VISVESVARAYA TECHNOLOGICAL UNIVERSITY

“JnanaSangama”, Belgaum -590014, Karnataka.

LAB REPORT
on

ARTIFICIAL INTELLIGENCE

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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B. M. S. College of Engineering,

Bull Temple Road, Bangalore 560019

(Affiliated To Visvesvaraya Technological University, Belgaum)

Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "**Artificial Intelligence**" carried out by **YASHASVINI M R(1BM21CS252),** who is 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 academic semester Nov -2023 to Feb-2024. The Lab report has been approved as it satisfies the academic requirements in respect of a **Artificial Intelligence (22CS5PCAIN)** work prescribed for the said degree.

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Index Sheet

Course Outcome

CO1	Apply knowledge of agent architecture, searching and reasoning techniques for different applications.
CO2	Analyse Searching and Inferencing Techniques.
CO3	Design a reasoning system for a given requirement.
CO4	Conduct practical experiments for demonstrating agents, searching and inferencing.

1. Implement Tic –Tac –Toe Game

```
import math

def print_board(board):
    for i in range(len(board)):
        for j in range(len(board[i])):
            print(board[i][j], end='')
            if j < len(board[i]) - 1:
                print('|', end='')
        print()
        if i < len(board) - 1:
            print('-'*5)
    print()

def check_winner(board):
    # Check rows, columns, and diagonals for a winner
    for i in range(3):
        if board[i][0] == board[i][1] == board[i][2] != ' ':
            return board[i][0]
        if board[0][i] == board[1][i] == board[2][i] != ' ':
            return board[0][i]
    if board[0][0] == board[1][1] == board[2][2] != ' ':
        return board[0][0]
    if board[0][2] == board[1][1] == board[2][0] != ' ':
        return board[0][2]
    return None

def get_empty_cells(board):
    # Returns a list of empty cells in the board
    return [(i, j) for i in range(3) for j in range(3) if board[i][j] == '
']

def minimax(board, depth, is_maximizing):
    winner = check_winner(board)
    if winner:
        return 10 - depth if winner == 'X' else -10 + depth
    elif not get_empty_cells(board):
        return 0

    if is_maximizing:
        best_score = -math.inf
        for i, j in get_empty_cells(board):
            board[i][j] = 'X'
```

```
            score = minimax(board, depth + 1, False)
            board[i][j] = ' '
            best_score = max(score, best_score)
        return best_score
    else:
        best_score = math.inf
        for i, j in get_empty_cells(board):
            board[i][j] = 'O'
            score = minimax(board, depth + 1, True)
            board[i][j] = ' '
            best_score = min(score, best_score)
        return best_score

def best_move(board):
    best_score = -math.inf
    move = None
    for i, j in get_empty_cells(board):
        board[i][j] = 'X'
        score = minimax(board, 0, False)
        board[i][j] = ' '
        if score > best_score:
            best_score = score
            move = (i, j)
    return 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) and get_empty_cells(board):
        user_move = input("Enter your move (row and column separated by a
space): ")
        x, y = map(int, user_move.split())
        if board[x][y] == ' ':
            board[x][y] = 'O'
            print_board(board)
        else:
            print("Invalid move. Try again.")
            continue

        if not get_empty_cells(board):
            break

        computer_move = best_move(board)
```

```python
        board[computer_move[0]][computer_move[1]] = 'X'
        print("Computer's move:")
        print_board(board)

    winner = check_winner(board)
    if winner:
        print(f"Player {winner} wins!")
    else:
        print("It's a tie!")

if __name__ == "__main__":
    play_game()
```

OUTPUT

```
Welcome to Tic Tac Toe!
 | |
-----
 | |
-----
 | |

Enter your move (row and column separated by a space): 2 2
 | |
-----
 | |
-----
 | |O

Computer's move:
 | |
-----
 |X|
-----
 | |O

Enter your move (row and column separated by a space): 1 2
 | |
-----
 |X|O
-----
 | |O
```

```
Computer's move:
 | |X
-----
 |X|O
-----
 | |O

Enter your move (row and column separated by a space): 2 0
 | |X
-----
 |X|O
-----
O| |O

Computer's move:
 | |X
-----
 |X|O
-----
O|X|O

Enter your move (row and column separated by a space): 1 1
Invalid move. Try again.
Enter your move (row and column separated by a space): 0 1
 |O|X
-----
 |X|O
-----
O|X|O
```

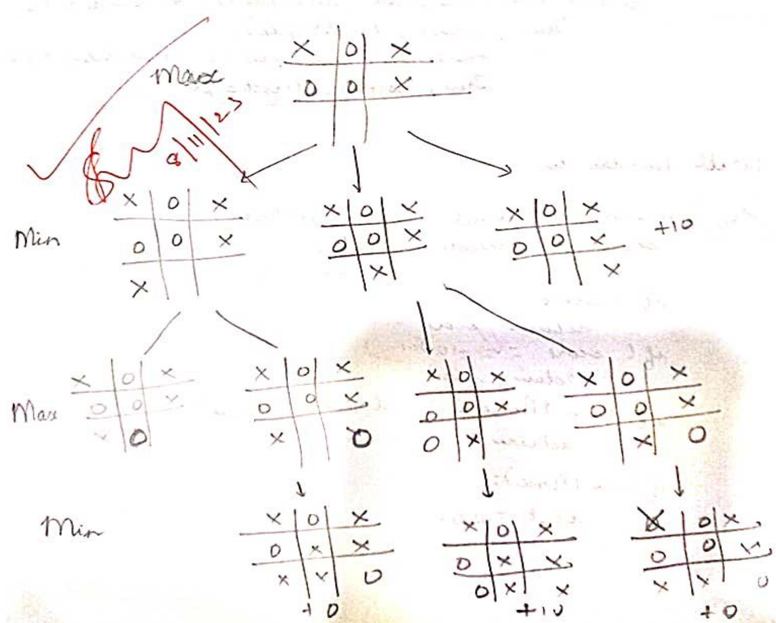
```
Computer's move:
X|O|X
-----
 |X|O
-----
O|X|O

Enter your move (row and column separated by a space): 1 0
X|O|X
-----
O|X|O
-----
O|X|O

It's a tie!
```

OBSERVATION

Tic - Tac - Toe

The tic-tac-toe game makes use of the Minimax algorithm.

- Consider a player - X as the maximizer. This player tries to maximize to win by choosing a move which gives higher score. The score will be chosen in such a way that it ensures faster victory of X using lesser moves.
-



15-11-2023

Minimax Algorithm

```
(In general)
import math

def minimax(curDepth, nodeIndex, maxTurn, scores,
            targetDepth):

    if (curDepth == targetDepth):
        return scores[nodeIndex]
    if (maxTurn):
        return max(minimax(curDepth+1, nodeIndex*2,
               False, scores, targetDepth),
               minimax(curDepth+1, nodeIndex*2+1,
               False, scores, targetDepth))
    else:
        return min(minimax(curDepth+1, nodeIndex*2,
               True, scores, targetDepth),
               minimax(curDepth+1, nodeIndex*2+1
               True, scores, targetDepth))
```

With tic-tac-toe :

```
def minimax(board, depth, isMax):
    score = evaluate(board)

    if (score == 10):
        return score
    if (score == -10):
        return score
    if (isMovesLeft(board) == False):
        return 0
    if (isMax):
        best = -1000
        for i in range(3):
            for j in range(3):
                if (board[i][j] == '_'):
                    board[i][j] = player
                    best = max(best, minimax(board,
                                   depth+1, not isMax))

                    board[i][j] = '_'
        return best
    # minimize
    else:
        best = 1000
        for i in range(3):
            for j in range(3):
                if (board[i][j] == '_'):
                    board[i][j] = opponent
                    best = min(best, minimax(board,
                           depth+1, not isMax))
                board[i][j] = '_'
        return best
```

AI- approaches

Rule - Based approach : Rules are given by us humans.

Machine - learning approach : Learns from the dataset

15/11/23

2. Implement vaccum cleaner agent

```
def printInformation(location):
    print("Location " + location + " is Dirty.")
    print("Cost for CLEANING " + location + ": 1")
    print("Location " + location + " has been Cleaned.")


def vacuumCleaner(goalState, currentState, location):
    # printing necessary data
    print("Goal State Required:", goalState)
    print("Vacuum is placed in Location " + location)

    # cleaning locations
    totalCost = 0

    while (currentState != goalState):
        if (location == "A"):
            # cleaning
            if (currentState["A"] == 1):
                currentState["A"] = 0
                totalCost += 1
                printInformation("A")
            # moving
            elif (currentState["B"] == 1 ):
                print("Moving right to the location B.\nCost for moving 
RIGHT: 1")
                location = "B"
                totalCost += 1

        elif (location == "B"):
            # cleaning
            if (currentState["B"] == 1):
                currentState["B"] = 0
                totalCost += 1
                printInformation("B")
            # moving
            elif (currentState["A"] == 1):
                print("Moving left to the location A.\nCost for moving LEFT: 
1")
                location = "A"
                totalCost += 1

    print("GOAL STATE:", currentState)
    return totalCost
```

```
# declaring dictionaries
goalState = {"A": 0, "B": 0}
currentState = {"A": -1, "B": -1}

# taking input from user
location = input("Enter Location of Vacuum (A/B): ");
currentState["A"] = int(input("Enter status of A (0/1): "))
currentState["B"] = int(input("Enter status of B (0/1): "))

# calling function
totalCost = vacuumCleaner(goalState, currentState, location)
print("Performance Measurement:", totalCost)
```

OUTPUT

```
Enter Location of Vacuum (A/B): B
Enter status of A (0/1): 1
Enter status of B (0/1): 1
Goal State Required: {'A': 0, 'B': 0}
Vacuum is placed in Location B
Location B is Dirty.
Cost for CLEANING B: 1
Location B has been Cleaned.
Moving left to the location A.
Cost for moving LEFT: 1
Location A is Dirty.
Cost for CLEANING A: 1
Location A has been Cleaned.
GOAL STATE: {'A': 0, 'B': 0}
Performance Measurement: 3
```

OBSERVATION

Vacuum World Program

- Takes input of initial location, and status of location A and B.
- If ~~location~~ it is in location 'A' and it is dirty, it cleans or if it is clean and location 'B' is dirty is moves to location 'B' and cleans till it reaches goal state {'A': 0, 'B': 0}
- Cost is one each for moving and cleaning.
- Performance measure is total cost.

Program:

```
def PrintInformation(location):
    print ("Location " + location + " is Dirty.")
    print ("Cost for cleaning " + location + ": 1")
    print (" Location " + location + " has been Cleaned.")
def vacuumCleaner(goalState, currentState, location):
    print( "Goal State required:", goalState)
    print ("Vacuum is placed in Location " + location)

    total cost = 0

    while (currentState != goalState):
        if (location == 'A'):
            if (currentState ["A"] == 1):
                currentState ["A"] = 0
                total Cost += 1
                print Information ("A")

            elif (currentState ["B"] == 1):
                print ("Moving right to the location B.\n
    Cost for moving right : 1")
            location = "B"
            total Cost += 1

        elif (location == "B"):
            if (currentState ["B"] == 1):
                currentState ["B"] = 0
                total Cost += 1
                print Information ("B")
            elif (currentState ["A"] == 1):
                print ("Moving left to the location A.\n
    Cost for moving left : 1")
                location = "A"
                total Cost += 1
print ("Goal State:", Current State)
return total Cost

goalState = {"A": 0, "B": 0}
currentState = {"A": -1, "B": -1}

location = input( "Enter location of Vacuum(A/B): ").
currentState ["A"] = int (input ("Enter state of A(0/1): ")
currentState ["B"] = int (input (" Enter status of B(0/1) : ")

total Cost = vacuum Cleaner( goalState, currentState, location)
print (" Performance Measurement:", total Cost)
```

Output

```
Enter location of Vacuum (A/B) : B
Enter State of A(0/1) : 1
Enter state of B(0/1) : 1.
Goal State required: {'A': 0, 'B': 0}
Vacuum is placed in Location B
Location B is dirty
Cost for Cleaning B: 1
Location B is Cleaned.
Moving left to the Location A.
Cost for moving Left : 1
```

3. Analyse 8 Puzzle problem and implement the same using Breadth First Search Algorithm

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

    while queue:
        source = queue.pop(0)
        visited.add(tuple(source))  # Store visited states as tuples for
faster lookup

        print(source[0], '|', source[1], '|', source[2])
        print(source[3], '|', source[4], '|', source[5])
        print(source[6], '|', source[7], '|', source[8])
        print("-----------")

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

        poss_moves_to_do = possible_moves(source, visited)
        for move in poss_moves_to_do:
            queue.append(move)

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

    # Add possible directions to move based on the position of the empty
cell
    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 possible moves that have not been visited yet
    return [move_it_can for move_it_can in pos_moves_it_can if
tuple(move_it_can) not in visited_states]

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

# Taking input for initial and goal states
print("Enter the initial state of the puzzle (use numbers 0-8 separated by
spaces):")
src = list(map(int, input().split()))

print("Enter the goal state of the puzzle (use numbers 0-8 separated by
spaces):")
target = list(map(int, input().split()))

bfs(src, target)
```

OUTPUT

```
Enter the initial state of the puzzle (use numbers 0-8 separated by spaces):
1 2 3 0 4 5 6 7 8
Enter the goal state of the puzzle (use numbers 0-8 separated by spaces):
1 2 3 4 5 0 6 7 8
1 | 2 | 3
0 | 4 | 5
6 | 7 | 8
-----------
0 | 2 | 3
1 | 4 | 5
6 | 7 | 8
-----------
1 | 2 | 3
6 | 4 | 5
0 | 7 | 8
-----------
1 | 2 | 3
4 | 0 | 5
6 | 7 | 8
-----------
2 | 0 | 3
1 | 4 | 5
6 | 7 | 8
-----------
1 | 2 | 3
6 | 4 | 5
7 | 0 | 8
-----------
1 | 0 | 3
4 | 2 | 5
6 | 7 | 8
-----------
1 | 2 | 3
4 | 7 | 5
6 | 0 | 8
-----------
1 | 2 | 3
4 | 5 | 0
6 | 7 | 8
-----------
Success
```

OBSERVATION

8 - Puzzle Problem Using - BFS

- Uses queue to hold all states that have to be / been visited
- When visited, pops them to a list called exp.
- The 8 - Puzzle problem requires the initial state to reach the goal state by moving the tiles to blank.
- Possible moves are 'd', 'u', 'r', 'l'.

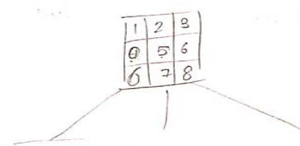
```
def bfs(src, target):
    queue = []
    queue.append(src)
    exp = []
    while len(queue) > 0:
        source = queue.pop(0)
        exp.append(source)
        print(source[0], '|', source[1], '|', source[2])
        print(source[3], '|', source[4], '|', source[5])
        print(source[6], '|', source[7], '|', source[8])
        print("..------")
        if source == target:
            print("Success")
            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)

def possible_moves(state, visited_states):
    b = state.index(0)
    d = []
    if b not in [0, 1, 2]:
        d.append('u')        //
    if b not in [6, 7, 8]:
        d.append('d')
```

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

 poss_moves_it_can = []
 for pos i in d:
      pos_moves_it_can.append(gen(state, i, b))
 return [move_it_can for move_it_can in pos_moves_
   it_can if move_it_can not in visited_states]

def gen(states, m, b):
   temp = state.copy()
    if m == 'd':
        temp[b+3], temp[b] = temp[b], temp[b+3]

    if m == 'u':
        temp[b-3], temp[b] = temp[b], temp[b-3]
                                  c; b- b. a
    if m == 'l':
        temp[b-1], temp[b] = temp[b], temp[b-1] //swap

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

    return temp
print (" Enter the initial state of the puzzle( use
  numbers 0-8 separated by spaces) : ")
src = list( map( int, input (). split ()))
print (" Enter the goal state of the puzzle ( use
numbers 0-8 separated by spaces ),")
target = list ( map( int , input (). split ()))
 bfs ( src , target)
```

Output
Enter the initial state of puzzle(use numbers 0-8
separated by spaces):
1 2 3 0 4 5 6 7 8

Enter the goal state of the puzzle(use numbers 0-8
separated by spaces):
1 2 3 4 5 0 6 7 8

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

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



4. Analyse Iterative Deepening Search Algorithm. Demonstrate how 8 Puzzle problem could be solved using this algorithm

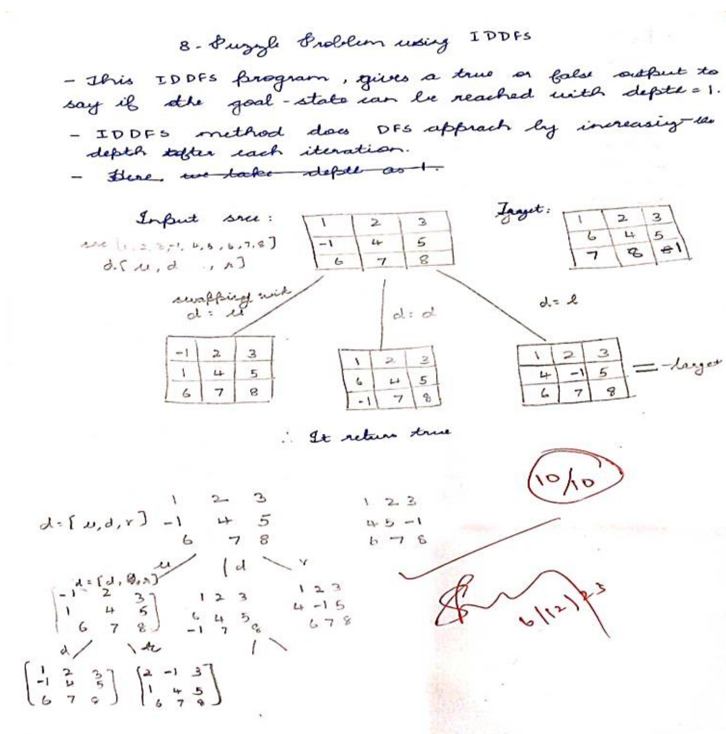
```
def dfs(src,target,limit,visited_states):
    if src == target:
        return True
    if limit <= 0:
        return False
    visited_states.append(src)
    moves = possible_moves(src,visited_states)
    for move in moves:
        if dfs(move, target, limit-1, visited_states):
            return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

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

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

def iddfs(src,target,depth):
    for i in range(depth):
```

```
        visited_states = []
        if dfs(src,target,i+1,visited_states):
            return True, i+1
    return False

print("Enter the initial state of the puzzle (use numbers 0-8 separated by spaces):")
src = list(map(int, input().split()))

print("Enter the goal state of the puzzle (use numbers 0-8 separated by spaces):")
target = list(map(int, input().split()))
depth = 8
iddfs(src, target, depth)
```

OUTPUT

```
Enter the initial state of the puzzle (use numbers 0-8 separated by spaces):
1 2 3 -1 4 5 6 7 8
Enter the goal state of the puzzle (use numbers 0-8 separated by spaces):
1 2 3 6 4 5 7 8 -1
(True, 3)
```

OBSERVATION



5. Implement A* search algorithm

```
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()
```

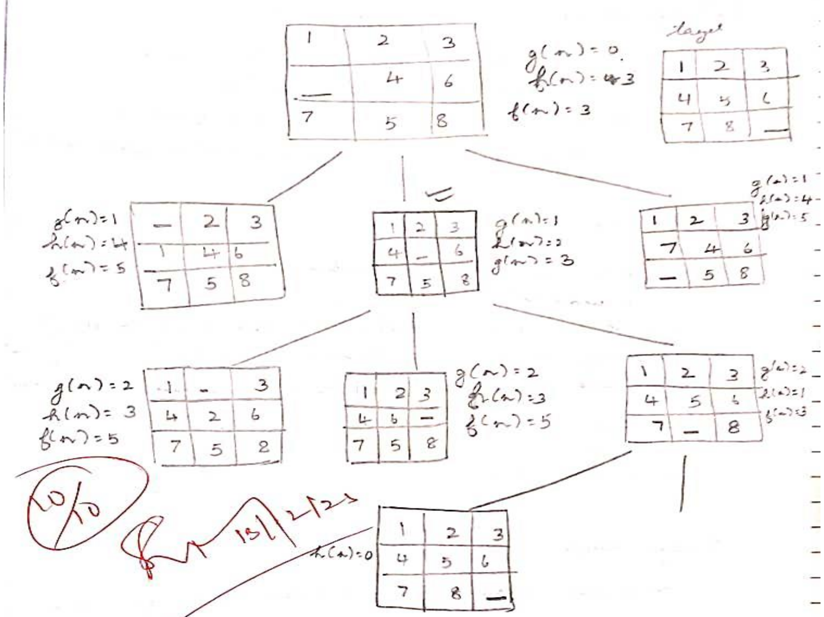
```
        start = Node(start,0,0)
        start.fval = self.f(start,goal)

        self.open.append(start)
        print("\n\n")
        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]


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


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

OUTPUT

```
Enter the start state matrix

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

1 2 3
4 5 6
7 8 _



   |
   |
 \'/

1 2 3
_ 4 6
7 5 8

   |
   |
 \'/

1 2 3
4 _ 6
7 5 8

   |
   |
 \'/

1 2 3
4 5 6
7 _ 8

   |
   |
 \'/

1 2 3
4 5 6
7 8
```

OBSERVATION

8 - Puzzle Problem using A*



- In A* search algorithm, the node to explore is chosen based on it's value of f(n)

ie $f(n) = h(n) + g(n)$

where $h(n)$ = heuristic function, in this code, it is the number of misplaced tiles in that state from goal state.

and $g(n)$ = depth of the node.

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

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

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


def ask(kb, q):
    for c in combinations:
        s = r1(c)
        f = q(c)
        print(s, f)
        if s != f and s != False:
            return 'Does not entail'
    return 'Entails'


kb = []

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

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


result = ask(kb, q)
print(result)
```

OUTPUT 1

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

OUTPUT 2

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

OBSERVATION

20-12-23

Propositional Logic

- If ¬q is true iff P is false in m
- P ∧ q is true iff P and q are true in m
- P ∨ q is true iff either P or q is true
- P → q is true unless P is true and Q is false in m.
- P ⟺ q is true iff P and q are both true or both false

Sample Input output.

Enter Rule 1 as a lambda function (eg, lambda x: x[0] or x[1] and (x[0] and x[1]):
lambda x: (x[0] or x[1]) and (not x[2] or x[0]
Enter Query as a lambda function (eg. lambda x: x[0] and x[1] and (x[0] or x[1]): lambda x: x[0] and x[2]

True True
True False
Does not entail

Query entails KB only if KB → Query
Does not entail if KB = true & Query = false

10/10

20/12/23

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

```
import re

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


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


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


def contradiction(goal, clause):
    contradictions = [ f'{goal}v{negate(goal)}',
f'{negate(goal)}v{goal}']
    return clause in contradictions
def resolve(rules, goal):
    temp = rules.copy()
    temp += [negate(goal)]
    steps = dict()
    for rule in temp:
        steps[rule] = 'Given.'
    steps[negate(goal)] = 'Negated conclusion.'
    i = 0
    while i < len(temp):
        n = len(temp)
        j = (i + 1) % n
        clauses = []
        while j != i:
            terms1 = split_terms(temp[i])
            terms2 = split_terms(temp[j])
            for c in terms1:
                if negate(c) in terms2:
                    t1 = [t for t in terms1 if t != c]
```

```
                    t2 = [t for t in terms2 if t != negate(c)]
                    gen = t1 + t2
                    if len(gen) == 2:
                        if gen[0] != negate(gen[1]):
                            clauses += [f'{gen[0]}v{gen[1]}']

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

OUTPUT

```
Enter the rules (space-separated): Rv~P Rv~Q ~RvP ~RvQ
Enter the goal: R

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

OBSERVATION

27/12/23 Create a knowledge base using propositional logic and prove the given query using resolution.

- The query is concluded to be true, using resolution of the clauses.
- While resolving, if we get null — then the query is true. (contradiction is found)

Enter the kb:
R V ~P   R V ~Q   ~R V P   ~R V Q
Enter the Query:
R

10/10

Tracing:

rules = R V ~P   R V ~Q   ~R V P   ~R V Q
Given goal = R

steps = (R V ~P (all rules) rule, R goal)
then create a copy of the rules and add ~R to it.
- dictionary - steps.
- Rules first as given, and then negation of goal as negated conclusion.

temp [1] = R V ~P
temp [2] = R V ~Q
terms 1 = 'R' '~P'
terms 2 = 'R' '~Q'

If sign C in term R & ~P
here ~P not in terms 2
then ~P is also not in term 2
clause is empty now.
so i = i++, temp [3] = ~R V P

8. Implement unification in first order logic

```
import re

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

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

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

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

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

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

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


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


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

```
    return newExpression

def unify(exp1, exp2):
    if exp1 == exp2:
        return []

    if isConstant(exp1) and isConstant(exp2):
        if exp1 != exp2:
            return False

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

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

    if isVariable(exp1):
        if checkOccurs(exp1, exp2):
            return False
        else:
            return [(exp2, exp1)]

    if isVariable(exp2):
        if checkOccurs(exp2, exp1):
            return False
        else:
            return [(exp1, exp2)]

    if getInitialPredicate(exp1) != getInitialPredicate(exp2):
        print("Predicates do not match. Cannot be unified")
        return False

    attributeCount1 = len(getAttributes(exp1))
    attributeCount2 = len(getAttributes(exp2))
    if attributeCount1 != attributeCount2:
        return False

    head1 = getFirstPart(exp1)
    head2 = getFirstPart(exp2)
    initialSubstitution = unify(head1, head2)
    if not initialSubstitution:
        return False
    if attributeCount1 == 1:
        return initialSubstitution

    tail1 = getRemainingPart(exp1)
    tail2 = getRemainingPart(exp2)
```

```
    if initialSubstitution != []:
        tail1 = apply(tail1, initialSubstitution)
        tail2 = apply(tail2, initialSubstitution)

    remainingSubstitution = unify(tail1, tail2)
    if not remainingSubstitution:
        return False

    initialSubstitution.extend(remainingSubstitution)
    return initialSubstitution


exp1 = input("Enter the first expression: ")
exp2 = input("Enter the second expression: ")


substitutions = unify(exp1, exp2)


print("Substitutions:")
print(substitutions)
```

OUTPUT

```
Enter the first expression: knows(f(x),y)
Enter the second expression: knows(J,John)
Substitutions:
[('J', 'f(x)'), ('John', 'y')]
```

OBSERVATION

10-1-24

Implementation of Unifications in First Order Logic

- Unification in first order is

- Starts with unify(exp1, exp2)

Input: knows(f(x), y) - first expression
knows(J, John) - second expression.

in unify((knows(f(x), y), (knows(~~f(x), y~~))) J, John

returns [] as exp1 ≠ exp2
returns as false for isConstant
returns false for is Variable.

then if checks id getInitialPredicate(exp1) &

- checks if the string before '(' is same in both expressions.

- Since it true, it returns True.

and goes to count the number of attributes in both the expression.

- Since it is same, it returns true.

Here exp1 = exp2 = 2

head 1 = getFirstPart(knows(f(x), y)) = f(x)
head 2 = getFirstPart(knows(J, John)) = J

Initial Substitution = unify(f(x), J)

i) exp1 ≠ exp2 return []
ii) f(x) && J ≠ constant, returns False
iii) is Constant (f(x)) - false
iv) is Constant (J) - true

∴ it returns [J, f(x)]

Initial Substitute = [J, f(x)]

now, tail 1 = getRemainingPart(knows (f(x), y))
tail 2 = getRemainingPart (knows (J, John))
Predicate = getInitialPredicate (knows (f(x), y))
= knows.
attributes = getAttributes (expression)
= (f(x), y)
new Express = knows (, y)

return (, y)
After doing for both.

tail 1 = (y)
tail 2 = (John)

initial Subn = [J, f(x)] – not empty.
tail 1 = apply(tail 1 (y), ~~initial subs~~ [J, f(x)])
tail 2 = apply(John , [J, f(x)])

apply (kn(y), [J, f(x)])
exp = y
exp = knows(y)
For subs in substitution
new = J
old = f(x)

exp = replace Attributes (y, f(x), J)
exp, old, new

attribute = getAttributes (kn(y)) = y
predicate = knows
[y]
return knows (y) y ≠ f(x)
return knows(y)
tail 1 = Knows (y)
tail 2 = knows (John)
remaining Substitution = unify (knows(y), knows(John))
Everything repeats.
is Variable (y)
if checkOccurs (John, y)
return false
hence return [(John, y)]

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

```
import re

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

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

def 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 == '|':
            s[i] = '&'
        elif c == '&':
            s[i] = '|'
    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] + '|' + 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 = '(~[∀|∃].)'
    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
```

```python
print(Skolemization(fol_to_cnf("animal(y)<=>loves(x,y)")))
print(Skolemization(fol_to_cnf("∀x[∀y[animal(y)=>loves(x,y)]]=>[∃z[loves(z,x)]]")))
print(fol_to_cnf("[american(x)&weapon(y)&sells(x,y,z)&hostile(z)]=>criminal(x)"))
```

OUTPUT

```
[~animal(y)|loves(x,y)]&[~loves(x,y)|animal(y)]
[animal(G(x))&~loves(x,G(x))]|[loves(F(x),x)]
[~american(x)|~weapon(y)|~sells(x,y,z)|~hostile(z)]|criminal(x)
```

OBSERVATION

17-1-24 Convert First Order Logic to CNF

- Remove implication.
  $a \rightarrow b \equiv \neg a \vee b$
- Move ¬ inwards. $\neg \forall x P = \exists x \neg$
  eg: $\neg(a \vee b) \equiv \neg a \wedge \neg b$
- Rename variables, - give different variables for each statement
- Eliminate existential instantiate by elimination.
  replace ∃ by constant and replace the constant by a f (skolem function)
- Drop universal quantifier.
  - keep ∨ as it is, change where there is ∧
  ~~ust~~ ~~∃~~ seperate the literals) clauses.

Algorithm :
- Take input calls fol_to_cnf :
  replaces <=> with "–", replace that with => a
  a<=>b as a=>b & b=>a
- Then replace => with '–' change it to
  a-b as ~a∨b
- Converts ~∀x P(x) to ∃x P(x)
- Coverts ~∃x p(x) to ∀x P(x)
- ~~Then~~ If ~[statement] performs DeMorgan's law:
  replace '~~' to ''
  flag = [— used later.
  Removes ~[&]
  replaces | with & and & with |
- Skolemization – eliminate . ∃
  makes a copy of list for the statement
  matches [∀∃] in reverse

eg: animal(y)<=> loves(x,y)
[~animal(y)|loves (x,y)] & [~loves(x,y)|animal(y)]

17/1/24

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

```
import re

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

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

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

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

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

    def getResult(self):
        return self.result

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

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

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

    def evaluate(self, facts):
        constants = {}
        new_lhs = []
```

```
        for fact in facts:
            for val in self.lhs:
                if val.predicate == fact.predicate:
                    for i, v in enumerate(val.getVariables()):
                        if v:
                            constants[v] = fact.getConstants()[i]
                    new_lhs.append(fact)
        predicate, attributes = getPredicates(self.rhs.expression)[0],
str(getAttributes(self.rhs.expression)[0])
        for key in constants:
            if constants[key]:
                attributes = attributes.replace(key, constants[key])
        expr = f'{predicate}{attributes}'
        return Fact(expr) if len(new_lhs) and all([f.getResult() for f
in new_lhs]) else None

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

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

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

    def display(self):
        print("All facts: ")
        for i, f in enumerate(set([f.expression for f in self.facts])):
            print(f'\t{i+1}. {f}')
kb = KB()
kb.tell('missile(x)=>weapon(x)')
kb.tell('missile(M1)')
kb.tell('enemy(x,America)=>hostile(x)')
```

```
kb.tell('american(West)')
kb.tell('enemy(Nono,America)')
kb.tell('owns(Nono,M1)')
kb.tell('missile(x)&owns(Nono,x)=>sells(West,x,Nono)')
kb.tell('american(x)&weapon(y)&sells(x,y,z)&hostile(z)=>criminal(x)')
kb.query('criminal(x)')
kb.display()
```

OUTPUT

```
Querying criminal(x):
        1. criminal(West)
All facts:
        1. enemy(Nono,America)
        2. weapon(M1)
        3. owns(Nono,M1)
        4. missile(M1)
        5. criminal(West)
        6. hostile(Nono)
        7. sells(West,M1,Nono)
        8. american(West)
```

OBSERVATION

24-01-234

Creating a knowledge base consists of first order logic statements and prove the given query using forward reasoning

tell('missile(x) => weapon(x)')
tell('missile(M1)')
tell('enemy(x, America) => hostile(x)')
tell('american(West)')
tell('enemy(Nono, America)')
tell('owns(Nono, M1)')
tell('missile(x) & owns(Nono, x) => sells(West, x, Nono)')
tell('american(x) & weapon(y) & sells(x, y, z) & hostile(z) => criminal(x)')

tell('criminal(x)'

tell('missile(x) => weapon(x)')
there is '=>' in s
lhs = missile(x)
rhs = weapon(x)

24/1/24