level

def h(self, start, goal):
    # Calculates the difference between the given puzzles
    temp = 0
    for i in range(0, self.n):
        for j in range(0, self.n):
            if start[i][j] != goal[i][j] and start[i][j] != '_':
                temp += 1
    return temp

def process(self):
    # Accept Start and Goal Puzzle state
    print("enter the start state matrix \n")
    start = self.accept()
    print("enter the goal state matrix \n")
    goal = self.accept()
    start = Node(start, 0, 0)
    start.fval = self.f(start, goal)
```

```
        # put the start node in the open list
        self.open.append(start)
        print("\n\n")
        while True:
            cur = self.open[0]
            print("======================================================\n")
            for i in cur.data:
                for j in i:
                    print(j, end=" ")
                print("")
            # if the difference between current and goal node is 0 we have reached the goal node
            if (self.h(cur.data, goal) == 0):
                break
            for i in cur.generate_child():
                i.fval = self.f(i, goal)
                self.open.append(i)
            self.closed.append(cur)
            del self.open[0]
            # sort the open list based on f value
            self.open.sort(key=lambda x: x.fval, reverse=False)
puz = Puzzle(3)
puz.process()
```

**OUTPUT**

```
enter the start state matrix

1 2 3
_ 4 6
7 5 8
enter the goal state matrix

1 2 3
4 5 6
7 8 _



==================================================

1 2 3
_ 4 6
7 5 8
==================================================

1 2 3
4 _ 6
7 5 8
==================================================

1 2 3
4 5 6
7 _ 8
==================================================

1 2 3
4 5 6
7 8 _
```

**5.Implement Vacuum Cleaner Agent**

```
def vacuum_world():
        # initializing goal_state
        # 0 indicates Clean and 1 indicates Dirty
    goal_state = {'A': '0', 'B': '0'}
    cost = 0

    location_input = input("Enter Location of Vacuum") #user_input of location vacuum is placed
    status_input = input("Enter status of " + location_input) #user_input if location is dirty or clean
    status_input_complement = input("Enter status of other room")
    print("Initial Location Condition" + str(goal_state))

    if location_input == 'A':
        # Location A is Dirty.
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            # suck the dirt  and mark it as clean
            goal_state['A'] = '0'
            cost += 1                      #cost for suck
            print("Cost for CLEANING A " + str(cost))
            print("Location A has been Cleaned.")

            if status_input_complement == '1':
                # if B is Dirty
                print("Location B is Dirty.")
                print("Moving right to the Location B. ")
                cost += 1                      #cost for moving right
                print("COST for moving RIGHT" + str(cost))
                # suck the dirt and mark it as clean
```

```
            goal_state['B'] = '0'
            cost += 1                       #cost for suck
            print("COST for SUCK " + str(cost))
            print("Location B has been Cleaned. ")
        else:
            print("No action" + str(cost))
            # suck and mark clean
            print("Location B is already clean.")

    if status_input == '0':
        print("Location A is already clean ")
        if status_input_complement == '1':# if B is Dirty
            print("Location B is Dirty.")
            print("Moving RIGHT to the Location B. ")
            cost += 1                       #cost for moving right
            print("COST for moving RIGHT " + str(cost))
            # suck the dirt and mark it as clean
            goal_state['B'] = '0'
            cost += 1                       #cost for suck
            print("Cost for SUCK" + str(cost))
            print("Location B has been Cleaned. ")
        else:
            print("No action " + str(cost))
            print(cost)
            # suck and mark clean
            print("Location B is already clean.")

else:
    print("Vacuum is placed in location B")
    # Location B is Dirty.
```

```
if status_input == '1':
    print("Location B is Dirty.")
    # suck the dirt  and mark it as clean
    goal_state['B'] = '0'
    cost += 1  # cost for suck
    print("COST for CLEANING " + str(cost))
    print("Location B has been Cleaned.")

    if status_input_complement == '1':
        # if A is Dirty
        print("Location A is Dirty.")
        print("Moving LEFT to the Location A. ")
        cost += 1  # cost for moving right
        print("COST for moving LEFT" + str(cost))
        # suck the dirt and mark it as clean
        goal_state['A'] = '0'
        cost += 1  # cost for suck
        print("COST for SUCK " + str(cost))
        print("Location A has been Cleaned.")

else:
    print(cost)
    # suck and mark clean
    print("Location B is already clean.")

    if status_input_complement == '1':  # if A is Dirty
        print("Location A is Dirty.")
        print("Moving LEFT to the Location A. ")
        cost += 1  # cost for moving right
        print("COST for moving LEFT " + str(cost))
```

```
            # suck the dirt and mark it as clean
            goal_state['A'] = '0'
            cost += 1  # cost for suck
            print("Cost for SUCK " + str(cost))
            print("Location A has been Cleaned. ")
        else:
            print("No action " + str(cost))
            # suck and mark clean
            print("Location A is already clean.")

    # done cleaning
    print("GOAL STATE: ")
    print(goal_state)
    print("Performance Measurement: " + str(cost))



vacuum_world()
```

**OUTPUT**

```
Enter Location of VacuumA
Enter status of A1
Enter status of other room1
Initial Location Condition{'A': '0', 'B': '0'}
Vacuum is placed in Location A
Location A is Dirty.
Cost for CLEANING A 1
Location A has been Cleaned.
Location B is Dirty.
Moving right to the Location B.
COST for moving RIGHT2
COST for SUCK 3
Location B has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 3
```

```
vacuum_world()
```

```
Enter Location of VacuumA
Enter status of A0
Enter status of other room0
Initial Location Condition{'A': '0', 'B': '0'}
Vacuum is placed in Location A
Location A is already clean
No action 0
0
Location B is already clean.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 0
```

```
Enter Location of VacuumB
Enter status of B0
Enter status of other room1
Initial Location Condition{'A': '0', 'B': '0'}
Vacuum is placed in location B
0
Location B is already clean.
Location A is Dirty.
Moving LEFT to the Location A.
COST for moving LEFT 1
Cost for SUCK 2
Location A has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 2
```

**6. Create a knowledge base using prepositional logic and show that the given query entails the knowledge base or not .**

```
def tell(kb, rule):
    kb.append(rule)

combinations = [(True, True, True), (True, True, False),
                (True, False, True), (True, False, False),
                (False, True, True), (False, True, False),
                (False, False, True), (False, False, False)]



def ask(kb, q):
    for c in combinations:
        s = all(rule(c) for rule in kb)
        f = q(c)
        print(s, f)
        if s != f and s != False:
            return 'Does not entail'
    return 'Entails'



kb = []

# Get user input for Rule 1
rule_str = input("Enter Rule 1 as a lambda function (e.g., lambda x: x[0] or x[1] and (x[0] and x[1]): ")
r1 = eval(rule_str)
tell(kb, r1)

# Get user input for Rule 2
```

```
#rule_str = input("Enter Rule 2 as a lambda function (e.g., lambda x: (x[0] or x[1]) and x[2]): ")
#r2 = eval(rule_str)
#tell(kb, r2)

# Get user input for Query
query_str = input("Enter Query as a lambda function (e.g., lambda x: x[0] and x[1] and (x[0] or x[1]): ")
q = eval(query_str)

# Ask KB Query
result = ask(kb, q)
print(result)
```

**OUTPUT**

```
Enter Rule 1 as a lambda function (e.g., lambda x: x[0] or x[1] and (x[0] and x[1]): lambda x:  (x[0] or x[1]) and ( not x[2] or x[0])
Enter Query as a lambda function (e.g., lambda x: x[0] and x[1] and (x[0] or x[1]): lambda x:  (x[0] and x[2])
True True
True False
Does not entail
```

**7. Create a knowledge base using prepositional logic and prove the given query using resolution**

```
import re

def main(rules, goal):
    rules = rules.split(' ')
    steps = resolve(rules, goal)
    print('\nStep\t|Clause\t|Derivation\t')
    print('-' * 30)
    i = 1
    for step in steps:
        print(f' {i}.\t| {step}\t| {steps[step]}\t')
        i += 1

def negate(term):
    return f'~{term}' if term[0] != '~' else term[1]

def reverse(clause):
    if len(clause) > 2:
        t = split_terms(clause)
        return f'{t[1]}v{t[0]}'
    return ''

def split_terms(rule):
    exp = '(~*[PQRS])'
    terms = re.findall(exp, rule)
    return terms

def contradiction(goal, clause):
```

```
    contradictions = [ f'{goal}v{negate(goal)}', f'{negate(goal)}v{goal}']
    return clause in contradictions or reverse(clause) in contradictions

def resolve(rules, goal):
    temp = rules.copy()
    temp += [negate(goal)]
    steps = dict()
    for rule in temp:
        steps[rule] = 'Given.'
    steps[negate(goal)] = 'Negated conclusion.'
    i = 0
    while i < len(temp):
        n = len(temp)
        j = (i + 1) % n
        clauses = []
        while j != i:
            terms1 = split_terms(temp[i])
            terms2 = split_terms(temp[j])
            for c in terms1:
                if negate(c) in terms2:
                    t1 = [t for t in terms1 if t != c]
                    t2 = [t for t in terms2 if t != negate(c)]
                    gen = t1 + t2
                    if len(gen) == 2:
                        if gen[0] != negate(gen[1]):
                            clauses += [f'{gen[0]}v{gen[1]}']
                        else:
                            if contradiction(goal,f'{gen[0]}v{gen[1]}'):
                                temp.append(f'{gen[0]}v{gen[1]}')
                                steps[''] = f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \
```

```
                \nA contradiction is found when {negate(goal)} is assumed as true. Hence, {goal} is
true."
                return steps
            elif len(gen) == 1:
                clauses += [f'{gen[0]}']
            else:
                if contradiction(goal,f'{terms1[0]}v{terms2[0]}'):
                    temp.append(f'{terms1[0]}v{terms2[0]}')
                    steps[''] = f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \
                    \nA contradiction is found when {negate(goal)} is assumed as true. Hence, {goal} is true."
                    return steps
        for clause in clauses:
            if clause not in temp and clause != reverse(clause) and reverse(clause) not in temp:
                temp.append(clause)
                steps[clause] = f'Resolved from {temp[i]} and {temp[j]}.'
        j = (j + 1) % n
    i += 1
return steps

rules = 'Rv~P Rv~Q ~RvP ~RvQ' #(P^Q)<=>R : (Rv~P)v(Rv~Q)^(~RvP)^(~RvQ)
goal = 'R'
main(rules, goal)
 rules = 'PvQ ~PvR ~QvR' #P=vQ, P=>Q : ~PvQ, Q=>R, ~QvR
goal = 'R'
main(rules, goal)
```

**OUTPUT**

```
Step     |Clause |Derivation
------------------------------
 1.      | Rv~P  | Given.
 2.      | Rv~Q  | Given.
 3.      | ~RvP  | Given.
 4.      | ~RvQ  | Given.
 5.      | ~R    | Negated conclusion.
 6.      |       | Resolved Rv~P and ~RvP to Rv~R, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.

Step     |Clause |Derivation
------------------------------
 1.      | PvQ   | Given.
 2.      | ~PvR  | Given.
 3.      | ~QvR  | Given.
 4.      | ~R    | Negated conclusion.
 5.      | QvR   | Resolved from PvQ and ~PvR.
 6.      | PvR   | Resolved from PvQ and ~QvR.
 7.      | ~P    | Resolved from ~PvR and ~R.
 8.      | ~Q    | Resolved from ~QvR and ~R.
 9.      | Q     | Resolved from ~R and QvR.
 10.     | P     | Resolved from ~R and PvR.
 11.     | R     | Resolved from QvR and ~Q.
 12.     |       | Resolved R and ~R to Rv~R, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.
```

**8. Implement unification in first order logic**

```
import re

def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = "(".join(expression)
    expression = expression[:-1]
    expression = re.split("(?<!\(.),(?!.\))", expression)
    return expression

def getInitialPredicate(expression):
    return expression.split("(")[0]

def isConstant(char):
    return char.isupper() and len(char) == 1

def isVariable(char):
    return char.islower() and len(char) == 1

def replaceAttributes(exp, old, new):
    attributes = getAttributes(exp)
    for index, val in enumerate(attributes):
        if val == old:
            attributes[index] = new
    predicate = getInitialPredicate(exp)
    return predicate + "(" + ",".join(attributes) + ")"

def apply(exp, substitutions):
    for substitution in substitutions:
        new, old = substitution
```

```
        exp = replaceAttributes(exp, old, new)
    return exp

def checkOccurs(var, exp):
    if exp.find(var) == -1:
        return False
    return True

def getFirstPart(expression):
    attributes = getAttributes(expression)
    return attributes[0]

def getRemainingPart(expression):
    predicate = getInitialPredicate(expression)
    attributes = getAttributes(expression)
    newExpression = predicate + "(" + ",".join(attributes[1:]) + ")"
    return newExpression

def unify(exp1, exp2):
    if exp1 == exp2:
        return []
    if isConstant(exp1) and isConstant(exp2):
        if exp1 != exp2:
            return False
    if isConstant(exp1):
        return [(exp1, exp2)]
    if isConstant(exp2):
        return [(exp2, exp1)]
    if isVariable(exp1):
        if checkOccurs(exp1, exp2):
```

```
            return False
        else:
            return [(exp2, exp1)]
    if isVariable(exp2):
        if checkOccurs(exp2, exp1):
            return False
        else:
            return [(exp1, exp2)]
    if getInitialPredicate(exp1) != getInitialPredicate(exp2):
        print("Predicates do not match. Cannot be unified")
        return False
    attributeCount1 = len(getAttributes(exp1))
    attributeCount2 = len(getAttributes(exp2))
    if attributeCount1 != attributeCount2:
        return False
    head1 = getFirstPart(exp1)
    head2 = getFirstPart(exp2)
    initialSubstitution = unify(head1, head2)
    if not initialSubstitution:
        return False
    if attributeCount1 == 1:
        return initialSubstitution
    tail1 = getRemainingPart(exp1)
    tail2 = getRemainingPart(exp2)
    if initialSubstitution != []:
        tail1 = apply(tail1, initialSubstitution)
        tail2 = apply(tail2, initialSubstitution)
    remainingSubstitution = unify(tail1, tail2)
    if not remainingSubstitution:
        return False
```

```
    initialSubstitution.extend(remainingSubstitution)
    return initialSubstitution

exp1 = "knows(A,x)"
exp2 = "knows(y,mother(y))"
substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)
```

**OUTPUT**

```
Substitutions:
[('A', 'y'), ('mother(y)', 'x')]
```

**9. Convert a given first order logic statement into Conjunctive Normal Form (CNF)**

```
import re
def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return [m for m in str(matches) if m.isalpha()]

def getPredicates(string):
    expr = '[a-z~]+\([A-Za-z,]+\)'
    return re.findall(expr, string)

def Skolemization(statement):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'), ord('Z')+1)]
    matches = re.findall('[∃].', statement)
    for match in matches[::-1]:
        statement = statement.replace(match, '')
        for predicate in getPredicates(statement):
            attributes = getAttributes(predicate)
            if ''.join(attributes).islower():
                statement = statement.replace(match[1],SKOLEM_CONSTANTS.pop(0))
    return statement

def fol_to_cnf(fol):
    statement = fol.replace("=>", "-")
    expr = '\[([^]]+)\]'
    statements = re.findall(expr, statement)
    print(statements)
    for i, s in enumerate(statements):
        if '[' in s and ']' not in s:
```

```
            statements[i] += ']'
    for s in statements:
        statement = statement.replace(s, fol_to_cnf(s))
    while '-' in statement:
        i = statement.index('-')
        br = statement.index('[') if '[' in statement else 0
        new_statement = '~' + statement[br:i] + '|' + statement[i+1:]
        statement = statement[:br] + new_statement if br > 0 else new_statement
    return Skolemization(statement)

print(fol_to_cnf("bird(x)=>~fly(x)"))
print(fol_to_cnf("∃x[bird(x)=>~fly(x)]"))
```

**OUTPUT**

```
~bird(x)|~fly(x)
[~bird(A)|~fly(A)]
```

**10. Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning.**

```
import re
def isVariable(x):
    return len(x) == 1 and x.islower() and x.isalpha()

def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return matches

def getPredicates(string):
    expr = '([a-z~]+)\([^&|]+\)'
    return re.findall(expr, string)

class Fact:
    def __init__(self, expression):
        self.expression = expression
        predicate, params = self.splitExpression(expression)
        self.predicate = predicate
        self.params = params
        self.result = any(self.getConstants())

    def splitExpression(self, expression):
        predicate = getPredicates(expression)[0]
        params = getAttributes(expression)[0].strip('()').split(',')
        return [predicate, params]

    def getResult(self):
```

```
        return self.result

    def getConstants(self):
        return [None if isVariable(c) else c for c in self.params]

    def getVariables(self):
        return [v if isVariable(v) else None for v in self.params]

    def substitute(self, constants):
        c = constants.copy()
        f = f"{self.predicate}({','.join([constants.pop(0) if isVariable(p) else p for p in self.params])})"
        return Fact(f)

class Implication:
    def __init__(self, expression):
        self.expression = expression
        l = expression.split('=>')
        self.lhs = [Fact(f) for f in l[0].split('&')]
        self.rhs = Fact(l[1])

    def evaluate(self, facts):
        constants = {}
        new_lhs = []
        for fact in facts:
            for val in self.lhs:
                if val.predicate == fact.predicate:
                    for i, v in enumerate(val.getVariables()):
                        if v:
                            constants[v] = fact.getConstants()[i]
                    new_lhs.append(fact)
```

```
        predicate, attributes = getPredicates(self.rhs.expression)[0], str(getAttributes(self.rhs.expression)[0])
        for key in constants:
            if constants[key]:
                attributes = attributes.replace(key, constants[key])
        expr = f'{predicate}{attributes}'
        return Fact(expr) if len(new_lhs) and all([f.getResult() for f in new_lhs]) else None

class KB:
    def __init__(self):
        self.facts = set()
        self.implications = set()

    def tell(self, e):
        if '=>' in e:
            self.implications.add(Implication(e))
        else:
            self.facts.add(Fact(e))
        for i in self.implications:
            res = i.evaluate(self.facts)
            if res:
                self.facts.add(res)

    def query(self, e):
        facts = set([f.expression for f in self.facts])
        i = 1
        print(f'Querying {e}:')
        for f in facts:
            if Fact(f).predicate == Fact(e).predicate:
                print(f'\t{i}. {f}')
                i += 1
```

```
    def display(self):
        print("All facts: ")
        for i, f in enumerate(set([f.expression for f in self.facts])):
            print(f'\t{i+1}. {f}')
kb_ = KB()
kb_.tell('king(x)&greedy(x)=>evil(x)')
kb_.tell('king(John)')
kb_.tell('greedy(John)')
kb_.tell('king(Richard)')
kb_.query('evil(x)')
```

**OUTPUT**

```
Querying evil(x):
        1. evil(John)
```