VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence LAB

Submitted by

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in partial fulfillment for the award of the degree of
BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING
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(Affiliated To Visvesvaraya Technological University, Belgaum)

Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence lab" carried out by **ROHAN SATISH KUMAR(1BM21CS168),** who is a bonafide student of **B. M. S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2023. The Lab report has been approved as it satisfies the academic requirementsin respect of a **Artificial Intelligence lab (22CS5PCAIN)** work prescribed for the said degree.

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Program 1:
Implement the vacuum cleaner program(20/11/23)

```
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()
```

Program-01

Implement vacuum cleaner agent.

```
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 status of other room")
    print("Initial location condition" + str(goal_State))
    if location_input == 'A':
        print("Location A is dirty")
        goal_state['A'] = '0'
        cost += 1
        print("cost for cleaning A" + str(cost))
        print("location A has been cleaned")
        if status_input_complement == '1':
            print("location B is dirty")
            print("Moving right to the location B")
            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(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)
if status_input_complement == '1':
print(" location A has been 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()
```

Output:

```
Enter location of vacuum B
Enter status of B 0
Enter status of other room 1
Initial location condition {'A': '0', 'B': '0'}
location A is already clean
Location B is dirty
Moving right to location B
cost for moving right 1
Cost for Suck 2
location B has been cleaned.
```

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.
```

Program 2:

Implement the 8 Puzzle Bíeadth Ïiíst Seaích Algoíithm.(11/12/23)

```
import numpy as np
import pandas as pd
import os

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

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

    return temp  # Return the modified state

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')

    pos_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 bfs(src, target):
    queue = []
    queue.append(src)
    cost=0

    exp = []

    while len(queue) > 0:
        source = queue.pop(0)
        exp.append(source)
        print("queue")
        for q in queue:
          print(q)
          print("..........***..........")

        print(source[0],'|',source[1],'|',source[2])
        print(source[3],'|',source[4],'|', source[5])
        print(source[6],'|', source[7],'|',source[8])
        print()
        cost=cost+1

        if source == target:
            print("success")
            print("path cost",cost)
            return
```

```
        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)

src = [1, 2, 3, 4, 5, 6, 0, 7, 8]
target = [1, 2, 3, 4, 5, 6, 7, 8, 0]
bfs(src, target)
```

11-Dec-2017

- Explore the working of Tic Tac Toe using min max strategy.

```
import sys

def print_board(board):
    for row in board:
        print(" ".join(row))
    print()

def check_winner(board, player):
    for i in range(3):
        if all(board[i][j] == player for j in
                range(3)):
            return True
        if all(board[i][j] == player for j in
                range(3)):
            return True

    if all(board[i][i] == player for i in range(3)
        or all(board[i][2-i] == player for i in
                range(3)):
            return True
    return False

def is_board_full(board):
    return all(board[i][j] != ' ' for i in range(
                for j in range(3))
```

```
def minimax(board, depth, is_maximizer):
    scores = {
        'x' : 10-depth,
        'o' : depth-10,
        'Tie' : 0
    }

    if check_winner(board, 'x'):
        return scores['x']
    elif check_winner(board, 'o'):
        return scores['o']
    elif is_board_full(board):
        return scores['Tie']

    if is_maximizer:
        best_score = -sys.maxsize
        for i in range(3):
            for j in range(3):
                if board[i][j] == ' ':
                    board[i][j] = 'x'
                    score = minimax(board, depth+1,
                                    False)
                    board[i][j] = ' '
                    best_score = max(best_score, score)
        return best_score
    else:
        best_score = sys.maxsize
        for i in range(3):
            for j in range(3):
                if board[i][j] = ' ':
```

```
                board[i][j] = 'O'
                score = minimax(board, depth+1, True)
                board[i][j] = ' '
                best_score = min(best_score, score)
        return best_score

def find_best_move(board):
    best_score = -sys.maxsize
    best_move = (-1, -1)

    for i in range(3):
        for j in range(3):
            if board[i][j] == ' ':
                board[i][j] = 'X'
                score = minimax(board, 0, False)
                board[i][j] = ' '

                if score > best_score:
                    best_score = score
                    best_move = (i, j)
    return best_move

def play_game():
    board = [[' ' for _ in range(3)] for _ in
             range(3)]
    print("Welcome to Tic Tac Toe!")
    print_board(board)

    while not check_winner(board, 'X') and not
      check_winner(board, 'O') and not is_board_full(
```

(5). Implement the 8 puzzle Breath First search algorithm

```
from collections import deque

def find_zero(puzzle):
    for i in range(3):
        for j in range(3):
            if puzzle[i][j] == 0:
                return i,j

def generate_next_states(state):
    next_states = []
    zero_i, zero_j = find_zero(state)

    movements = [(0,1), (0,-1), (1,0), (-1,0)]

    for move in movements:
        new_i, new_j = zero_i + move[0], zero_j +
                                        move[1]
        if 0 <= new_i < 3 and
           0 <= new_j < 3:

            new_state = [row[:] for row in state]
            new_state[zero_i][zero_j], new_state[new_i]
            [new_j] = new_state[new_i][new_j],
                      new_state[zero_i], zero_j]
            new_states.append(new_state)

    return next_states

def bfs(start):
    queue = deque([(start, [])])
```

```
    visited = set()

    while queue:
        current_state, path = queue.popleft()
        visited.add(str(current_state))

        if is_goal(current_state):
            return path

        for next_state in generate_next_states(cu_state):
            if str(next_state) not in visited:
                queue.append((next_state, path +
                              [next_state]))
                visited.add(str(next_state))

    return None

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

solution = bfs(initial_state)

if solution:
    print("solution found!")
    print("steps to reach the goal:")
    for step in solution:
        print(step)

else:
    print("No solution exists for this puzzle.")
```

Output: Welcome to Tic Tac Toe!

Enter your move(row and column): 1 1

O

AI's move:

X

O

Enter your move: 0 2

X

O

AI's move:

X O

O

X

Enter your move: 1 0

X

O O O

X

AI's move:

X O

O O X

X

Enter your move: 2 1

X X O

O O X

X O X

AI's move:

X X O

O O X

X O

Enter your move: 2 2

X X O

O O X

X O O

It's a tie!

Output

```
queue
1 | 2 | 3
4 | 5 | 6
0 | 7 | 8

queue
[1, 2, 3, 4, 5, 6, 7, 0, 8]
----------***------------
1 | 2 | 3
0 | 5 | 6
4 | 7 | 8

queue
[0, 2, 3, 1, 5, 6, 4, 7, 8]
----------***------------
[1, 2, 3, 5, 0, 6, 4, 7, 8]
----------***------------
1 | 2 | 3
4 | 5 | 6
7 | 0 | 8
```

```
queue
[1, 2, 3, 5, 0, 6, 4, 7, 8]
----------***------------
[1, 2, 3, 4, 0, 6, 7, 5, 8]
----------***------------
[1, 2, 3, 4, 5, 6, 7, 8, 0]
----------***------------
0 | 2 | 3
1 | 5 | 6
4 | 7 | 8

queue
[1, 2, 3, 4, 0, 6, 7, 5, 8]
----------***------------
[1, 2, 3, 4, 5, 6, 7, 8, 0]
----------***------------
[2, 0, 3, 1, 5, 6, 4, 7, 8]
----------***------------
1 | 2 | 3
5 | 0 | 6
4 | 7 | 8

queue
[1, 2, 3, 4, 5, 6, 7, 8, 0]
----------***------------
[2, 0, 3, 1, 5, 6, 4, 7, 8]
----------***------------
[1, 0, 3, 5, 2, 6, 4, 7, 8]
----------***------------
[1, 2, 3, 5, 7, 6, 4, 0, 8]
----------***------------
[1, 2, 3, 5, 6, 0, 4, 7, 8]
----------***------------
1 | 2 | 3
4 | 0 | 6
7 | 5 | 8

queue
[2, 0, 3, 1, 5, 6, 4, 7, 8]
----------***------------
[1, 0, 3, 5, 2, 6, 4, 7, 8]
----------***------------
[1, 2, 3, 5, 7, 6, 4, 0, 8]
----------***------------
[1, 2, 3, 5, 6, 0, 4, 7, 8]
----------***------------
[1, 0, 3, 4, 2, 6, 7, 5, 8]
----------***------------
[1, 2, 3, 0, 4, 6, 7, 5, 8]
----------***------------
[1, 2, 3, 4, 6, 0, 7, 5, 8]
----------***------------
1 | 2 | 3
4 | 5 | 6
7 | 8 | 0

success
path cost 7
```

Program 3:

Exploíe the woíking of Ɪ'ic Ɪ'ac Ɪ'oe using Min max stíategy.(11/12/23)

```
board = [[" ", " ", " "], [" ", " ", " "], [" ", " ", " "]]
print("0,0|0,1|0,2")
print("1,0|1,1|1,2")
print("2,0|,2,1|2,2 \n\n")
def print_board():
  for row in board:
    print("|".join(row))
    print("-" * 5)

def check_winner(player):
  for i in range(3):
    if all([board[i][j] == player for j in range(3)]) or all([board[j][i] == player for j in range(3)]):
      return True

  if all([board[i][i] == player for i in range(3)]) or all([board[i][2 - i] == player for i in range(3)]):
    return True
  return False

def is_full():
  return all([cell != " " for row in board for cell in row])

def minimax(depth, is_maximizing):
  if check_winner("X"):
    return -1
  if check_winner("O"):
    return 1
  if is_full():
    return 0
  if is_maximizing:
    max_eval = float("-inf")
    for i in range(3):
      for j in range(3):
        if board[i][j] == " ":
          board[i][j] = "O"
          eval = minimax(depth + 1, False)
          board[i][j] = " "
          max_eval = max(max_eval, eval)
    return max_eval
  else:
    min_eval = float("inf")
```

```
    for i in range(3):
      for j in range(3):
        if board[i][j] == " ":
            board[i][j] = "X"
            eval = minimax(depth + 1, True)
            board[i][j] = " "
            min_eval = min(min_eval, eval)

    return min_eval

def ai_move():
  best_move = None
  best_eval = float("-inf")
  for i in range(3):
    for j in range(3):
      if board[i][j] == " ":
        board[i][j] = "O"
        eval = minimax(0, False)
        board[i][j] = " "
        if eval > best_eval:
          best_eval = eval
          best_move = (i, j)

  return best_move

while not is_full() and not check_winner("X") and not check_winner("O"):
  print_board()
  row = int(input("Enter row (0, 1, or 2): "))
  col = int(input("Enter column (0, 1, or 2): "))
  if board[row][col] == " ":
    board[row][col] = "X"
    if check_winner("X"):
    print_board()
    print("You win!")
    break
    if is_full():
      print_board()
      print("It's a draw!")
      break
    ai_row, ai_col = ai_move()
    board[ai_row][ai_col] = "O"
    if check_winner("O"):
    print_board()
      print("AI wins!")
```

```
      break

  else:
    print("Cell is already occupied. Try again.")
```

output

```
player_row, player_col = map(int, input("Enter
        your move (row & column):").split())
if board[player_row][player_col] != ' ':
    print("Invalid move. Try again:")
    continue

board[player_row][player_col] = 'O'
print_board(board)

if check_winner(board, 'O'):
    print("Congratulations! You win!")
    break
if is_board_full(board):
    print("It's a tie!")
    break

print("AI's move:")
ai_row, ai_col = find_best_move(board)
board[ai_row][ai_col] = 'X'
print_board(board)

if check_winner(board, 'X'):
    print("AI wins!")
    break.
if is_board_full(board):
    print("It's a tie")
    break

play_game()
```

Iterative deepening Search

```
def iterative_deepening_search(graph, start, goal):
    depth_limit = 0
    while true:
        result, path = depth_limited_search(graph, start,
                                            goal, depth_limit, [limit])
        if result == goal
            return result, path
        depth_limit += 1

def depth_limited_search(graph, current, goal, depth_limi
                                                path):
    if current == goal:
        return current, path
    if depth_limit == 0:
        return None, ()
    if depth_limit >= 0:
        for neighbor in graph[current]:
            return
            result, new_path = depth_limited_search(
                graph, neighbor, goal, depth_limit-1,
                    path + [neighbor]).
    if result == goal
        return result, new_path
return None, ()
def main():
    graph = {}
```

Output:

Solution found!

Steps to reach the goal:

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

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

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

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

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

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

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

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

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

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

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

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

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

P8/12/23

```
0,0|0,1|0,2
1,0|1,1|1,2
2,0|,2,1|2,2


 | |
-----
 | |
-----
 | |
-----
Enter row (0, 1, or 2): 1
Enter column (0, 1, or 2): 1
O| |
-----
 |X|
-----
 | |
-----
Enter row (0, 1, or 2): 0
Enter column (0, 1, or 2): 2
O| |X
-----
 |X|
-----
O| |
-----
Enter row (0, 1, or 2): 1
Enter column (0, 1, or 2): 0
O| |X
-----
X|X|O
-----
O| |
-----
Enter row (0, 1, or 2): 2
Enter column (0, 1, or 2): 1
O|O|X
-----
X|X|O
-----
O|X|
-----
Enter row (0, 1, or 2): 2
Enter column (0, 1, or 2): 2
O|O|X
-----
X|X|O
-----
O|X|X
-----
It's a draw!
```

Program 4:

Implement Iteíative deepening seaích algoíithm.(18/12/23)

```
from collections import defaultdict

# This class represents a directed graph using adjacency
# list representation
class Graph:

    def__init__(self,vertices):

        # No. of vertices
        self.V = vertices

        # default dictionary to store graph
        self.graph = defaultdict(list)
        self.ans = list()

    # function to add an edge to graph
    def addEdge(self,u,v):
        self.graph[u].append(v)

    # A function to perform a Depth-Limited search
    # from given source 'src'
    def DLS(self,src,target,maxDepth,l):

        if src == target :
          #  print(self.ans)
            return True

        # If reached the maximum depth, stop recursing.
        if maxDepth <= 0 : return False

        # Recur for all the vertices adjacent to this vertex
        for i in self.graph[src]:
                if(self.DLS(i,target,maxDepth-1,l)):
                    l.append(i)
                    return True
        return False

    # IDDFS to search if target is reachable from v.
    # It uses recursive DLS()
    def IDDFS(self,src, target, maxDepth):
```

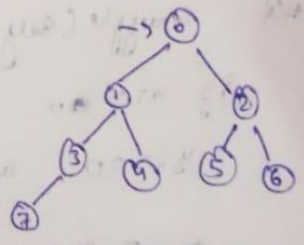
```
        # Repeatedly depth-limit search till the
        # maximum depth
        for i in range(maxDepth):
            l = []
            if (self.DLS(src, target, i,l)):
                l.append(src)
                l.reverse()
                return l
        return l

# Create a graph given in the above diagram
n,e = map(int ,input("Enter no.of vertices and edges").split())
g = Graph (n);
for i in range(e):
    a,b = map(int , input().split())
    g.addEdge(a,b)

# g.addEdge(0, 1)
# g.addEdge(0, 2)
# g.addEdge(1, 3)
# g.addEdge(1, 4)
# g.addEdge(2, 5)
# g.addEdge(2, 6)

target = int(input("Enter the target vertex"))
maxDepth = int(input("Enter the max depth"))
src = 0
l = g.IDDFS(src, target, maxDepth)
if len(l)!=0:
    print(l)
    print ("Target is reachable from source " +
        "within max depth")
else :
    print ("Target is NOT reachable from source " +
        "within max depth")
```

Output

```
while True:
    Node = input("enter a node (or 'done' to
                                finish):")
    if node.lower() == 'done':
        break
neighbor = input("enter neighbor for {node}").spli
    graph[node] = neighbors
Start-node = input("enter the Start node:")
goal-node = input("enter the goal node:")
result, path = Iterative_deepening_search
                    (graph, start_node, goal_node)
if result:
    print("Goal '{goal_node}' found.path = {path}")
else:
    Print("Goal '{goal_node}' not found")
if __name__ == "__main__":
    main()
```

o/p

```
enter no. of vertices : 8
enter no. of edges : 7
enter the edge(x,y) : 0 1
enter the edge(x,y) : 0 2
enter the edge(x,y) : 1 3
enter the edge(x,y) : 1 4
enter the edge(x,y) : 2 5
enter the edge(x,y) : 2 6
enter the edge(x,y) : 3 7
enter the source node : 0
enter the target node : 7
enter max-depth : 4
Target 7 is reachable from source 0
Traversal path 0->3->7
```



Status (5) Iterate Using DFS Search

```
class Node:
    def __init__(self, data, level, fval):
        self.data = data
        self.level = level
        self.fval = fval

    def generate_child(self):
        x, y = self.find(self.data, '_')
        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):
        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):
        temp = []
        for i in root:
            t = []
            for j in i:
                t.append()
            temp.append()
        return temp
    def find(self, puz, x):
        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):
        self.n = size
        self.open() = []
        self.closed = []
    def accept(self):
        puz = []
        for i in range(0, self.n):
            temp = input().split(" ")
            puz.append(temp)
        return puz
```

```
def f(self, start.goal):
    return self.h(start.data, goal) + start.level

def h(self, start, goal):
    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):
    print("Take the start of matrix\n")
    start = self.accept()
    print("enter the goal state of matrix\n")
    goal = self.accept()
    start = Node(start, 0, 0)
    start.fval = self.f(start, goal)
    self.open.append(start)
    print("\n\n")
    while(True):
        cur = self.open(0)
        print(" ")
        print(" | ")
        print(" \ ")
        print("\t" / "\n")
```

```
        for i in cur.data:
            for j in i:
                print(j, end = " ")
            print(" ")
        if(self.h(cur.data, goal) == 0):
            break
        for i in cur.generate_child():
            i.fval = self.h(i, goal)
            self.open.append(i)
        self.closed.append(cur.data)

def self.open(0):
    self.open = sort(key = lambda x: x.fval,
                     reverse = False)

puz = puzzle(2)
puz.process()
```

Op:

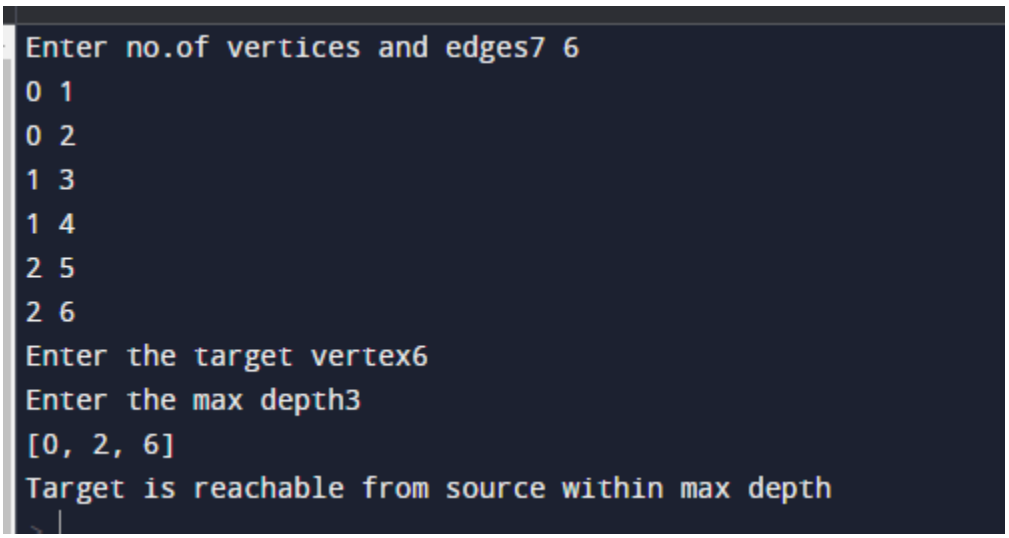
Enter the start state matrix.

1 2 3
4 5 6
- 7 8

Enter the goal state matrix

1 2 3
4 5 6
7 8 -

↓
↓
↓



Program 5:

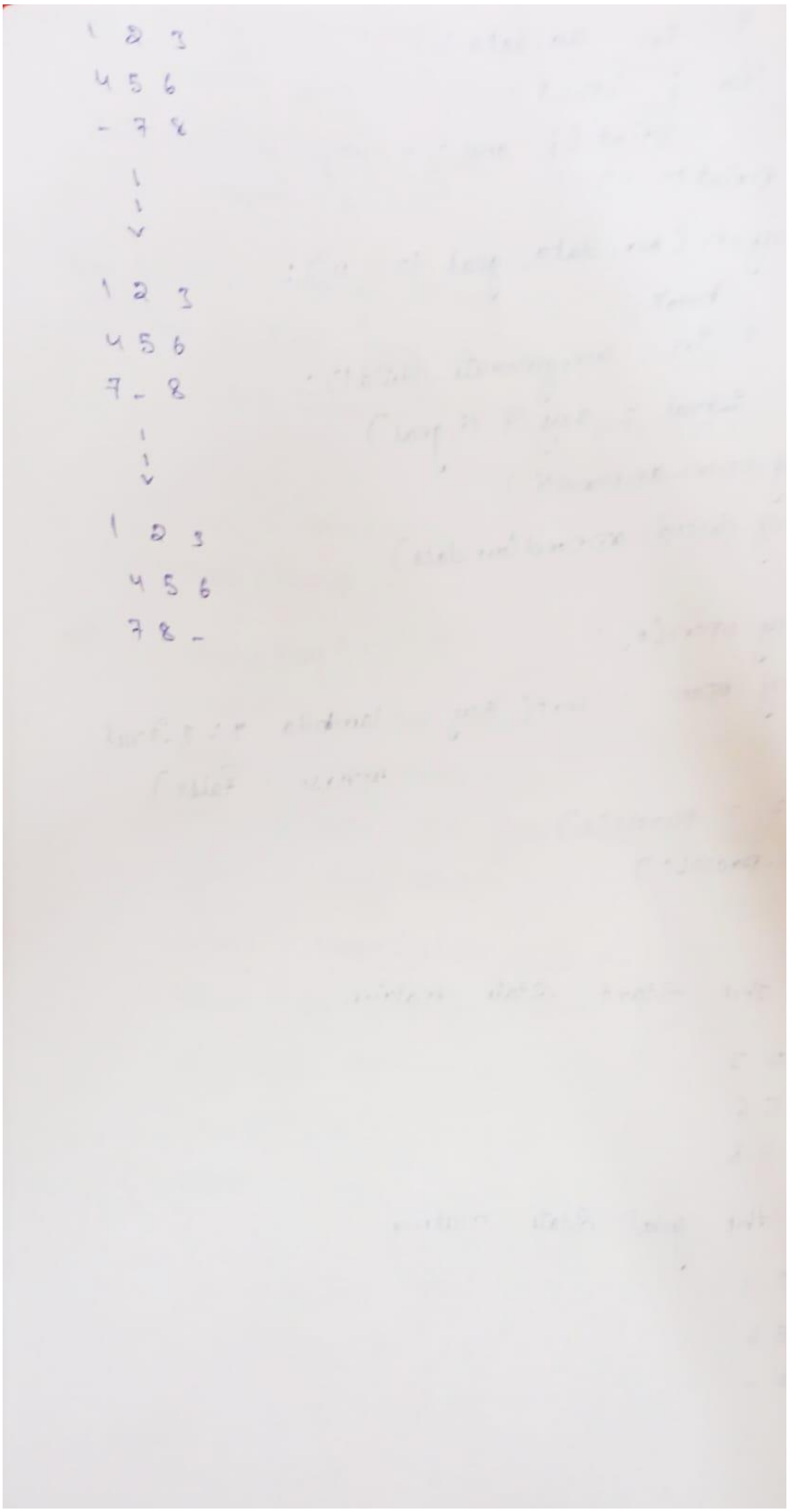
Implement A* foí 8 puzzle píoblem(8/1/24)

```
# Online Python compiler (interpreter) to run Python online.
# Write Python 3 code in this online editor and run it.
class Node:
    def__init_(self,data,level,fval):
        self.data = data
        self.level = level
        self.fval = fval

    def generate_child(self):
        x,y = self.find(self.data,'_')
        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):
        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):
        temp = []
        for i in root:
            t = []
            for j in i:
                t.append(j)
            temp.append(t)
        return temp

    def find(self,puz,x):
        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):
        self.n = size
        self.open = []
        self.closed = []

    def accept(self):
        puz = []
        for i in range(0,self.n):
            temp = input().split(" ")
            puz.append(temp)
        return puz

    def f(self,start,goal):
        return self.h(start.data,goal)+start.level

    def h(self,start,goal):
        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):
        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)
        self.open.append(start)

        while True:
            cur = self.open[0]
            print("")
            print("  | ")--
            print("  | ")
            print(" \\\'/ \n")
            for i in cur.data:
                for j in i:
                    print(j,end=" ")
                print("")
            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 opne list based on f value """
            self.open.sort(key = lambda x:x.fval,reverse=False)


puz = Puzzle(3)
puz.process()
```

output


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

22-1-24 ⑥. Create a knowledge based bot using propositional logic & show that the given query entails the KB or not.

//Algorithm

function TT entails (KB, α) returns T/F

//Inputs : KB, the knowledge bot
α, the query : a, sentence

//Symbols : a list of proprtion symbols in KB & α

function TT. CHECK - ALL (KB, α, Symbol, model)
returns true or false

if EMPTY? (symbols) then
if PL_True? (KB, model, then
return PL-True (α, model)
else return true,
else do
P = FIRST (symbols)
rest = REST (symbols)
return TT-CHECK-ALL (KB, α, rest,
EXTEND (P, true, model) and
TT-CHECK-ALL (KB, α, rest, EXTEND (P, false
model))

Knowledge Base (Truth Table).

T	T	T	T	F	F	F
T	T	F	T	T	T	T
T	F	T	T	F	F	F
T	F	F	T	T	T	T
F	T	T	T	F	F	F
F	T	F	T	T	F	F
F	F	T	F	F	F	F
F	F	F	F	T	F	F

The knowledge base entails the query

Output enter result : $(p \vee q) \wedge (p \wedge r)$

enter query : p

** Truth Table Reference **

F	T
T	T
F	T
T	T
F	F
F	F
F	F
F	F

The KB entails the query

Q2 query = 'r'

The KB doesn't entail query

```
Enter the start state matrix

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

1 2 3
5 8 6
_ 7 4
|
  |
 \'/
1 2 3
5 6 _
7 8 4
cost: 3

  |
  |
 \'/

1 2 3
5 _ 6
7 8 4
cost: 3

  |
  |
 \'/

1 2 3
5 8 6
7 _ 4
cost: 3

  |
  |
 \'/

1 2 3
```

Program 6:

Creation of Knowledge Base using prepositional logic and show that the query entails the KB or not (22/1/24)

```
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)]
variable={'p':0,'q':1, 'r':2}
kb=''
q=''
priority={'~':3,'v':1,'^':2}
def input_rules():
    global kb, y
    kb = (input("Enter rule: "))
    y = input("Enter the Query: ")
def entailment():
    global kb, q
    print('*'*10+"Truth Table Reference"+'*'*10)
    print('kb','alpha')
    print('*'*10)
    for comb in combinations:
        s = evaluatePostfix(toPostfix(kb), comb)
        f = evaluatePostfix(toPostfix(y), comb)
        print(s, f)
        print('-'*10)
        if s and not f:
            return False
    return  True
def isOperand(c):
    return c.isalpha() and c!='v'

def isLeftParanthesis(c):
    return c == '('

def isRightParanthesis(c):
    return c == ')'

def isEmpty(stack):
    return len(stack) == 0
```

```
def peek(stack):
    return stack[-1]

def hasLessOrEqualPriority(c1, c2):
    try:
        return priority[c1]<=priority[c2]
    except KeyError:
        return False
def toPostfix(infix):
    stack = []
    postfix = ''
    for c in infix:
        if isOperand(c):
            postfix += c
        else:
            if isLeftParanthesis(c):
                stack.append(c)
            elif isRightParanthesis(c):
                operator = stack.pop()
                while not isLeftParanthesis(operator):
                    postfix += operator
                    operator = stack.pop()
            else:
                while (not isEmpty(stack)) and hasLessOrEqualPriority(c, peek(stack)):
                    postfix += stack.pop()
                stack.append(c)
    while (not isEmpty(stack)):
        postfix += stack.pop()

    return postfix
def evaluatePostfix(exp, comb):
    stack = []
    for i in exp:
        if isOperand(i):
            stack.append(comb[variable[i]])
        elif i == '~':
            val1 = stack.pop()
            stack.append(not val1)
        else:
            val1 = stack.pop()
            val2 = stack.pop()
            stack.append(_eval(i,val2,val1))
    return stack.pop()
def _eval(i, val1, val2):
```

```
    if i == '^':
        return val2 and val1
    return val2 or val1

input_rules()
ans = entailment()
if ans:
    print("The Knowledge Base entails query")
else:
    print("The Knowledge Base does not entail query")
```

22-1-24 (4). Create a knowledge not using propositional logic & prove the given query using resolution

Algorithm

Function PL-RESOLUTION (KB, α) return T/F

//Inputs : KB, the knowledge bot,
α sentence, Propositional logic α,
the query a sentence in PL

clauses ⇒ the set of clause in the CNF representation of KB ∧ ¬α

new ← { }

loop do

For each pair of clause (Ci, Cj) in clauses do

resolvent ⇐ PL-RESOLVE (Ci, Cj)

if resolvent contains the empty clause then return true

new ← new ∪ resolvents

if new ⊆ clause then return false

clause ← clause ∪ new

KB

P

query

q

P ∧ Q → R

S ∨ T → Q

T

S

=> KB ∨ ¬R

convert to CNF

output:

```
Enter rule: (pvq)^(p^~r)
Enter the Query: p
**********Truth Table Reference**********
kb alpha
**********
False True
----------
True True
----------
False True
----------
True True
----------
False False
----------
False False
----------
False False
----------
False False
----------
The Knowledge Base entails query
>
```

Program 7:

Creation of Knowledge Base using prepositional logic and prove the query using resolution(22/1/24)

```
kb = []


def CLEAR():
    global kb
```

```
    kb = []


def TELL(sentence):
    global kb
    # If the sentence is a clause, insert directly.
    if isClause(sentence):
        kb.append(sentence)
    # If not, convert to CNF, and then insert clauses one by one.
    else:
        sentenceCNF = convertCNF(sentence)
        if not sentenceCNF:
            print("Illegal input")
            return
        # Insert clauses one by one when there are multiple clauses
        if isAndList(sentenceCNF):
            for s in sentenceCNF[1:]:
                kb.append(s)
        else:
            kb.append(sentenceCNF)


def ASK(sentence):
    global kb

    # Negate the sentence, and convert it to CNF accordingly.
    if isClause(sentence):
        neg = negation(sentence)
    else:
        sentenceCNF = convertCNF(sentence)
        if not sentenceCNF:
            print("Illegal input")
            return
        neg = convertCNF(negation(sentenceCNF))

    # Insert individual clauses that we need to ask to ask_list.
    ask_list = []
    if isAndList(neg):
        for n in neg[1:]:
            nCNF = makeCNF(n)
```

```
            if type(nCNF).__name__== 'list':
                ask_list.insert(0, nCNF)
            else:
                ask_list.insert(0, nCNF)
        else:
            ask_list = [neg]
        clauses = ask_list + kb[:]
        while True:
            new_clauses = []
            for c1 in clauses:
                for c2 in clauses:
                    if c1 is not c2:
                        resolved = resolve(c1, c2)
                        if resolved == False:
                            continue
                        if resolved == []:
                            return True
                        new_clauses.append(resolved)

            if len(new_clauses) == 0:
                return False

            new_in_clauses = True
            for n in new_clauses:
                if n not in clauses:
                    new_in_clauses = False
                    clauses.append(n)

            if new_in_clauses:
                return False
        return False


    def resolve(arg_one, arg_two):
        resolved = False

        s1 = make_sentence(arg_one)
        s2 = make_sentence(arg_two)

        resolve_s1 = None
```

```
resolve_s2 = None

# Two for loops that iterate through the two clauses.
for i in s1:
    if isNotList(i):
        a1 = i[1]
        a1_not = True
    else:
        a1 = i
        a1_not = False

    for j in s2:
        if isNotList(j):
            a2 = j[1]
            a2_not = True
        else:
            a2 = j
            a2_not = False

        # cancel out two literals such as 'a' $ ['not', 'a']
        if a1 == a2:
            if a1_not != a2_not:
                # Return False if resolution already happend
                # but contradiction still exists.
                if resolved:
                    return False
                else:
                    resolved = True
                    resolve_s1 = i
                    resolve_s2 = j
                    break
                # Return False if not resolution happened
if not resolved:
    return False

# Remove the literals that are canceled
s1.remove(resolve_s1)
s2.remove(resolve_s2)

# # Remove duplicates
```

```
    result = clear_duplicate(s1 + s2)

    # Format the result.
    if len(result) == 1:
        return result[0]
    elif len(result) > 1:
        result.insert(0, 'or')

    return result


def make_sentence(arg):
    if isLiteral(arg) or isNotList(arg):
        return [arg]
    if isOrList(arg):
        return clear_duplicate(arg[1:])
    return


def clear_duplicate(arg):
    result = []
    for i in range(0, len(arg)):
        if arg[i] not in arg[i+1:]:
            result.append(arg[i])
    return result


def isClause(sentence):
    if isLiteral(sentence):
        return True
    if isNotList(sentence):
        if isLiteral(sentence[1]):
            return True
        else:
            return False
    if isOrList(sentence):
        for i in range(1, len(sentence)):
            if len(sentence[i]) > 2:
                return False
            elif not isClause(sentence[i]):
```

```
                return False
        return True
    return False


def isCNF(sentence):
    if isClause(sentence):
        return True
    elif isAndList(sentence):
        for s in sentence[1:]:
            if not isClause(s):
                return False
        return True
    return False


def negation(sentence):
    if isLiteral(sentence):
        return ['not', sentence]
    if isNotList(sentence):
        return sentence[1]

    # DeMorgan:
    if isAndList(sentence):
        result = ['or']
        for i in sentence[1:]:
            if isNotList(sentence):
                result.append(i[1])
            else:
                result.append(['not', sentence])
        return result
    if isOrList(sentence):
        result = ['and']
        for i in sentence[:]:
            if isNotList(sentence):
                result.append(i[1])
            else:
                result.append(['not', i])
        return result
    return None
```

```
def convertCNF(sentence):
    while not isCNF(sentence):
        if sentence is None:
            return None
        sentence = makeCNF(sentence)
    return sentence


def makeCNF(sentence):
   if isLiteral(sentence):
        return sentence

    if (type(sentence).__name__== 'list'):
        operand = sentence[0]
        if isNotList(sentence):
            if isLiteral(sentence[1]):
                return sentence
            cnf = makeCNF(sentence[1])
            if cnf[0] == 'not':
                return makeCNF(cnf[1])
            if cnf[0] == 'or':
                result = ['and']
                for i in range(1, len(cnf)):
                    result.append(makeCNF(['not', cnf[i]]))
                return result
            if cnf[0] == 'and':
                result = ['or']
                for i in range(1, len(cnf)):
                    result.append(makeCNF(['not', cnf[i]]))
                return result
            return "False: not"

        if operand == 'implies' and len(sentence) == 3:
            return makeCNF(['or', ['not', makeCNF(sentence[1])], makeCNF(sentence[2])])

        if operand == 'biconditional' and len(sentence) == 3:
            s1 = makeCNF(['implies', sentence[1], sentence[2]])
            s2 = makeCNF(['implies', sentence[2], sentence[1]])
```

```
    return makeCNF(['and', s1, s2])

if isAndList(sentence):
    result = ['and']
    for i in range(1, len(sentence)):
        cnf = makeCNF(sentence[i])
        # Distributivity:
        if isAndList(cnf):
            for i in range(1, len(cnf)):
                result.append(makeCNF(cnf[i]))
            continue
        result.append(makeCNF(cnf))
    return result

if isOrList(sentence):
    result1 = ['or']
    for i in range(1, len(sentence)):
        cnf = makeCNF(sentence[i])
        # Distributivity:
        if isOrList(cnf):
            for i in range(1, len(cnf)):
                result1.append(makeCNF(cnf[i]))
            continue
        result1.append(makeCNF(cnf))
        # Associativity:
    while True:
        result2 = ['and']
        and_clause = None
        for r in result1:
            if isAndList(r):
                and_clause = r
                break

        # Finish when there's no more 'and' lists
        # inside of 'or' lists
        if not and_clause:
            return result1

        result1.remove(and_clause)
```

```
            for i in range(1, len(and_clause)):
                temp = ['or', and_clause[i]]
                for o in result1[1:]:
                    temp.append(makeCNF(o))
                result2.append(makeCNF(temp))
            result1 = makeCNF(result2)
        return None
    return None


def isLiteral(item):
    if type(item).__name__ == 'str':
        return True
    return False


def isNotList(item):
    if type(item).__name__ == 'list':
        if len(item) == 2:
            if item[0] == 'not':
                return True
    return False


def isAndList(item):
    if type(item).__name__ == 'list':
        if len(item) > 2:
            if item[0] == 'and':
                return True
    return False


def isOrList(item):
    if type(item).__name__ == 'list':
        if len(item) > 2:
            if item[0] == 'or':
                return True
    return False
```

```
CLEAR()

TELL('p')
TELL(['implies', ['and', 'p', 'q'], 'r'])
TELL(['implies', ['or', 's', 't'], 'q'])
TELL('t')
print(ASK('r'))
```

Output

Program 8:

Implement unification in first order logic(29/1/24)

```
import re
def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = "(".join(expression)
    expression = expression.split(")")[:-1]
    expression = ")".join(expression)
    attributes = expression.split(',')
    return attributes

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)
    predicate = getInitialPredicate(exp)
    for index, val in enumerate(attributes):
```

```
        if val == old:
            attributes[index] = new
    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:
            print(f"{exp1} and {exp2} are constants. Cannot be unified")
            return []

    if isConstant(exp1):
        return [(exp1, exp2)]

    if isConstant(exp2):
        return [(exp2, exp1)]

    if isVariable(exp1):
        return [(exp2, exp1)] if not checkOccurs(exp1, exp2) else []

    if isVariable(exp2):
```

```
        return [(exp1, exp2)] if not checkOccurs(exp2, exp1) else []

    if getInitialPredicate(exp1) != getInitialPredicate(exp2):
        print("Cannot be unified as the predicates do not match!")
        return []

    attributeCount1 = len(getAttributes(exp1))
    attributeCount2 = len(getAttributes(exp2))
    if attributeCount1 != attributeCount2:
        print(f"Length of attributes {attributeCount1} and {attributeCount2} do not match. Cannot
be unified")
        return []

    head1 = getFirstPart(exp1)
    head2 = getFirstPart(exp2)
    initialSubstitution = unify(head1, head2)
    if not initialSubstitution:
        return []
    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 []

    return initialSubstitution + remainingSubstitution
def main():
    print("Enter the first expression")
    e1 = input()
    print("Enter the second expression")
    e2 = input()
    substitutions = unify(e1, e2)
    print("The substitutions are:")
    print([' / '.join(substitution) for substitution in substitutions])
main()
```

```
Enter the first expression
knows(y,f(x))
Enter the second expression
knows(pri,p)
The substitutions are:
['pri / y', 'f(x) / p']
```

Program 9:

Convert a given first order logic statement into Conjunctive Normal Form (CNF).(29/1/24)

```
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 DeMorgan(sentence):
    string = ''.join(list(sentence).copy())
    string = string.replace('~~','')
    flag = '[' in string
    string = string.replace('~[','')
    string = string.strip(']')
    for predicate in getPredicates(string):
        string = string.replace(predicate, f'~{predicate}')
    s = list(string)
    for i, c in enumerate(string):
        if c == 'V':
            s[i] = '^'
        elif c == '^':
            s[i] = 'V'
    string = ''.join(s)
```

```
    string = string.replace('~~','')
    return f'[{string}]' if flag else string
def Skolemization(sentence):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'), ord('Z')+1)]
    statement = ''.join(list(sentence).copy())
    matches = re.findall('[∀∃].', statement)
    for match in matches[::-1]:
        statement = statement.replace(match, '')
        statements = re.findall('\[\[[^]]+\]]', statement)
        for s in statements:
            statement = statement.replace(s, s[1:-1])
        for predicate in getPredicates(statement):
            attributes = getAttributes(predicate)
            if ''.join(attributes).islower():
                statement = statement.replace(match[1],SKOLEM_CONSTANTS.pop(0))
            else:
                aL = [a for a in attributes if a.islower()]
                aU = [a for a in attributes if not a.islower()][0]
                statement = statement.replace(aU, f'{SKOLEM_CONSTANTS.pop(0)}({aL[0] if
len(aL) else match[1]})')
    return statement
def fol_to_cnf(fol):

    statement = fol.replace("<=>", "_")
    while '_' in statement:
        i = statement.index('_')
        new_statement = '[' + statement[:i] + '=>' + statement[i+1:] + ']^['+ statement[i+1:] +
'=>' + statement[:i] + ']'
        statement = new_statement
    statement = statement.replace("=>", "-")
    expr = '\[([^]]+)\]'
    statements = re.findall(expr, statement)
    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] + 'V' + statement[i+1:]
            statement = statement[:br] + new_statement if br > 0 else new_statement
        while '~∀' in statement:
            i = statement.index('~∀')
            statement = list(statement)
            statement[i], statement[i+1], statement[i+2] = '∃', statement[i+2], '~'
            statement = ''.join(statement)
        while '~∃' in statement:
            i = statement.index('~∃')
            s = list(statement)
            s[i], s[i+1], s[i+2] = '∀', s[i+2], '~'
            statement = ''.join(s)
        statement = statement.replace('~[∀','[~∀')
        statement = statement.replace('~[∃','[~∃')
        expr = '(~[∀V∃].)'
        statements = re.findall(expr, statement)
        for s in statements:
            statement = statement.replace(s, fol_to_cnf(s))
        expr = '~\[[^]]+\]'
        statements = re.findall(expr, statement)
        for s in statements:
            statement = statement.replace(s, DeMorgan(s))
        return statement
    def main():
        print("Enter FOL:")
        fol = input()
        print("The CNF form of the given FOL is: ")
        print(Skolemization(fol_to_cnf(fol)))

    main()
```

Forward chaining [Reasoning]

Procedure forward-chain(KB, f)

if there is a fact in KB that is identical to f then return add f to KB

for each $(l_1 \wedge l_2 \wedge \ldots \wedge l_n \Rightarrow d)$ in KB such that for some i, unify $(l_i, f) = \theta$ succeeds do

FIND-AND-INFER(KB, $[l_1, \ldots l_{i-1}, l_{i+1} \ldots l_n]$, d, θ)

Procedure FIND and INFER(KB, conditions, conclusion, θ)

if conditions = [] then

forward-chain [KB, subst(θ, conclusion)]

else for each f in KB such that UNIFY

(f, Close(θ, First(conditions))) = θ_1, do

Find and Infer(KB, REST conditions)

conclusion, compose(θ_1, θ_2))

end

O/P :

KB :

missile(x) => weapon(x)

missile(m_1)

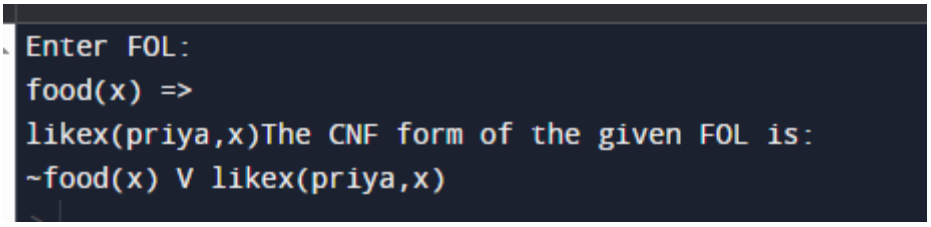
enemy(x, america) => hostile(x)

american(west)

enemy(china, america)

owns(china, m_1)

missile(x) & owns(china, x) => sells(west, x, china).



Program 10:

Forward Chaining (29/1/24)

Code

```
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}')
def main():
    kb = KB()
    print("Enter KB: (enter e to exit)")
```

```
    while  True:
        t = input()
        if(t == 'e'):
            break
        kb.tell(t)
    print("Enter Query:")
    q = input()
    kb.query(q)
    kb.display()
main()
```

Output

④ Convert a given first order logic statement into conjunctive Normal Form (CNF).

Algo:

(1). Eliminate biconditional & implications

Eliminate $\Rightarrow$ replacing $\alpha \Leftrightarrow \beta$ with $(\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)$

Eliminate $\Rightarrow$ replacing $\alpha \Rightarrow \beta$ with $\neg\alpha \vee \beta$

(2). remove $\neg$ inwards:

$\neg(\forall x\ P) \equiv \exists x \neg P$

$\neg(\exists x\ P) \equiv \forall x \neg P$

$\neg(\alpha \vee \beta) \equiv \neg\alpha \wedge \neg\beta$

$\neg(\alpha \wedge \beta) \equiv \neg\alpha \vee \neg\beta$

$\neg\neg\alpha \equiv \alpha$.

(3). Standardize variables part by renaming them each quantifier should be a different variable.

(4). skolemize: Each existential variable is replaced by a stolen constant or universally quantified variable.

(5). Drop universal quantifiers

(6). Distribute $\wedge$ over $\vee$

OIP: Enter FOL:

Food(x) $\Rightarrow$ likes(Sai, x)

The CNF Form of the given FOL is

$\neg$Food(x) $\vee$ likes(Sai, x).

```
Enter KB: (enter e to exit)
missile(x) => weapon(x)
missile(m1)
enemy(x,america) => hostile(x)
american(west)
enemy(china,america)
owns(china,m1)
missile(x) & owns(china,x) => sells(west,x,china)
american(x)&weapon(y)&sells(x,y,z)&hostile(z)=>criminal(x)
e
Enter Query:
criminal(x)
Querying criminal(x):
    1. criminal(west)
All facts:
    1. weapon(m1)
    2. criminal(west)
    3. missile(m1)
    4. owns(china,m1)
    5. american(west)
    6. sells(west,m1,china)
    7. hostile(china)
    8. enemy(china,america)
>
```

⑤ Implement unification in FOL

Algo: Function unify(x, y, θ) returns a substitution to make x & y identical.

If θ = failure then return false
else if x = y then return θ
else if variable?(x) then return unify-var(x, y, θ)
else if variable?(y) then return unify-var(y, x, θ)
else if compound?(x) & compound?(x, op.θ)
return unify(x.args, y.args, unify(x, op, y, op, θ))
else if list?(x) & list?(y) then return unify(x.Rest, y.Rest, unify(x.First, y.First, θ))
else return failure

Function unify var(var, x, θ) return a substitution

if {var/val} ∈ θ then return unify(val, x, θ)
else if {x/val} ∈ θ then unify(var, val, θ)
else if occur-check?(var, x) then return failure
else return add {var/x} to θ.

O/P:

Enter the first expression
knows(y, f(x))

Enter the second expression
knows(pre, p)

the substitutions are:-
['pre/y', 'f(x)/p'].