Artificial Intelligence Lab Report

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Table of contents

LAB PROGRAM 1

Implement Tic –Tac –Toe Game.

Objective: The objective of tic-tac-toe is that players have to position their marks so that they make a continuous line of three cells horizontally, vertically or diagonally.

Code:

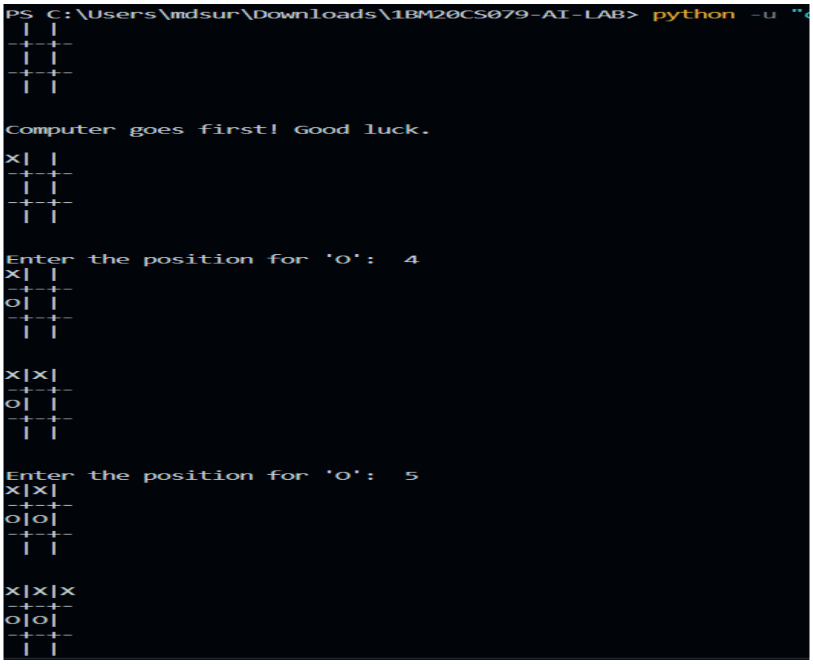
```
def printBoard(board):
    print(board[1] + '|' + board[2] + '|' + board[3])
    print('-+-+-')
    print(board[4] + '|' + board[5] + '|' + board[6])
    print('-+-+-')
    print(board[7] + '|' + board[8] + '|' + board[9])
    print("\n")
def spaceIsFree(position):
    if board[position] == ' ':
        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!")
```

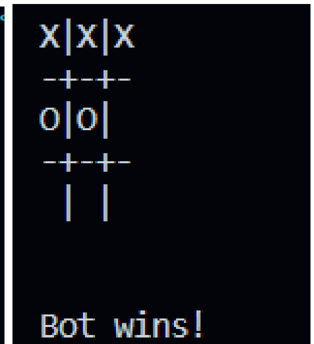
```
        position = int(input("Please enter new position:  "))
        insertLetter(letter, position)
        return
def checkForWin():
    if (board[1] == board[2] and board[1] == board[3] and board[1] != ' '):
        return True
    elif (board[4] == board[5] and board[4] == board[6] and board[4] != ' '):
        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)
```

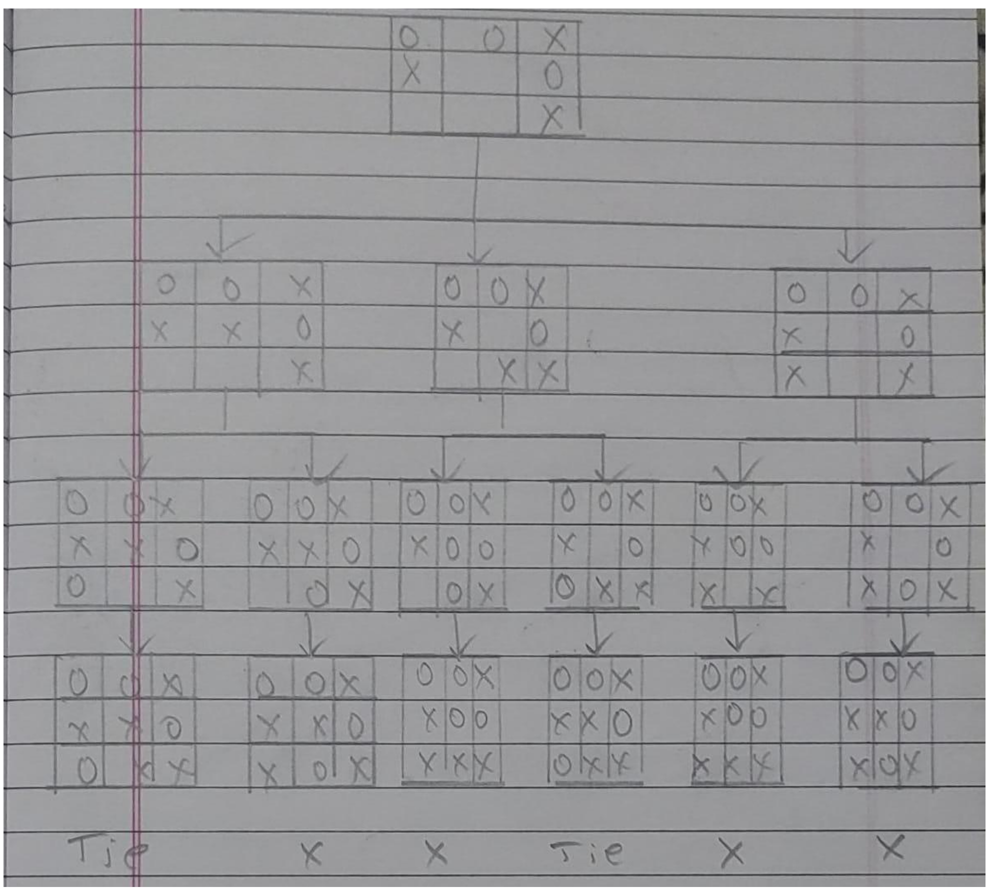
```
            board[key] = ' '
            if (score > bestScore):
                bestScore = score
        return bestScore
    else:
        bestScore = 800
        for key in board.keys():
            if (board[key] == ' '):
                board[key] = player
                score = minimax(board, 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 Snapshot





State Space Tree



LAB PROGRAM 2

Solve 8 puzzle problem.

Objective: The objective of 8-puzzle problem is to reach the end state from the start state by considering all possible movements of the tiles without any heuristic.

<u>Code:</u>

```
from queue import Queue

class Puzzle:
    goal_state=[1,2,3,5,8,6,0,7,4]
    heuristic=None
    evaluation_function=None
    num_of_instances=0
    def __init__(self,state,parent,action,path_cost):
        self.parent=parent
        self.state=state
        self.action=action
        if parent:
            self.path_cost = parent.path_cost + path_cost
        else:
            self.path_cost = path_cost
        Puzzle.num_of_instances+=1

    def __str__(self):
        return str(self.state[0:3])+'\n'+str(self.state[3:6])+'\n'+str(self.state[6:9])

    def goal_test(self):
        if self.state == self.goal_state:
            return True
        return False

    @staticmethod
    def find_legal_actions(i,j):
        legal_action = ['U', 'D', 'L', 'R']
        if i == 0:  # up is disable
```

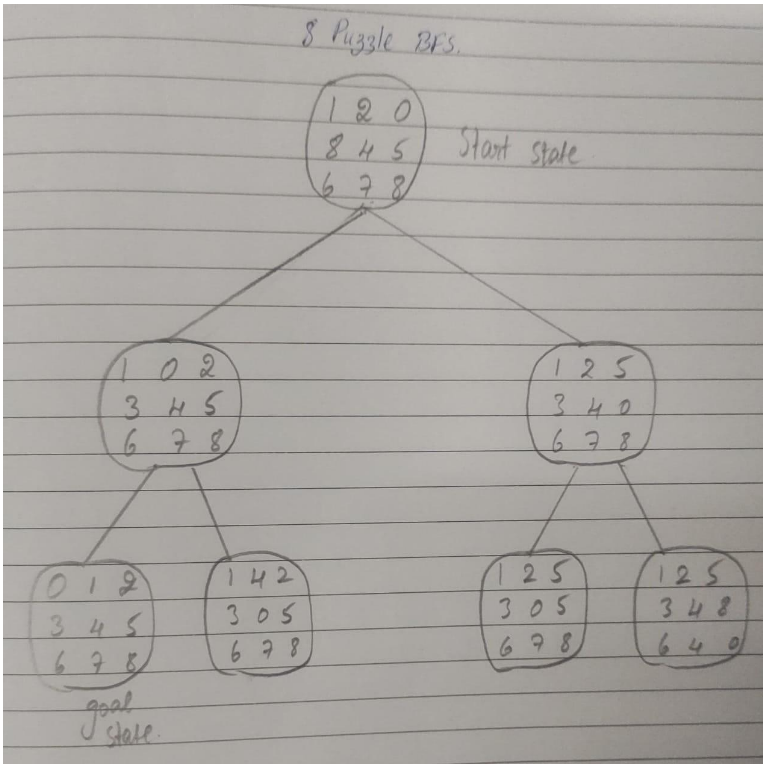
```
            legal_action.remove('U')
        elif i == 2:  # down is disable
            legal_action.remove('D')
        if j == 0:
            legal_action.remove('L')
        elif j == 2:
            legal_action.remove('R')
        return legal_action

    def generate_child(self):
        children=[]
        x = self.state.index(0)
        i = int(x / 3)
        j = int(x % 3)
        legal_actions=self.find_legal_actions(i,j)

        for action in legal_actions:
            new_state = self.state.copy()
            if action == 'U':
                new_state[x], new_state[x-3] = new_state[x-3], new_state[x]
            elif action == 'D':
                new_state[x], new_state[x+3] = new_state[x+3], new_state[x]
            elif action == 'L':
                new_state[x], new_state[x-1] = new_state[x-1], new_state[x]
            elif action == 'R':
                new_state[x], new_state[x+1] = new_state[x+1], new_state[x]
            children.append(Puzzle(new_state,self,action,1))
        return children

    def find_solution(self):
        solution = []
        solution.append(self.action)
        path = self
        while path.parent != None:
            path = path.parent
            solution.append(path.action)
        solution = solution[:-1]
        solution.reverse()
        return solution
```

```
def breadth_first_search(initial_state):
    start_node = Puzzle(initial_state, None, None, 0)
    if start_node.goal_test():
        return start_node.find_solution()
    q = Queue()
    q.put(start_node)
    explored=[]
    while not(q.empty()):
        node=q.get()
        explored.append(node.state)
        children=node.generate_child()
        for child in children:
            if child.state not in explored:
                node.__str__()
                if child.goal_test():
                    return child.find_solution()
                q.put(child)
    return

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

Puzzle.num_of_instances=0
bfs=breadth_first_search(state)
print('BFS:', bfs)
print('space:',Puzzle.num_of_instances)
print()
```

Output Snapshot

```
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB> python -u "c:\Users\mdsur\Downloads\1BM20CS079-AI-LAB\8 Puzzle BFS\8_puzzle_bfs.py"
BFS: ['L', 'D', 'L']
space: 24
```

State Space Tree



LAB PROGRAM 3

Implement Iterative deepening search algorithm.

Objective: IDDFS combines depth first search's space efficiency and breadth first search's completeness. It improves depth definition, heuristic and score of searching nodes so as to improve efficiency.

Code:

```
import itertools
import random
import time
def id_dfs(puzzle, goal, get_moves):
    def idfs(path, depth):
        if depth == 0:
            return
        if path[-1] == goal:
            return path
        for move in get_moves(path[-1]):
            if move not in path:
                next_path = idfs(path + [move], depth - 1)
                if next_path:
                    #print(next_path, end="")
                    return next_path
    for depth in itertools.count():
        path = idfs([puzzle], depth)
        if path:
            #print(path)
            return path
def num_matrix(rows, cols, steps=25):
    nums = list(range(1, rows * cols)) + [0]
    goal = [ nums[i:i+rows] for i in range(0, len(nums), rows) ]
    get_moves = num_moves(rows, cols)
    puzzle = goal
    for steps in range(steps):
```

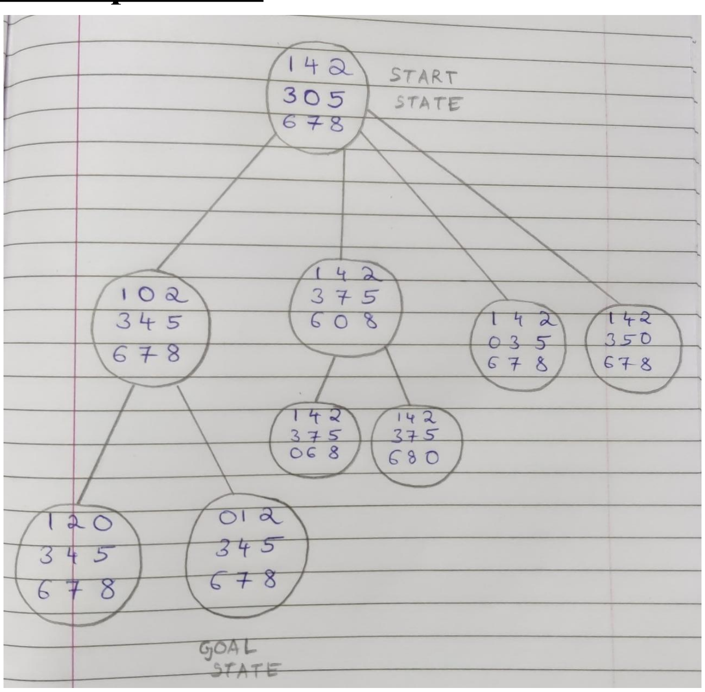
```
        puzzle = random.choice(get_moves(puzzle))
    return puzzle, goal
def num_moves(rows, cols):
    def get_moves(subject):
        moves = []
        zrow, zcol = next((r, c)
            for r, l in enumerate(subject)
                for c, v in enumerate(l) if v == 0)
        def swap(row, col):
            import copy
            s = copy.deepcopy(subject)
            s[zrow][zcol], s[row][col] = s[row][col], s[zrow][zcol]
            return s
        if zrow > 0:
            moves.append(swap(zrow - 1, zcol))
        if zcol < cols - 1:
            moves.append(swap(zrow, zcol + 1))
        if zrow < rows - 1:
            moves.append(swap(zrow + 1, zcol))
        if zcol > 0:
            moves.append(swap(zrow, zcol - 1))
        return moves
    return get_moves
if __name__ == '__main__':
    reps = 25
    total_time = 0
    for i in range(reps):
        puzzle = [[1,2,3],[4,0,6],[7,5,8]]
        goal = [[1,2,3],[4,5,6],[7,8,0]]
        puzzle,goal = num_matrix(3,3)
        t0 = time.time()
        solution = id_dfs(puzzle, goal, num_moves(3, 3))
        t1 = time.time()
        total_time += t1 - t0
    total_time /= reps
    print("Goal State: ")
    for i in goal:
        print(i, end="\n")
    print("Starting State: ")
    for i in puzzle:
```

```
    print(i, end="\n")
print("Solution: ")
for i in solution:
    print("")
    print("  | ")
    print("  | ")
    print(" \\\'/ \n")
    for j in i:
        print(j)
print('Puzzle solved using iterative depth first search in', total_time, 'seconds.') # 0.20 seconds
```

Output Snapshot

```
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB> python -u "c:\Users\mdsur\Downloads\1BM20CS079-AI-LAB\8 Puzzle IDDF
Goal State:
[1, 2, 3]
[4, 5, 6]
[7, 8, 0]
Starting State:
[1, 6, 2]
[4, 3, 0]
[7, 5, 8]
Solution:

  |
  |
 \'/

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

  |
  |
 \'/

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

  |
  |
 \'/

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

  |
  |
 \'/


[1, 2, 3]
[4, 5, 6]
[7, 8, 0]
Puzzle solved using iterative depth first search in 0.036723117828369144 seconds.
```

State Space Tree



LAB PROGRAM 4

Implement A* search algorithm.

Objective: The a* algorithm takes into account both the cost to go to goal from present state as well the cost already taken to reach the present state. In 8 puzzle problem, both depth and number of misplaced tiles are considered to take decision about the next state that has to be visited.

Code:

```
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:
```

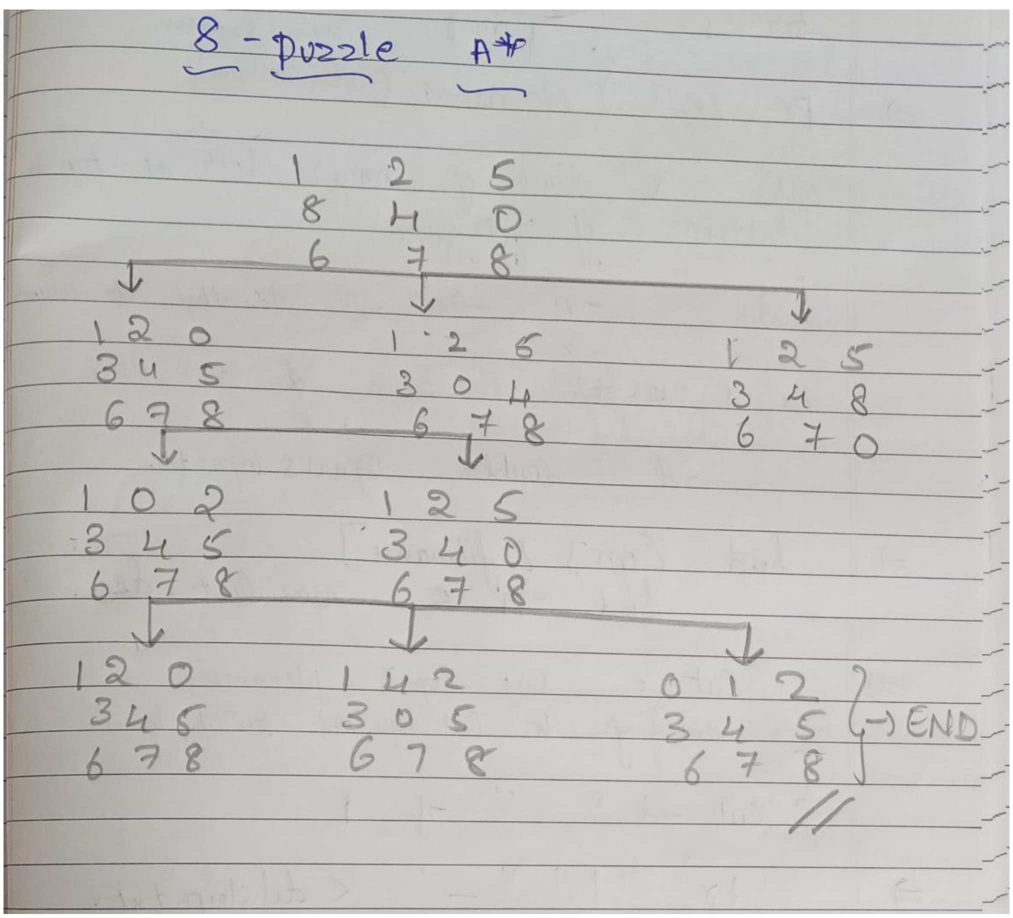
```
        return None


    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 Snapshot

```
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB> python -u "c:\Users\mdsur\Downloads\1BM20CS079-AI-LAB\
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

  |
  |
 \'/

1 2 3
5 _ 6
7 8 4

  |
  |
 \'/

1 2 3
5 8 6
7 _ 4

  |
  |
 \'/

1 2 3
5 8 6
_ 7 4
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB>
```

State Space Tree



LAB PROGRAM 5

Implement vacuum cleaner agent.

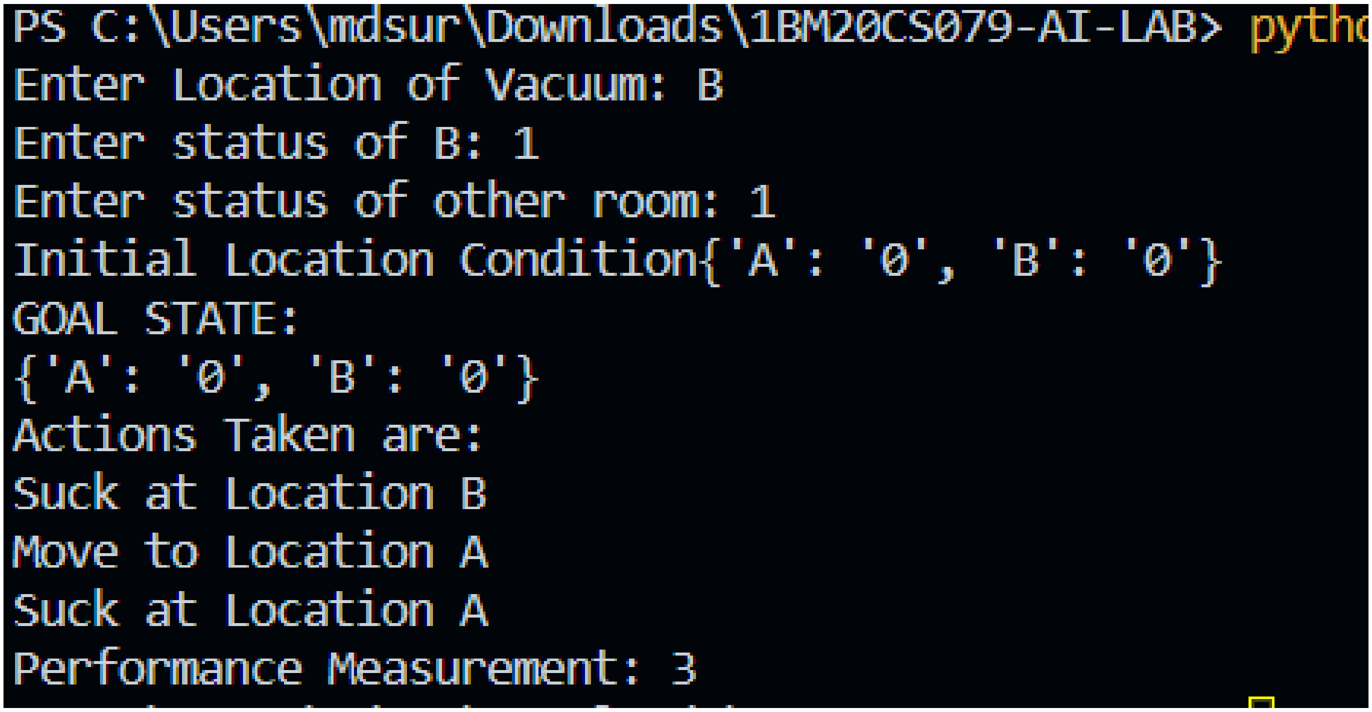
Objective: The objective of the vacuum cleaner agent is to clean the whole of two rooms by performing any of the actions – move right, move left or suck. Vacuum cleaner agent is a goal based agent.

Code:

```
def vacuum_world():
    goal_state = {'A': '0', 'B': '0'}
    cost = 0
    actions = []
    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':
        location_complement = 'B'
    else:
        location_complement = 'A'
    if status_input == '1':
        actions.append("Suck at Location "+location_input)
        goal_state[location_input] = '0'
        cost += 1
        actions.append("Move to Location "+location_complement)
        if status_input_complement == '1':
            cost += 1
            actions.append("Suck at Location "+location_complement)
            goal_state[location_complement] = '0'
            cost += 1
    if status_input == '0':
        actions.append("Move to Location "+location_complement)
        if status_input_complement == '1':
            actions.append("Suck at Location "+location_complement)
```

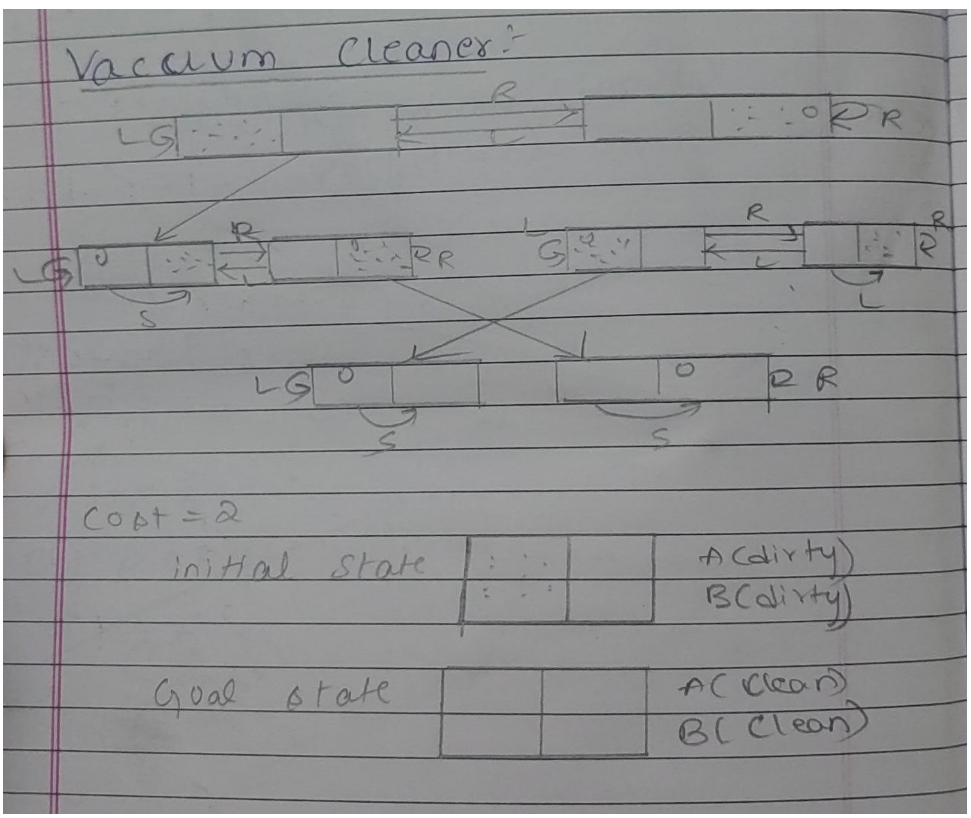
```
            cost += 1
            goal_state[location_complement] = '0'
            cost += 1
    print("GOAL STATE: ")
    print(goal_state)
    print("Actions Taken are: ")
    for var in actions:
        print(var)
    print("Performance Measurement: " + str(cost))
vacuum_world()
```

Output Snapshot



```
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB> pytho
Enter Location of Vacuum: B
Enter status of B: 1
Enter status of other room: 1
Initial Location Condition{'A': '0', 'B': '0'}
GOAL STATE:
{'A': '0', 'B': '0'}
Actions Taken are:
Suck at Location B
Move to Location A
Suck at Location A
Performance Measurement: 3
```

State Space Tree



LAB PROGRAM 6

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

Objective: The objective of this program is to see if the given query entails a knowledge base. A query is said to entail a knowledge base if the query is true for all the models where knowledge base is true.

Code:

```
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, q
    kb = (input("Enter rule: "))
    q = 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(q), 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")
```

OUTPUT SNAPSHOT

```
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB> python -u "c:\Users\mdsur\Downloads\1BM20CS079-AI-LAB\Knowledge_Based_Entailing\Lab6.py"
Enter rule: (~qv~pvr)^(~q^p)^q(~qv~pvr)^(~q^p)^q
Enter the Query: r
**********Truth Table Reference**********
kb alpha
**********
False True
----------
False False
----------
False True
----------
False False
----------
False True
----------
False False
----------
False True
----------
False False
----------
The Knowledge Base entails query
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB>
```

LAB PROGRAM 7

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

Objective: The resolution takes two clauses and produces a new clause which includes all the literals except the two complementary literals if exists. The knowledge base is conjuncted with the not of the give query and then resolution is applied.

Code

```
kb = []

# Reset kb to an empty list
def CLEAR():
    global kb
    kb = []

# Insert sentence to the 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)
```

```
# 'ASK' the kb whether a sentence is True or not
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]
# Create a new list combining the asked sentence and kb.
    # Resolution will happen between the items in the list.
    clauses = ask_list + kb[:]

    # Recursivly conduct resoltion between items in the clauses list
    # until it produces an empty list or there's no more pregress.
    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

# Conduct resolution on two CNF clauses.
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

# Prepare sentences for resolution.
def make_sentence(arg):
    if isLiteral(arg) or isNotList(arg):
        return [arg]
    if isOrList(arg):
        return clear_duplicate(arg[1:])
```

```
    return

# Clear out duplicates in a sentence.
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

# Check whether a sentence is a legal CNF clause.
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

# Check if a sentence is a legal CNF.
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

# Negate a sentence.
```

```
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


# Convert a sentence into CNF.
def convertCNF(sentence):
    while not isCNF(sentence):
        if sentence is None:
            return None
        sentence = makeCNF(sentence)
    return sentence

# Help make a sentence into CNF.
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"

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

# Below are 4 functions that check the type of a variable
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

if __name__ == "__main__":
    CLEAR()

    print("Test 1")
    TELL(['implies', 'p', 'q'])
    TELL(['implies', 'r', 's'])
    ASK(['implies',['or','p','r'], ['or', 'q', 's']])

    CLEAR()

    print("Test 2")
    TELL('p')
    TELL(['implies',['and','p','q'],'r'])
    TELL(['implies',['or','s','t'],'q'])
    TELL('t')
```

```
ASK('r')

CLEAR()

print("Test 3")
TELL('a')
TELL('b')
TELL('c')
TELL('d')
ASK(['or', 'a', 'b', 'c', 'd'])

CLEAR()

print("Test 4")
TELL('a')
TELL('b')
TELL(['or', ['not', 'a'], 'b'])
TELL(['or', 'c', 'd'])
TELL('d')
ASK('c')
```

Output Snapshot

```
Test 1
True
Test 2
True
Test 3
True
Test 4
False
```

LAB PROGRAM 8

Implement unification in first order logic

Objective: Unification can find substitutions that make different logical expressions identical. Unify takes two sentences and make a unifier for the two if a unification exist.

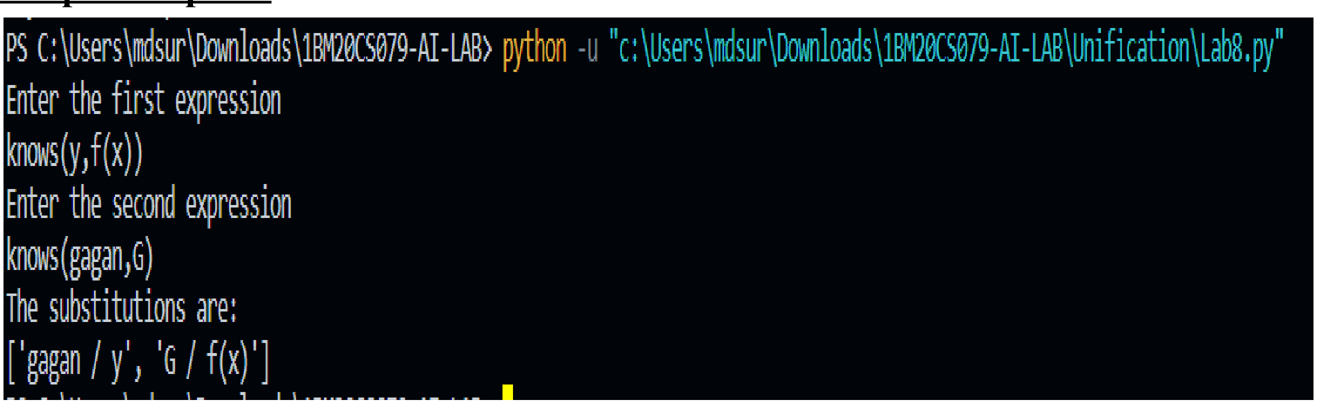
Code:

```
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()
```

Output Snapshot



```
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB> python -u "c:\Users\mdsur\Downloads\1BM20CS079-AI-LAB\Unification\Lab8.py"
Enter the first expression
knows(y,f(x))
Enter the second expression
knows(gagan,G)
The substitutions are:
['gagan / y', 'G / f(x)']
```

LAB PROGRAM 9

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

Objective: FOL logic is converted to CNF makes implementing resolution theorem easier.

Code:

```
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()
```

Output Snapshot

```
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB> python -u "c:\Users\mdsur\Downloads\1BM20CS079-AI-LAB\CNF\Lab9.py"
Enter FOL:
food(x) => likes(John, x)
The CNF form of the given FOL is:
~food(x) V likes(John, x)
```

LAB PROGRAM 10

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

Objective: A forward-chaining algorithm will begin with facts that are known. It will proceed to trigger all the inference rules whose premises are satisfied and then add the new data derived from them to the known facts, repeating the process till the goal is achieved or the problem is solved.

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()
```

<u>Output Snapshot</u>

```
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB> python -u "c:\Users\mdsur\Downloads\1BM20CS079-AI-LAB\First_Order_Logic\Lab10.py"
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. enemy(china,america)
        2. owns(china,m1)
        3. american(west)
        4. missile(m1)
        5. weapon(m1)
        6. sells(west,m1,china)
        7. hostile(china)
        8. criminal(west)
PS C:\Users\mdsur\Downloads\1BM20CS079-AI-LAB>
```