VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

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
(Autonomous Institution under VTU)
BENGALURU-560019

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 (23CS5PCAIN)" carried out by **Kshitiz Anand(1BM22CS349),** 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. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

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Github Link: https://github.com/KshitizAnandBMS/AI_LAB

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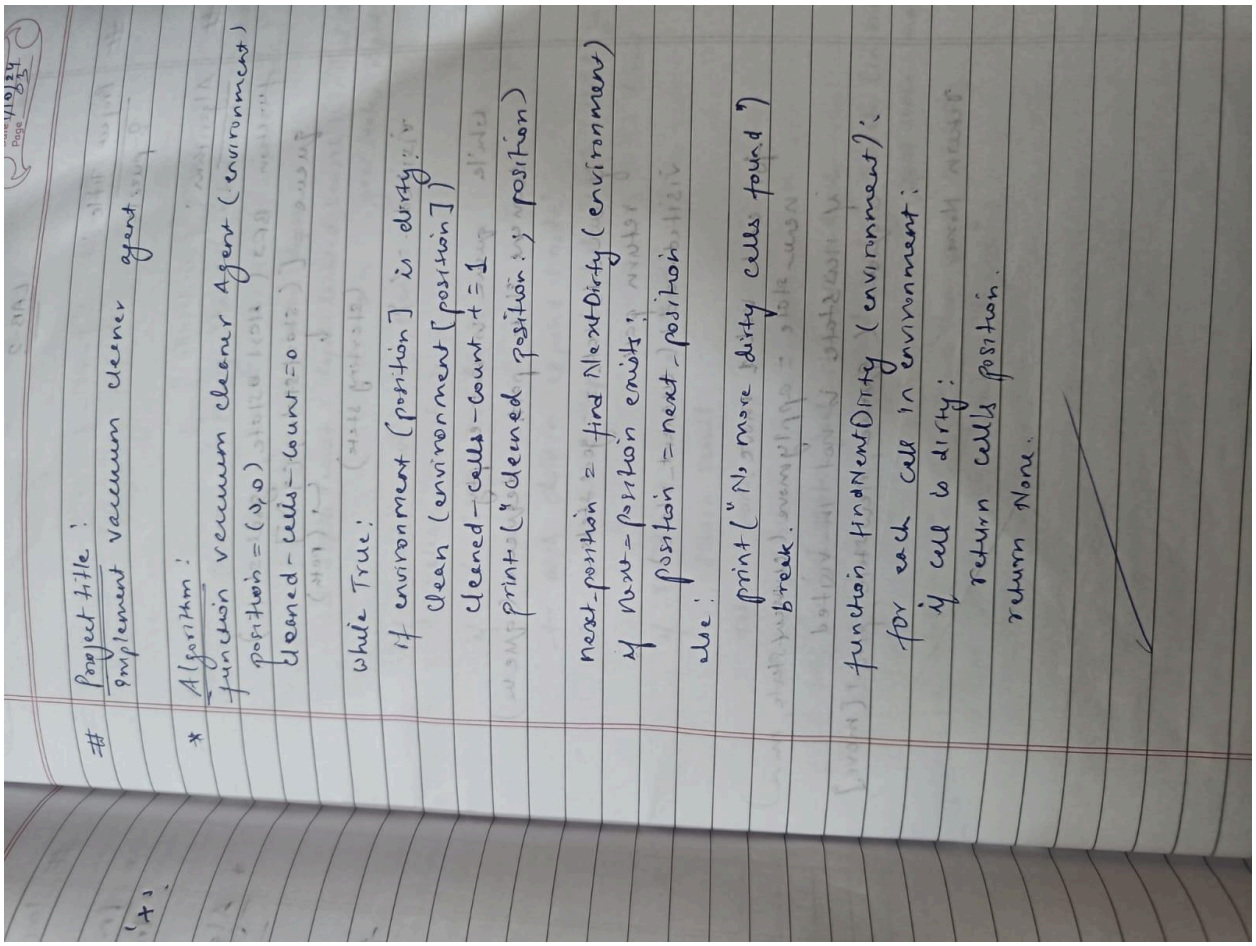
AI OBSERVATION BOOK

LAB-01

Implementation of a Vacuum Cleaner Agent

ALGORITHM:



CODE:

```
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 + " (0 for
Clean, 1 for Dirty): ")  # 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))
                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("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 left
            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("Location A 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 left
        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))
            print("Location A is already clean.")

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


vacuum_world()
```

OUTPUT:

```
Enter Location of Vacuum: B
Enter status of B (0 for Clean, 1 for Dirty): 1
Enter status of other room: 1
Initial Location Condition: {'A': '0', 'B': '0'}
Vacuum is placed in Location B
Location B is Dirty.
COST for CLEANING: 1
Location B has been Cleaned.
Location A is Dirty.
Moving LEFT to the Location A.
COST for moving LEFT: 2
COST for SUCK: 3
Location A has been Cleaned.
Location A is Dirty.
Moving LEFT to the Location A.
COST for moving LEFT: 4
Cost for SUCK: 5
Location A has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 5
```

Implementation of Tic Tac Toe Game:

ALGORITHM:

LAB 1

Implement a tic-tac-toe game

* Program title:
Implement a tic-tac-toe game.

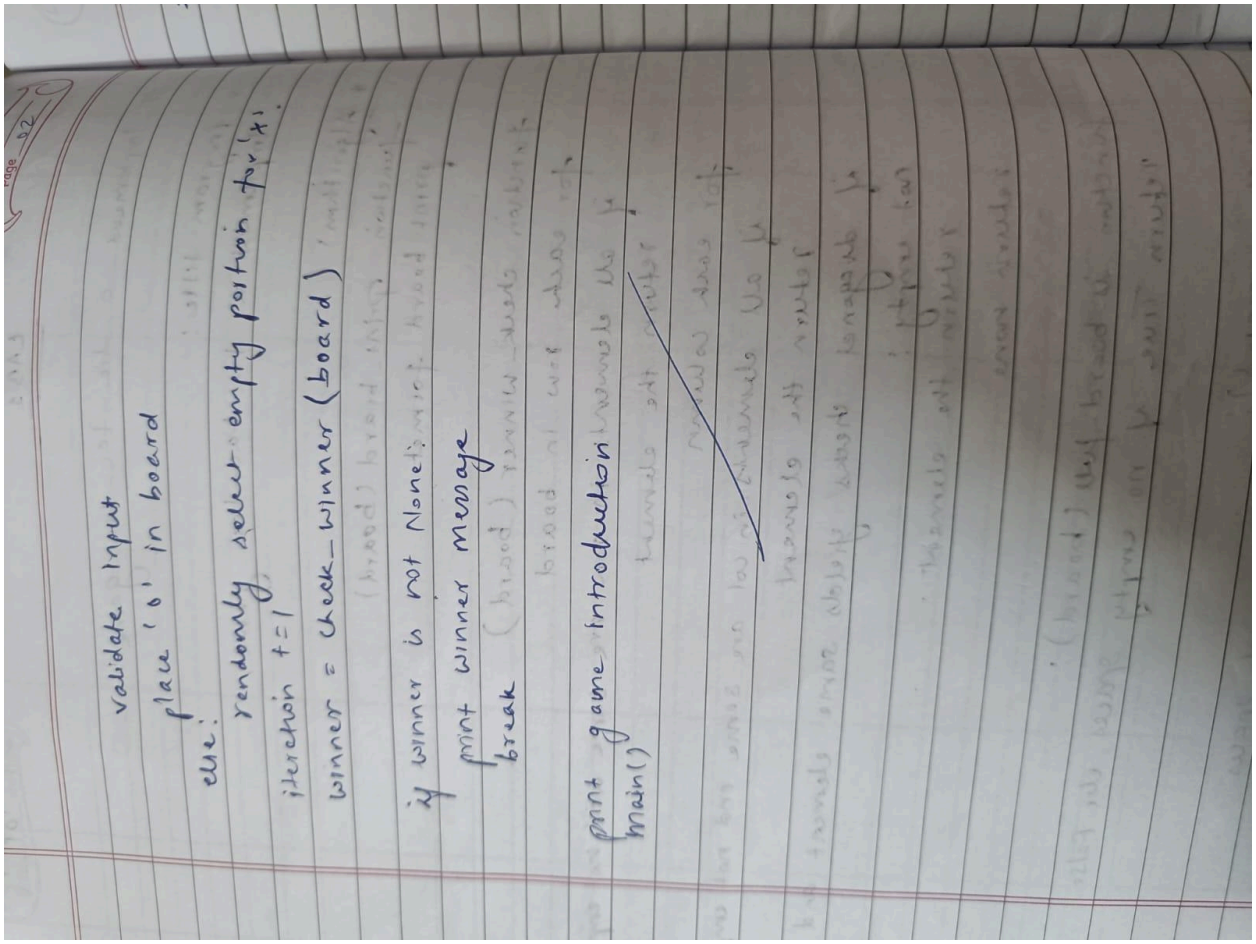
* Algorithm:

function print_board (board)
print board format

function check_winner (board)
for each row in board
if all elements in row are same and not empty:
return the element
for each column
if all elements in col are same and not empty:
return the element
if diagonal checks yields same element and
not empty:
return the element.
return none

function is_board_full (board):
Return True if no empty spaces, else False.

function main():
initialise board with empty spaces
iteration = 0
winner = none
while winner is none:
if iteration is even:
print_board (board)
get user input for row & column.



CODE:

```
board={1:' ',2:' ',3:' ',
      4:' ',5:' ',6:' ',
      7:' ',8:' ',9:' '

}

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 spaceFree(pos):
```

```
    if(board[pos]==' '):
        return True
    else:
        return False

def checkWin():
    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[5] and board[1] == board[9] and board[1] != '
'):
        return True
    elif (board[3] == board[5] and board[3] == board[7] and board[3] != '
'):
        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
    else:
        return False

def checkMoveForWin(move):
    if (board[1]==board[2] and board[1]==board[3] and board[1] ==move):
        return True
    elif (board[4]==board[5] and board[4]==board[6] and board[4] ==move):
        return True
    elif (board[7]==board[8] and board[7]==board[9] and board[7] ==move):
        return True
    elif (board[1]==board[5] and board[1]==board[9] and board[1] ==move):
        return True
    elif (board[3]==board[5] and board[3]==board[7] and board[3] ==move):
```

```
        return True
    elif (board[1]==board[4] and board[1]==board[7] and board[1] ==move):
        return True
    elif (board[2]==board[5] and board[2]==board[8] and board[2] ==move):
        return True
    elif (board[3]==board[6] and board[3]==board[9] and board[3] ==move):
        return True
    else:
        return False

def checkDraw():
    for key in board.keys():
        if (board[key]==' '):
            return False
    return True


def insertLetter(letter, position):
    if (spaceFree(position)):
        board[position] = letter
        printBoard(board)

        if (checkDraw()):
            print('Draw!')
        elif (checkWin()):
            if (letter == 'X'):
                print('Bot wins!')
            else:
                print('You win!')
        return

    else:
        print('Position taken, please pick a different position.')
        position = int(input('Enter new position: '))
        insertLetter(letter, position)
        return

player = 'O'
bot ='X'
```

```
def playerMove():
   position=int(input('Enter position for O:'))
   insertLetter(player, position)
   return

def compMove():
   bestScore=-1000
   bestMove=0
   for key in board.keys():
       if (board[key]==' '):
           board[key]=bot
           score = minimax(board, False)
           board[key] = ' '
           if (score > bestScore):
               bestScore = score
               bestMove = key

   insertLetter(bot, bestMove)
   return


def minimax(board, isMaximizing):
   if (checkMoveForWin(bot)):
       return 1
   elif (checkMoveForWin(player)):
       return -1
   elif (checkDraw()):
       return 0

   if isMaximizing:
       bestScore = -1000

       for key in board.keys():
           if board[key] == ' ':
               board[key] = bot
               score = minimax(board, False)
               board[key] = ' '
               if (score > bestScore):
                   bestScore = score
       return bestScore
```

```
    else:
        bestScore = 1000

        for key in board.keys():
            if board[key] == ' ':
                board[key] = player
                score = minimax(board, True)
                board[key] = ' '
                if (score < bestScore):
                    bestScore = score
        return bestScore

while not checkWin():
    compMove()
    playerMove()
```

OUTPUT:

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


Enter position for O:5
X| |
-+-+-
 |O|
-+-+-
 | |


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

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


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


Enter position for O:4
X|X|O
-+-+-
O|O|
-+-+-
X| |
```

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


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


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


Draw!
```

LAB-02
Implementation of 8 puzzles games using BFS and DFS

ALGORITHM:

LAB-2

Project Title:
8-puzzle

Algorithm:

function BFS (start state, goal state)
queue = [(start state, [ ])]
(starting state) (path)

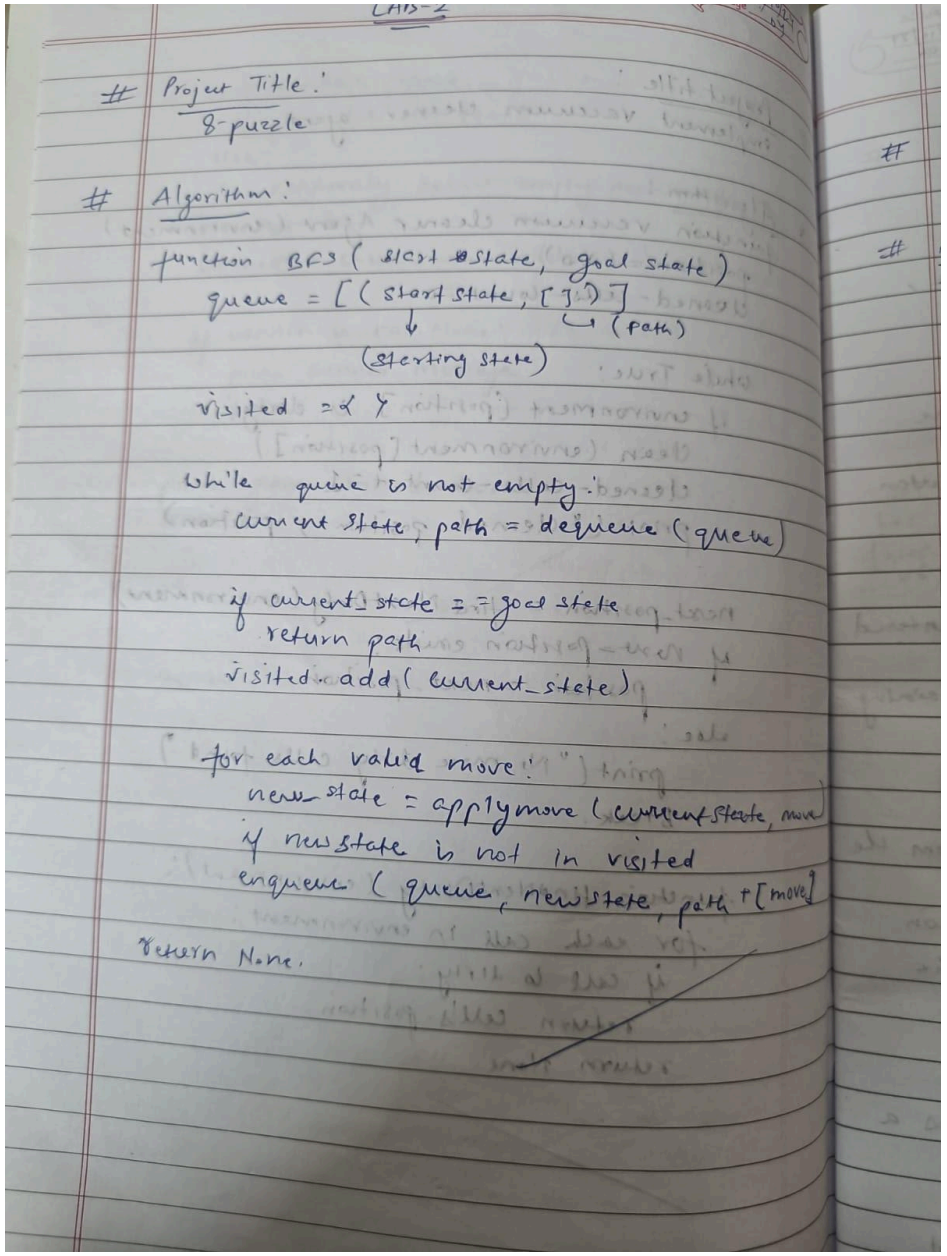
visited = { }

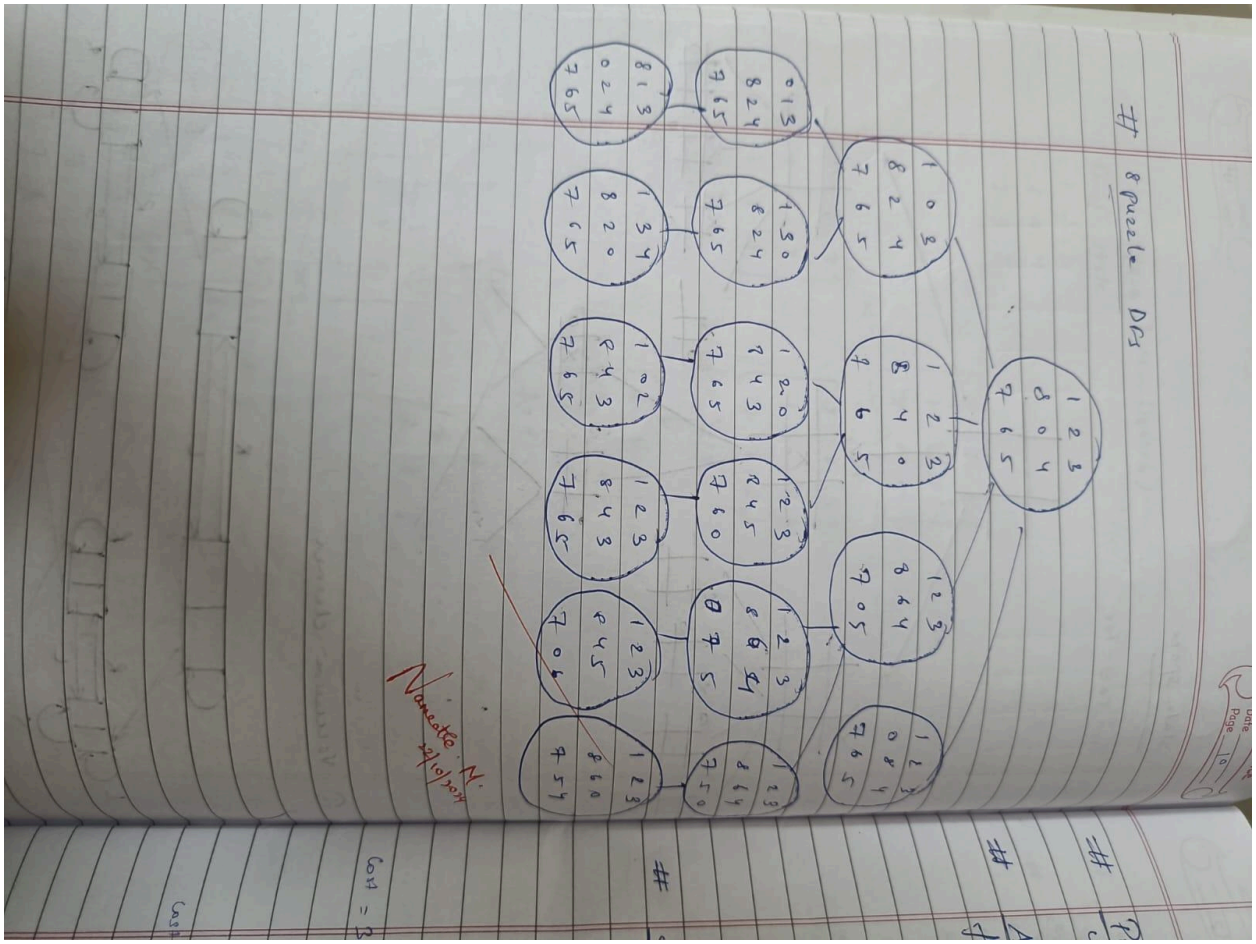
while queue is not empty:
current state, path = dequeue (queue)

if current_state == goal state
return path
visited.add (current_state)

for each valid move:
new_state = applymove (current state, move)
if new state is not in visited
enqueue (queue, new state, path + [move])

return None.





CODE-BFS

```
import numpy as np
from collections import deque

class Node:
    def __init__(self, state, parent, action):
        self.state = state  # The puzzle configuration (as a 2D array)
        self.parent = parent  # Parent node (used to trace back the solution)
        self.action = action  # Action taken to reach this state (e.g., 'up', 'down')

class Puzzle:
    def __init__(self, start, start_index, goal, goal_index):
        self.start = [start, start_index]  # Starting puzzle state and blank tile index
        self.goal = [goal, goal_index]  # Goal puzzle state and blank tile index
```

```
    self.solution = None  # To store the final solution path

def neighbors(self, state):
    mat, (row, col) = state  # Puzzle state and the position of the blank tile (0)
    results = []

    # Move the blank tile up
    if row > 0:
        mat1 = np.copy(mat)
        mat1[row][col] = mat1[row - 1][col]
        mat1[row - 1][col] = 0
        results.append(('up', [mat1, (row - 1, col)]))

    # Move the blank tile left
    if col > 0:
        mat1 = np.copy(mat)
        mat1[row][col] = mat1[row][col - 1]
        mat1[row][col - 1] = 0
        results.append(('left', [mat1, (row, col - 1)]))

    # Move the blank tile down
    if row < 2:
        mat1 = np.copy(mat)
        mat1[row][col] = mat1[row + 1][col]
        mat1[row + 1][col] = 0
        results.append(('down', [mat1, (row + 1, col)]))

    # Move the blank tile right
    if col < 2:
        mat1 = np.copy(mat)
        mat1[row][col] = mat1[row][col + 1]
        mat1[row][col + 1] = 0
        results.append(('right', [mat1, (row, col + 1)]))

    return results

def solve_bfs(self):
    """Breadth-First Search (BFS) implementation for solving the 8-puzzle."""
    # Initialize the frontier with the starting node (queue)
    start = Node(state=self.start, parent=None, action=None)
    frontier = deque([start])  # Using deque for fast popping from the left (FIFO)

    explored = []  # List to keep track of explored states
```

```
    while frontier:
        # Dequeue the node (FIFO)
        node = frontier.popleft()

        # Check if the current state is the goal state
        if (node.state[0] == self.goal[0]).all():
            actions = []
            cells = []
            while node.parent is not None:
                actions.append(node.action)
                cells.append(node.state)
                node = node.parent
            actions.reverse()
            cells.reverse()
            self.solution = (actions, cells)
            return self.solution

        # Add the current state to the explored set
        explored.append(node.state)

        # Expand the neighbors of the current state
        for action, neighbor in self.neighbors(node.state):
            # If the neighbor state has not been explored and is not in the frontier
            if not any((explored_state[0] == neighbor[0]).all() for explored_state in explored):
                if not any((frontier_node.state[0] == neighbor[0]).all() for frontier_node in frontier):
                    # Add the neighbor to the frontier
                    child_node = Node(state=neighbor, parent=node, action=action)
                    frontier.append(child_node)

    # No solution found
    raise Exception("No solution found.")

def print_solution(self):
    if self.solution is None:
        print("No solution available.")
        return

    # Print the solution path
    print("Initial State:")
    print(self.start[0], "\n")

    for action, state in zip(self.solution[0], self.solution[1]):
        print(f"Action: {action}")
        print(state[0], "\n")
```

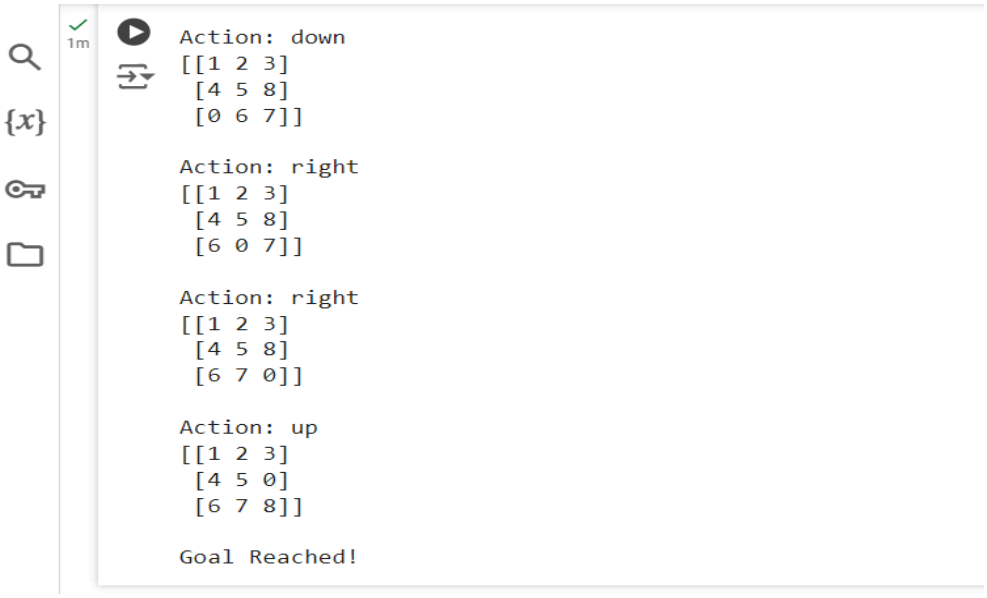
```
        print("Goal Reached!")


# Function to take user input and convert it to a 3x3 matrix
def get_puzzle_input():
    print("Enter the 8-puzzle configuration (use 0 for the blank space):")
    puzzle = []
    for i in range(3):
        row = input(f"Enter row {i + 1} (space-separated numbers): ").split()
        puzzle.append([int(num) for num in row])
    return np.array(puzzle)

# Get user input for start and goal states
start = get_puzzle_input()
goal = get_puzzle_input()

# Find the index of the blank tile (0) in the initial and goal states
start_index = (np.where(start == 0)[0][0], np.where(start == 0)[1][0])
goal_index = (np.where(goal == 0)[0][0], np.where(goal == 0)[1][0])

# Create the puzzle object
puzzle = Puzzle(start, start_index, goal, goal_index)

# Solve the puzzle using BFS
puzzle.solve_bfs()

# Print the solution path
puzzle.print_solution()
```

OUPUT- BFS

```
Enter the 8-puzzle configuration (use 0 for the blank space):
Enter row 1 (space-separated numbers): 1 2 3
Enter row 2 (space-separated numbers): 4 5 6
Enter row 3 (space-separated numbers): 7 8 0
Enter the 8-puzzle configuration (use 0 for the blank space):
Enter row 1 (space-separated numbers): 1 2 3
Enter row 2 (space-separated numbers): 4 5 0
Enter row 3 (space-separated numbers): 6 7 8
Initial State:
[[1 2 3]
 [4 5 6]
 [7 8 0]]

Action: left
[[1 2 3]
 [4 5 6]
 [7 0 8]]

Action: left
[[1 2 3]
 [4 5 6]
 [0 7 8]]

Action: up
[[1 2 3]
 [0 5 6]
 [4 7 8]]
```

1m

```
Action: right
[[1 2 3]
 [5 0 6]
 [4 7 8]]

Action: right
[[1 2 3]
 [5 6 0]
 [4 7 8]]

Action: down
[[1 2 3]
 [5 6 8]
 [4 7 0]]

Action: left
[[1 2 3]
 [5 6 8]
 [4 0 7]]

Action: up
[[1 2 3]
 [5 0 8]
 [4 6 7]]

Action: left
[[1 2 3]
 [0 5 8]
 [4 6 7]]
```



CODE-DFS

```
import numpy as np
from collections import deque

class Node:
    def __init__(self, state, parent, action):
        self.state = state  # The puzzle configuration (as a 2D array)
        self.parent = parent  # Parent node (used to trace back the solution)
        self.action = action  # Action taken to reach this state (e.g., 'up', 'down')

class Puzzle:
    def __init__(self, start, start_index, goal, goal_index):
        self.start = [start, start_index]  # Starting puzzle state and blank tile index
        self.goal = [goal, goal_index]  # Goal puzzle state and blank tile index
        self.solution = None  # To store the final solution path
```

```
def neighbors(self, state):
    mat, (row, col) = state  # Puzzle state and the position of the blank tile (0)
    results = []

    # Move the blank tile up
    if row > 0:
        mat1 = np.copy(mat)
        mat1[row][col] = mat1[row - 1][col]
        mat1[row - 1][col] = 0
        results.append(('up', [mat1, (row - 1, col)]))

    # Move the blank tile left
    if col > 0:
        mat1 = np.copy(mat)
        mat1[row][col] = mat1[row][col - 1]
        mat1[row][col - 1] = 0
        results.append(('left', [mat1, (row, col - 1)]))

    # Move the blank tile down
    if row < 2:
        mat1 = np.copy(mat)
        mat1[row][col] = mat1[row + 1][col]
        mat1[row + 1][col] = 0
        results.append(('down', [mat1, (row + 1, col)]))

    # Move the blank tile right
    if col < 2:
        mat1 = np.copy(mat)
        mat1[row][col] = mat1[row][col + 1]
        mat1[row][col + 1] = 0
        results.append(('right', [mat1, (row, col + 1)]))

    return results

def solve_dfs(self):
    """Depth-First Search (DFS) implementation for solving the 8-puzzle."""
    # Initialize the frontier with the starting node (stack)
    start = Node(state=self.start, parent=None, action=None)
    frontier = [start]  # Using a list as a stack (LIFO)

    explored = []  # List to keep track of explored states

    while frontier:
```

```
        # Pop the node from the stack (LIFO)
        node = frontier.pop()

        # Check if the current state is the goal state
        if (node.state[0] == self.goal[0]).all():
            actions = []
            cells = []
            while node.parent is not None:
                actions.append(node.action)
                cells.append(node.state)
                node = node.parent
            actions.reverse()
            cells.reverse()
            self.solution = (actions, cells)
            return self.solution

        # Add the current state to the explored set
        explored.append(node.state)

        # Expand the neighbors of the current state
        for action, neighbor in self.neighbors(node.state):
            # If the neighbor state has not been explored and is not in the frontier
            if not any((explored_state[0] == neighbor[0]).all() for explored_state in explored):
                if not any((frontier_node.state[0] == neighbor[0]).all() for frontier_node in frontier):
                    # Add the neighbor to the frontier
                    child_node = Node(state=neighbor, parent=node, action=action)
                    frontier.append(child_node)

    # No solution found
    raise Exception("No solution found.")

def print_solution(self):
    if self.solution is None:
        print("No solution available.")
        return

    # Print the solution path
    print("Initial State:")
    print(self.start[0], "\n")

    for action, state in zip(self.solution[0], self.solution[1]):
        print(f"Action: {action}")
        print(state[0], "\n")
```

```
        print("Goal Reached!")


# Function to take user input and convert it to a 3x3 matrix
def get_puzzle_input():
    print("Enter the 8-puzzle configuration (use 0 for the blank space):")
    puzzle = []
    for i in range(3):
        row = input(f"Enter row {i + 1} (space-separated numbers): ").split()
        puzzle.append([int(num) for num in row])
    return np.array(puzzle)

# Get user input for start and goal states
start = get_puzzle_input()
goal = get_puzzle_input()

# Find the index of the blank tile (0) in the initial and goal states
start_index = (np.where(start == 0)[0][0], np.where(start == 0)[1][0])
goal_index = (np.where(goal == 0)[0][0], np.where(goal == 0)[1][0])

# Create the puzzle object
puzzle = Puzzle(start, start_index, goal, goal_index)

# Print the initial state before solving
print("Initial State:")
print(start, "\n")

# Solve the puzzle using DFS
puzzle.solve_dfs()

# Print the solution path
puzzle.print_solution()
```

OUPUT-DFS

```
Enter the 8-puzzle configuration (use 0 for the blank space):
Enter row 1 (space-separated numbers): 1 2 3
Enter row 2 (space-separated numbers): 4 5 6
Enter row 3 (space-separated numbers): 7 8 0
Enter the 8-puzzle configuration (use 0 for the blank space):
Enter row 1 (space-separated numbers): 1 2 3
Enter row 2 (space-separated numbers): 4 5 6
Enter row 3 (space-separated numbers): 0 7 8
Initial State:
[[1 2 3]
 [4 5 6]
 [7 8 0]]

Initial State:
(1, 2, 3)
(4, 5, 6)
(7, 8, 0)

Action: left
(1, 2, 3)
(4, 5, 6)
(7, 0, 8)

Action: left
(1, 2, 3)
(4, 5, 6)
(0, 7, 8)

Goal Reached!
```

Lab-03
Applying A* algorithm to solve 8-puzzle problem

ALGORITHM:

LAB-3

A* algorithm for 8-puzzle problem:
$f(n) = g(n) + h(n)$

Algorithm & pseudocode:
To implement the A* algorithm for the 8-puzzle, we define a heuristic $h(n)$:
① No of misplaced tiles
② Manhattan Distance
The A* algo will use $f(n) = g(n) + h(n)$, where $g(n)$ is the depth of the node
$h(n)$ is heuristics, whether misplaced tile or manhattan.

- Algo

Initialise
→ start with initial state of the puzzle.
→ Use a priority queue to hold the nodes, entered by $f(n) = g(n) + h(n)$
→ Keep a set of visited nodes to avoid re-exploring nodes.

Expend nodes
→ while the priority queue is not empty.
→ Rename the node with the lowest $f(n)$ from the queue
→ If this node is the goal, return the solution
Generate all possible child node by moving the blank space
→ for each child, calculate $g(n)$
• calculate $h(n)$ by chosen state
If the child has not been visited or if it has a better $f(n)$ than before, add it to the queue

Termination
→ If the goal is found, return the path and total cost
→ If no solution is found, return failure.

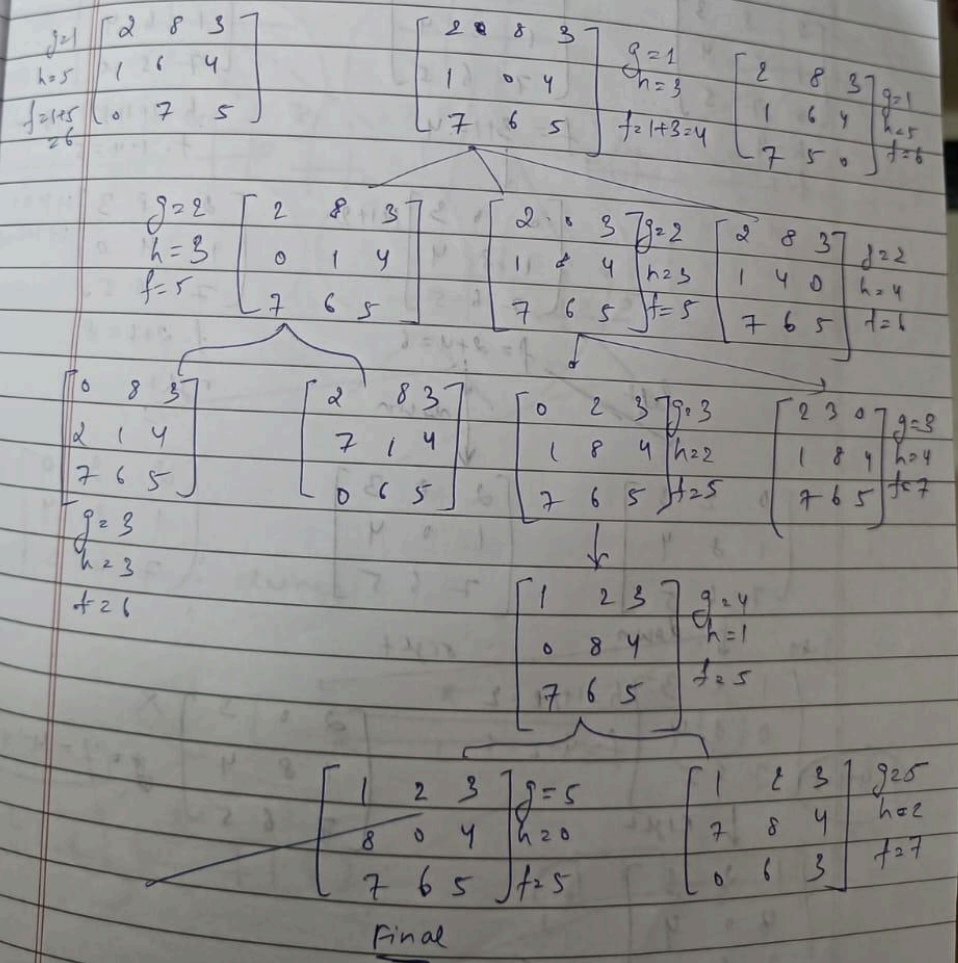
State space tree (misplaced tiles)

Final state:

1	2	3
8		4
7	6	5

Initial state

2	8	3
1	6	4
7	0	5



State space (Manhattan)

Final state

1	2	3
8	0	4
7	6	5

$$\begin{bmatrix} 2 & 8 & 3 \\ 1 & 6 & 4 \\ 7 & 0 & 5 \end{bmatrix} \quad h = 1+1+0+0+0+1+0+1 = 4$$

left, up, right

$$\begin{bmatrix} 2 & 8 & 3 \\ 1 & 6 & 4 \\ 6 & 7 & 5 \end{bmatrix} \quad h=4, \; f=5$$

$$\begin{bmatrix} 2 & 8 & 3 \\ 1 & 0 & 4 \\ 7 & 6 & 5 \end{bmatrix} \quad f = 3+1 = 4$$

$$\begin{bmatrix} 2 & 8 & 3 \\ 1 & 6 & 4 \\ 7 & 5 & 0 \end{bmatrix} \quad h = 1+1+1+1 = 4, \; f = 1+4 = 5$$

$$\begin{bmatrix} 2 & 0 & 3 \\ 1 & 8 & 4 \\ 7 & 6 & 5 \end{bmatrix} \; 1+1+2$$

$$f = 2+4 = 6$$

$$\begin{bmatrix} 2 & 8 & 3 \\ 1 & 4 & 0 \\ 7 & 6 & 5 \end{bmatrix} \; 1+1+0+1+1+2$$

$$f = 2+6 = 8$$

left, down, right

$$\begin{bmatrix} 0 & 2 & 3 \\ 1 & 8 & 4 \\ 7 & 6 & 5 \end{bmatrix} \quad g=4$$

$$\begin{bmatrix} 2 & 8 & 3 \\ 1 & 0 & 4 \\ 7 & 6 & 5 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 3 & 0 \\ 1 & 8 & 4 \\ 7 & 6 & 5 \end{bmatrix}$$

down, right

$$\begin{bmatrix} 1 & 2 & 3 \\ 0 & 8 & 4 \\ 7 & 6 & 5 \end{bmatrix} \quad h = 1+1+1 = 2, \; f = 4+2 = 6, \; f = 4+1 = 5$$

$$\begin{bmatrix} 2 & 0 & 3 \\ 1 & 8 & 4 \\ 7 & 6 & 5 \end{bmatrix} \times \quad f = 4+4 = 8$$

right

$$\begin{bmatrix} 1 & 2 & 3 \\ 8 & 0 & 4 \\ 7 & 6 & 5 \end{bmatrix}$$

final state

Namrata M. 15/10/2024

CODE:

Misplaced Tiles

```
import heapq

def misplaced_tiles(state, goal):
    count = 0
    for i in range(3):
        for j in range(3):
            if state[i][j] != goal[i][j] and state[i][j] != 0:
                count += 1
    return count

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

def generate_new_states(state):
    i, j = get_empty_tile_position(state)
    possible_moves = []
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]
    for di, dj in directions:
        new_i, new_j = i + di, j + dj
        if 0 <= new_i < 3 and 0 <= new_j < 3:
            new_state = [row[:] for row in state]

            new_state[i][j], new_state[new_i][new_j] = new_state[new_i][new_j], new_state[i][j]
            possible_moves.append(new_state)
    return possible_moves


def print_puzzle(state):
    for row in state:
        print(' '.join(str(x) if x != 0 else '_' for x in row))
    print()


def a_star(start, goal):
    queue = []
    heapq.heappush(queue, (misplaced_tiles(start, goal), 0, start, []))

    visited = set()
```

```
    visited.add(tuple(tuple(row) for row in start))

    while queue:
        f, g, current_state, path = heapq.heappop(queue)

        print(f"Step {g}:")
        print(f"g(n) = {g}, h(n) = {f - g}")
        print("Current puzzle state:")
        print_puzzle(current_state)

        if current_state == goal:
            print("Goal state reached!")
            print(f"Total moves: {g}")
            print("Solution path:")
            for step, state in enumerate(path + [current_state], 1):
                print(f"Move {step}:")
                print_puzzle(state)
            return

        print("Generated new states (possible moves):")
        trial_states = []
        for new_state in generate_new_states(current_state):
            if tuple(tuple(row) for row in new_state) not in visited:
                h = misplaced_tiles(new_state, goal)
                trial_states.append((g + h + 1, g + 1, new_state, h))
                print(f"g(n) = {g + 1}, h(n) = {h}")
                print_puzzle(new_state)

        print("Evaluating and choosing the best state based on f(n):")
        for f_new, g_new, state, h_new in trial_states:
            if tuple(tuple(row) for row in state) not in visited:
                heapq.heappush(queue, (f_new, g_new, state, path + [current_state]))
                visited.add(tuple(tuple(row) for row in state))
                print(f"Chosen state with f(n) = {f_new} (g(n) = {g_new}, h(n) = {h_new}):")
                print_puzzle(state)

    print("No solution found")
    return

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

goal_state = [[1, 2, 3],
```

```
    [8, 0, 4],
    [7, 6, 5]]
```

a_star(start_state, goal_state)

OUTPUT:

```
Goal state reached!
Total moves: 5
Solution path:
Move 1:
2 8 3
1 6 4
7 _ 5

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

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

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

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

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

CODE:

Manhattan distance

```
import heapq


def manhattan_distance(state, goal):
    distance = 0
    for i in range(3):
        for j in range(3):
            if state[i][j] != 0:
                # Find the goal position of the current tile
                goal_x, goal_y = divmod(goal.index(state[i][j]), 3)
                distance += abs(i - goal_x) + abs(j - goal_y)
    return distance

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

def generate_new_states(state):
    i, j = get_empty_tile_position(state)
    possible_moves = []
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]
    for di, dj in directions:
        new_i, new_j = i + di, j + dj
        if 0 <= new_i < 3 and 0 <= new_j < 3:
            new_state = [row[:] for row in state]
            # Swap the empty tile with the neighboring tile
            new_state[i][j], new_state[new_i][new_j] = new_state[new_i][new_j], new_state[i][j]
            possible_moves.append(new_state)
    return possible_moves

def print_puzzle(state):
    for row in state:
        print(' '.join(str(x) if x != 0 else '_' for x in row))
    print()

def a_star(start, goal):

    goal_flat = [num for row in goal for num in row]


    queue = []
    heapq.heappush(queue, (manhattan_distance(start, goal_flat), 0, start, []))
```

```
    visited = set()
    visited.add(tuple(tuple(row) for row in start))

    while queue:
        f, g, current_state, path = heapq.heappop(queue)

        print(f"Step {g}:")
        print(f"g(n) = {g}, h(n) = {f - g}")
        print("Current puzzle state:")
        print_puzzle(current_state)


        if current_state == goal:
            print("Goal state reached!")
            print(f"Total moves: {g}")
            print("Solution path:")
            for step, state in enumerate(path + [current_state], 1):
                print(f"Move {step}:")
                print_puzzle(state)
            return

        print("Generated new states (possible moves):")
        trial_states = []
        for new_state in generate_new_states(current_state):
            if tuple(tuple(row) for row in new_state) not in visited:
                h = manhattan_distance(new_state, goal_flat)
                trial_states.append((g + h + 1, g + 1, new_state, h))
                print(f"g(n) = {g + 1}, h(n) = {h}")
                print_puzzle(new_state)

        print("Evaluating and choosing the best state based on f(n):")
        for f_new, g_new, state, h_new in trial_states:
            if tuple(tuple(row) for row in state) not in visited:
                heapq.heappush(queue, (f_new, g_new, state, path + [current_state]))
                visited.add(tuple(tuple(row) for row in state))
                print(f"Chosen state with f(n) = {f_new} (g(n) = {g_new}, h(n) = {h_new}):")
                print_puzzle(state)

    print("No solution found")
    return

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

goal_state = [
```

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

a_star(start_state, goal_state)
```

OUTPUT:

```
Goal state reached!
Total moves: 2
Solution path:
Move 1:
1 2 3
4 _ 6
7 5 8

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

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

LAB-04
Hill Climb algorithm to solve n-queen problem

ALGORITHM:

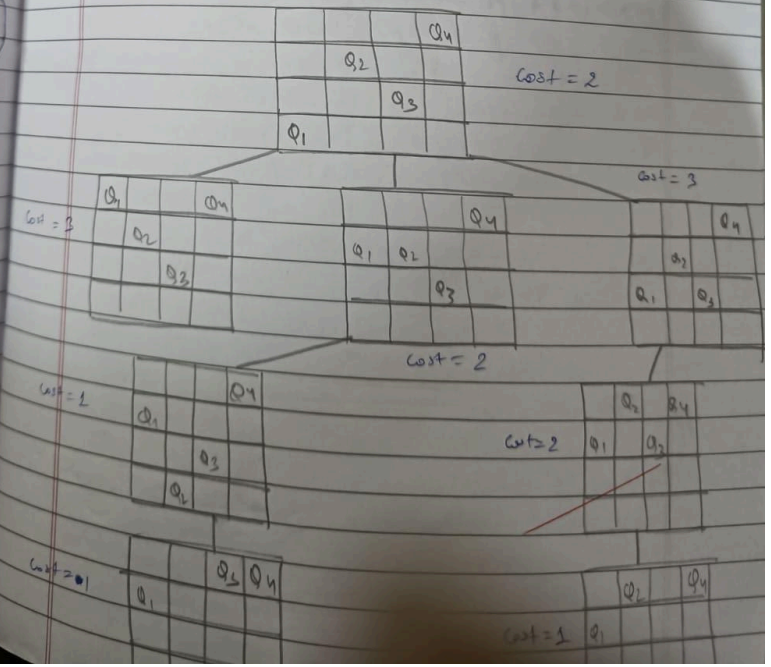
LAB-4

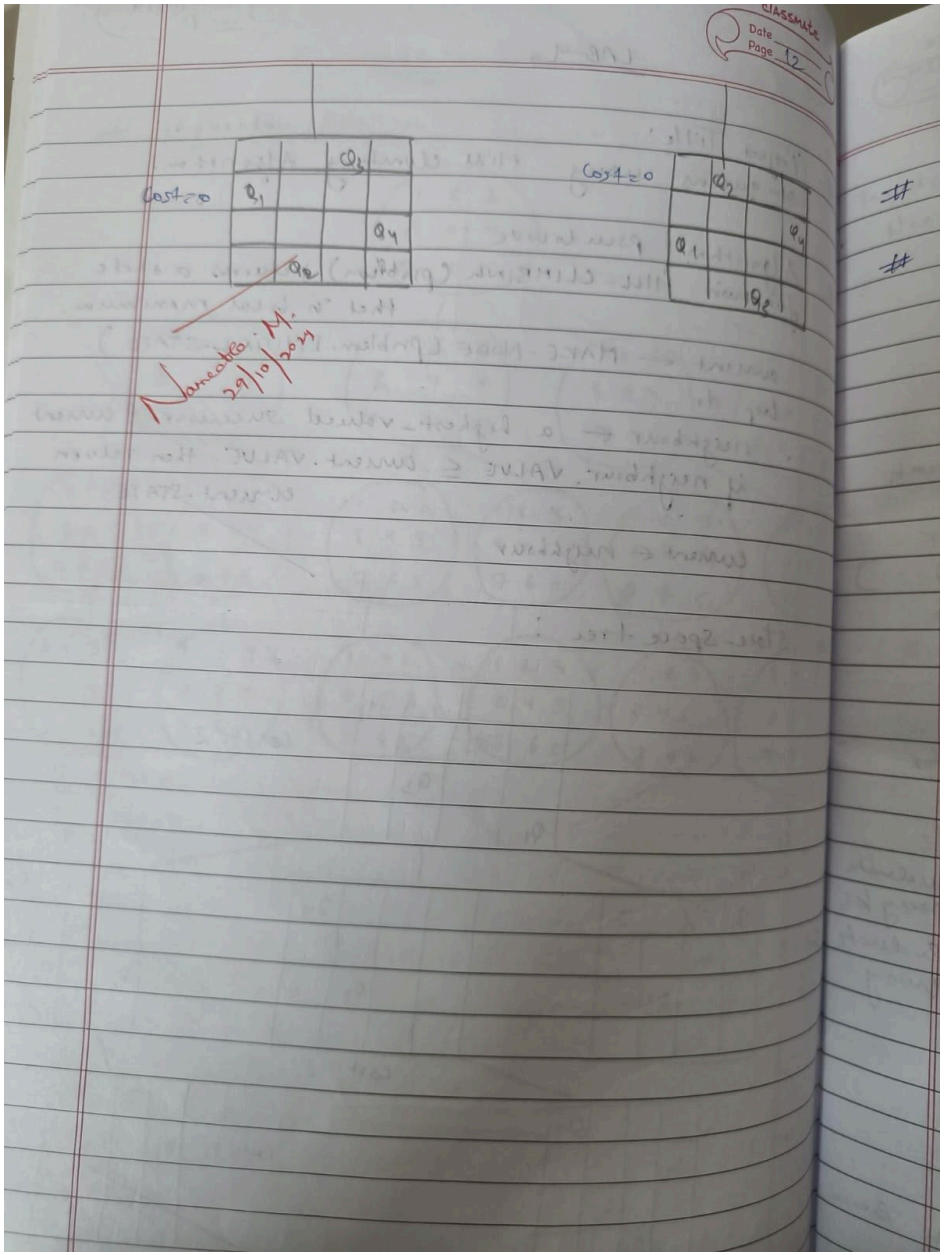
Date 23/10/24
Page 11

Project Title:
4-queens using Hill Climbing Algorithm.

Algorithm / pseudocode:
function HILL-CLIMBING (problem) returns a state that is local maximum.
current ← MAKE-NODE (problem. INITIAL-STATE)
loop do
neighbour ← a highest-valued successor of current
if neighbour. VALUE ≤ current. VALUE then return current. STATE
current ← neighbour

State-Space tree:




Cost=∞
Q1
Q2
Q3
Q4
Cost=0
Q1
Q2
Q3
Q4
Namaste : M.
29/10/2024

CODE:

```
import random

def heuristic(state):
    """Calculate the number of conflicts between queens."""
    conflicts = 0
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                conflicts += 1
    return conflicts

def generate_neighbors(state):
    """Generate all neighboring states by swapping two queens."""
    neighbors = []
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):

            new_state = state.copy()
            new_state[i], new_state[j] = new_state[j], new_state[i]
            neighbors.append(new_state)
    return neighbors

def print_board(state):
    """Print the board configuration."""
    n = len(state)
    board = [["." for _ in range(n)] for _ in range(n)]
    for row in range(n):
        board[row][state[row]] = "Q"
    for line in board:
        print(" ".join(line))
    print()

def get_user_input(n):
    """Get initial state from user input."""
    while True:
        try:
            input_state = input(f"Enter the initial positions for {n} queens (0
to {n-1}, space-separated): ")
            positions = list(map(int, input_state.split()))
            if len(positions) != n or any(p < 0 or p >= n for p in positions):
                raise ValueError
            return positions
        except ValueError:
            print("Invalid input. Please enter exactly {} numbers between 0 and
{}.".format(n, n - 1))
```

```
def hill_climbing(n):
    """Perform the Hill-Climbing algorithm using the swapping technique."""
    current_state = get_user_input(n)
    current_cost = heuristic(current_state)

    print("Initial State:")
    print_board(current_state)
    print(f"Initial Heuristic (Conflicts): {current_cost}\n")

    while current_cost > 0:
        neighbors = generate_neighbors(current_state)
        next_state = None
        next_cost = current_cost

        for neighbor in neighbors:
            cost = heuristic(neighbor)
            print(f"Evaluating Neighbor:")
            print_board(neighbor)
            print(f"Heuristic (Conflicts): {cost}")

            if cost < next_cost:
                next_cost = cost
                next_state = neighbor

        if next_state is None:
            print("Local maximum reached. No better neighbors found.")
            break


        print("Moving to Next State:")
        current_state = next_state
        current_cost = next_cost
        print_board(current_state)
        print(f"Heuristic (Conflicts): {current_cost}\n")

    return current_state, current_cost

n = 4
solution, solution_cost = hill_climbing(n)
print("Best Solution Found:")
print_board(solution)
print(f"Final Heuristic (Conflicts): {solution_cost}")
```

OUTPUT:

Enter the initial positions for 4 queens (0 to 3, space-separated): 3 1 2 0
Initial State:

. . . Q
. Q . .
. . Q .
Q . . .

Initial Heuristic (Conflicts): 2

Evaluating Neighbor:
. Q . .
. . . Q
. . Q .
Q . . .

Heuristic (Conflicts): 1
Evaluating Neighbor:
. . Q .
. Q . .
. . . Q
Q . . .

Heuristic (Conflicts): 1
Evaluating Neighbor:
Q . . .
. Q . .
. . Q .
. . . Q

Heuristic (Conflicts): 6
Evaluating Neighbor:
. . . Q
. . Q .
. Q . .
Q . . .

Heuristic (Conflicts): 6
Evaluating Neighbor:
. . . Q
Q . . .
. . Q .
. Q . .

Heuristic (Conflicts): 1
Evaluating Neighbor:
. . . Q
. Q . .
Q . . .
. . Q .

Heuristic (Conflicts): 1

Moving to Next State:
. Q . .
. . . Q
. . Q .
Q . . .

Heuristic (Conflicts): 1

Evaluating Neighbor:
. . . Q
. Q . .
. . Q .
Q . . .

Heuristic (Conflicts): 2
Evaluating Neighbor:
. . Q .
. . . Q
. Q . .
Q . . .

Heuristic (Conflicts): 2
Evaluating Neighbor:
Q . . .
. . . Q
. . Q .
. Q . .

Heuristic (Conflicts): 4
Evaluating Neighbor:
. Q . .
. . Q .
. . . Q
Q . . .

Heuristic (Conflicts): 4
Evaluating Neighbor:
. Q . .
Q . . .
. . Q .
. . . Q

Heuristic (Conflicts): 2
Evaluating Neighbor:
. Q . .
. . . Q
Q . . .
. . Q .

Heuristic (Conflicts): 0
Moving to Next State:
. Q . .
. . . Q
Q . . .
. . Q .

Heuristic (Conflicts): 0

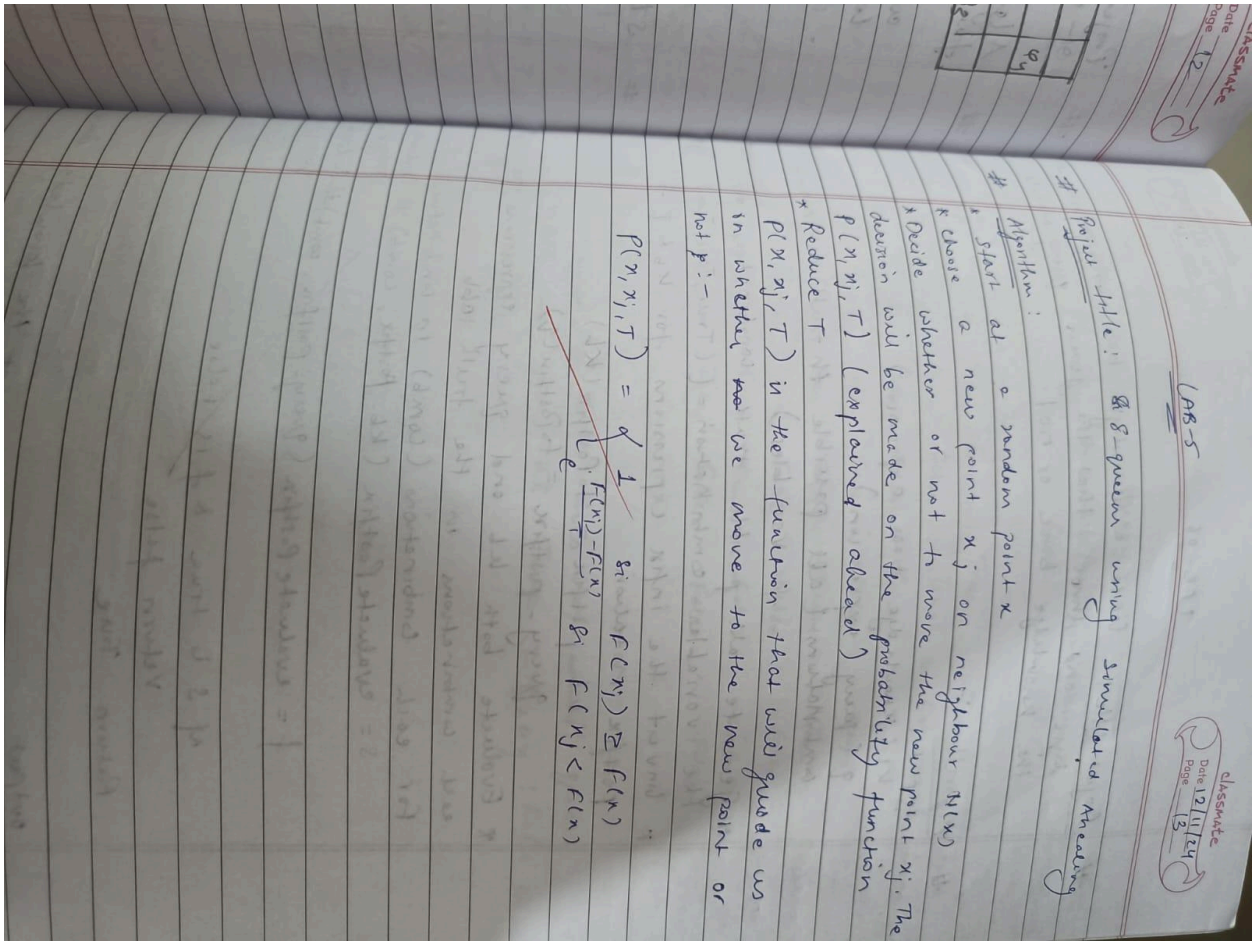
Best Solution Found:
. Q . .
. . . Q
Q . . .
. . Q .

Final Heuristic (Conflicts): 0

LAB-05

Implementing simulated annealing to solve N-queens problem

ALGORITHM:



CODE:

```
import random
import math

def calculate_cost(state):
    attacking_pairs = 0
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            if state[i] == state[j] or abs(state[i] - state[j]) ==
abs(i - j):
                attacking_pairs += 1
    return attacking_pairs

def generate_neighbor(state):
    neighbor = state[:]
    column = random.randint(0, len(state) - 1)
    new_row = random.randint(0, len(state) - 1)
    while new_row == state[column]:
        new_row = random.randint(0, len(state) - 1)
    neighbor[column] = new_row
    return neighbor

def simulated_annealing(n, initial_temperature, cooling_factor,
max_iterations):
    current_state = [random.randint(0, n-1) for _ in range(n)]
    current_cost = calculate_cost(current_state)
    best_state = current_state
    best_cost = current_cost
    temperature = initial_temperature

    print(f"Initial state: {current_state} with cost:
{current_cost}")

    iteration = 0
    while iteration < max_iterations and temperature > 0:
        neighbor_state = generate_neighbor(current_state)
        neighbor_cost = calculate_cost(neighbor_state)

        delta_cost = neighbor_cost - current_cost
```

```
        if delta_cost < 0:
            current_state = neighbor_state
            current_cost = neighbor_cost
        else:
            acceptance_probability = math.exp(-delta_cost /
temperature)
            if random.random() < acceptance_probability:
                current_state = neighbor_state
                current_cost = neighbor_cost

        if current_cost < best_cost:
            best_state = current_state
            best_cost = current_cost

        print(f"Iteration {iteration+1}: {current_state} with cost:
{current_cost}")

        temperature *= cooling_factor
        iteration += 1

    return best_state, best_cost

if __name__ == "__main__":
    N = 4
    initial_temperature = 100
    cooling_factor = 0.95
    max_iterations = 1000

    best_state, best_cost = simulated_annealing(N,
initial_temperature, cooling_factor, max_iterations)

    print(f"\nFinal solution: {best_state} with cost: {best_cost}")
```

OUTPUT:

Initial state: [3, 3, 1, 0] with cost: 4
Iteration 1: [3, 0, 1, 0] with cost: 5
Iteration 2: [3, 0, 1, 1] with cost: 3
Iteration 3: [3, 3, 1, 1] with cost: 4
Iteration 4: [3, 3, 1, 2] with cost: 3
Iteration 5: [3, 0, 1, 2] with cost: 4
Iteration 6: [3, 0, 1, 3] with cost: 3
Iteration 7: [3, 0, 3, 3] with cost: 3
Iteration 8: [2, 0, 3, 3] with cost: 1

Iteration 9: [2, 0, 2, 3] with cost: 2
Iteration 10: [3, 0, 2, 3] with cost: 2
Iteration 11: [1, 0, 2, 3] with cost: 2
Iteration 12: [1, 0, 2, 1] with cost: 3
Iteration 13: [1, 0, 2, 2] with cost: 3
Iteration 14: [1, 0, 3, 2] with cost: 4
Iteration 15: [1, 2, 3, 2] with cost: 5
Iteration 16: [3, 2, 3, 2] with cost: 5
Iteration 17: [3, 2, 3, 1] with cost: 3
Iteration 18: [3, 2, 3, 1] with cost: 3
Iteration 19: [3, 2, 3, 3] with cost: 5
Iteration 20: [3, 2, 3, 1] with cost: 3
Iteration 21: [3, 2, 3, 0] with cost: 5
Iteration 22: [3, 2, 1, 0] with cost: 6
Iteration 23: [3, 3, 1, 0] with cost: 4
Iteration 24: [3, 0, 1, 0] with cost: 5
Iteration 25: [3, 0, 1, 2] with cost: 4
Iteration 26: [1, 0, 1, 2] with cost: 5
Iteration 27: [1, 3, 1, 2] with cost: 2
Iteration 28: [0, 3, 1, 2] with cost: 1
Iteration 29: [0, 3, 1, 0] with cost: 2
Iteration 30: [0, 3, 3, 0] with cost: 2
Iteration 31: [0, 2, 3, 0] with cost: 3
Iteration 32: [0, 2, 1, 0] with cost: 4
Iteration 33: [0, 3, 1, 0] with cost: 2
Iteration 34: [0, 1, 1, 0] with cost: 4
Iteration 35: [0, 3, 1, 0] with cost: 2
Iteration 36: [0, 3, 3, 0] with cost: 2
Iteration 37: [0, 3, 3, 3] with cost: 4
Iteration 38: [0, 3, 2, 3] with cost: 5
Iteration 39: [0, 0, 2, 3] with cost: 4
Iteration 40: [3, 0, 2, 3] with cost: 2
Iteration 41: [3, 0, 0, 3] with cost: 2
Iteration 42: [3, 0, 0, 1] with cost: 2
Iteration 43: [3, 1, 0, 1] with cost: 3
Iteration 44: [3, 0, 0, 1] with cost: 2
Iteration 45: [3, 1, 0, 1] with cost: 3
Iteration 46: [3, 1, 0, 3] with cost: 3
Iteration 47: [3, 1, 2, 3] with cost: 4
Iteration 48: [3, 0, 2, 3] with cost: 2
Iteration 49: [3, 0, 2, 1] with cost: 1
Iteration 50: [3, 0, 3, 1] with cost: 1
Iteration 51: [3, 1, 3, 1] with cost: 2
Iteration 52: [3, 3, 3, 1] with cost: 4

Iteration 53: [3, 0, 3, 1] with cost: 1
Iteration 54: [0, 0, 3, 1] with cost: 1
Iteration 55: [0, 0, 3, 3] with cost: 3
Iteration 56: [3, 0, 3, 3] with cost: 3
Iteration 57: [3, 0, 3, 1] with cost: 1
Iteration 58: [2, 0, 3, 1] with cost: 0
Iteration 59: [2, 0, 3, 1] with cost: 0
Iteration 60: [2, 0, 3, 1] with cost: 0
Iteration 61: [2, 0, 0, 1] with cost: 3
Iteration 62: [1, 0, 0, 1] with cost: 4
Iteration 63: [1, 0, 3, 1] with cost: 3
Iteration 64: [1, 0, 3, 0] with cost: 3
Iteration 65: [1, 0, 3, 1] with cost: 3
Iteration 66: [1, 1, 3, 1] with cost: 4
Iteration 67: [1, 3, 3, 1] with cost: 4
Iteration 68: [1, 3, 0, 1] with cost: 3
Iteration 69: [0, 3, 0, 1] with cost: 3
Iteration 70: [0, 3, 2, 1] with cost: 4
Iteration 71: [0, 0, 2, 1] with cost: 3
Iteration 72: [0, 0, 2, 2] with cost: 4
Iteration 73: [0, 0, 0, 2] with cost: 4
Iteration 74: [0, 0, 0, 0] with cost: 6
Iteration 75: [0, 3, 0, 0] with cost: 3
Iteration 76: [0, 3, 0, 0] with cost: 3
Iteration 77: [0, 3, 2, 0] with cost: 3
Iteration 78: [0, 3, 2, 0] with cost: 3
Iteration 79: [3, 3, 2, 0] with cost: 3
Iteration 80: [3, 3, 2, 1] with cost: 4
Iteration 81: [3, 3, 3, 1] with cost: 4
Iteration 82: [3, 1, 3, 1] with cost: 2
Iteration 83: [3, 1, 3, 1] with cost: 2
Iteration 84: [3, 1, 3, 2] with cost: 2
Iteration 85: [0, 1, 3, 2] with cost: 2
Iteration 86: [1, 1, 3, 2] with cost: 3
Iteration 87: [3, 1, 3, 2] with cost: 2
Iteration 88: [3, 1, 0, 2] with cost: 1
Iteration 89: [3, 1, 0, 2] with cost: 1
Iteration 90: [3, 1, 0, 2] with cost: 1
Iteration 91: [3, 1, 0, 2] with cost: 1
Iteration 92: [1, 1, 0, 2] with cost: 2
Iteration 93: [1, 1, 3, 2] with cost: 3
Iteration 94: [1, 1, 3, 0] with cost: 2
Iteration 95: [1, 1, 3, 0] with cost: 2
Iteration 96: [1, 1, 3, 0] with cost: 2

Iteration 97: [2, 1, 3, 0] with cost: 1
Iteration 98: [2, 1, 3, 0] with cost: 1
Iteration 99: [2, 1, 3, 0] with cost: 1
Iteration 100: [2, 0, 3, 0] with cost: 1
Iteration 101: [1, 0, 3, 0] with cost: 3
Iteration 102: [1, 2, 3, 0] with cost: 4
Iteration 103: [1, 2, 3, 0] with cost: 4
Iteration 104: [1, 2, 3, 3] with cost: 4
Iteration 105: [1, 2, 2, 3] with cost: 3
Iteration 106: [1, 2, 2, 3] with cost: 3
Iteration 107: [1, 2, 2, 0] with cost: 3
Iteration 108: [1, 2, 2, 3] with cost: 3
Iteration 109: [1, 2, 3, 3] with cost: 4
Iteration 110: [1, 0, 3, 3] with cost: 3
Iteration 111: [1, 0, 0, 3] with cost: 2
Iteration 112: [1, 0, 0, 3] with cost: 2
Iteration 113: [1, 0, 0, 3] with cost: 2
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Iteration 920: [2, 0, 3, 1] with cost: 0
Iteration 921: [2, 0, 3, 1] with cost: 0
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Iteration 992: [2, 0, 3, 1] with cost: 0
Iteration 993: [2, 0, 3, 1] with cost: 0
Iteration 994: [2, 0, 3, 1] with cost: 0
Iteration 995: [2, 0, 3, 1] with cost: 0
Iteration 996: [2, 0, 3, 1] with cost: 0
Iteration 997: [2, 0, 3, 1] with cost: 0
Iteration 998: [2, 0, 3, 1] with cost: 0
Iteration 999: [2, 0, 3, 1] with cost: 0
Iteration 1000: [2, 0, 3, 1] with cost: 0

Final solution: [2, 0, 3, 1] with cost: 0

LAB-06
Creating Knowledge base using propositional logic

ALGORITHM:

LAB-06

Project title :- Create a knowledge base using propositional logic and throw that the given query entails the knowledge base or not

Algorithm :-

Input :

kb (knowledge base expression)

q (query expression)

combinations (all possible truth assignments for variables)

* Generate all possible truth combinations for the variables combination = [(True, True, True)...
* Convert the infix expressions for kb & q to postfix notation

kb_postfix = toPostfix(kb)

query_postfix = toPostfix(q)

* Evaluate both kb and query expressions for each combinations in the truth table

For each combinations (comb) in combinations:

S = evaluatePostfix (kb_postfix, comb) # Evaluate query kb

f = evaluatePostfix (query_postfix, comb) # Evaluate query

if S is true & f is false:

Return false

Return True

output

if the result is True, print the knowledge Base entails query"

Else, print "the knowledge Base does not entail query".

State S
Expressio
State

1 T
2 T
3 T
4 T
5 F
6 F
7
8

Result

The k
trees
state

Narrate. M
19/11/2024

State Space

Expression : $p \wedge q$, Query : r

State	p	q	r	KB Eval	Query Eval	kb → Query entails
1	True	True	True	True	True	True
2	True	True	False	True	False	False
3	True	False	True	False	True	True
4	True	False	False	False	False	True
5	False	True	True	False	True	True
6	False	True	False	False	False	True
7	False	False	True	False	True	True
8	False	False	False	False	False	True

Result :-

The knowledge base does not entail query since we found KB : True & Query : false in state 2

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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:

Enter rule: ~p
Enter the Query: p
********** Truth Table Reference **********
kb alpha
****
False True

False True

False True

False True

True False

The Knowledge Base does not entail query

LAB-07
Implementing Unification in First Order Logic

ALGORITHM:

LAB-07

Project title :- Unification Algorithm for first order logic
Implementation - Logic

Algorithm :-
Input : Two expressions E_1 & E_2
Output : A substitution θ or failure E_1 and E_2 cannot be unified.

Step1 Initialize Solution :
Start with an empty substitution $\theta = \{\}$

Step2 Compare Expression :
Case 1 : E_1 & E_2 are constants
- If $E_1 = E_2$, return θ (no substitution needed)
- If $E_1 \neq E_2$, return failure

Case 2 : Either E_1 or E_2 is a variable
Let X be the variable
If $x \in \theta$ (not yet substituted) :
- Add $\{X \mapsto E\}$ to θ, where E is the other term
- Ensure no cyclic substitution (e.g. $X \neq E$).

If $X \in \theta$, recursively unify $\theta[X]$ with other term.

Case 3 : E_1 & E_2 have their functors (function names) and arguments.
Example $f(a,b) \rightarrow$ Functor : f, Arguments (a,b)
If their functors differs, return failure
Otherwise, recursively unify each pair of arguments and accumulate substitutions

Case 4 : E_1 or E_2 is neither a variable nor a term (unexpected case)
Return failure.

Step3 Apply substitution.
After obtaining θ, apply it consistently to all variables E_1 & E_2

Step 4 Repeat until fully unified or failure.

- If O is complete, return 1 as the result.
- If unification fails at any recursive step, return failure.

CODE:

```
def unify(psi1, psi2):
    if isinstance(psi1, str) and psi1.islower():
        if psi1 == psi2:
            return []
        elif occurs_check(psi1, psi2):
            return "FAILURE"
        else:
            return [(psi1, psi2)]
    elif isinstance(psi2, str) and psi2.islower():
        if occurs_check(psi2, psi1):
            return "FAILURE"
        else:
            return [(psi2, psi1)]
    elif psi1 == psi2:
        return []
    elif isinstance(psi1, list) and isinstance(psi2, list):
        if psi1[0] != psi2[0]:
            return "FAILURE"
        if len(psi1) != len(psi2):
            return "FAILURE"
        subst = []
        for i in range(len(psi1)):
            s = unify(apply_substitution(subst, psi1[i]),
apply_substitution(subst, psi2[i]))
            if s == "FAILURE":
                return "FAILURE"
            subst.extend(s)
        return subst
    else:
        return "FAILURE"


def occurs_check(var, term):
    """
    Checks if variable `var` occurs in term `term`.
    """
    if var == term:
        return True
    elif isinstance(term, list):
        return any(occurs_check(var, subterm) for subterm in term)
    return False
```

```
def apply_substitution(subst, term):
    """
    Applies a set of substitutions to a term.
    """
    if isinstance(term, str):
        for var, replacement in subst:
            if term == var:
                return apply_substitution(subst, replacement)
        return term
    elif isinstance(term, list):
        return [apply_substitution(subst, subterm) for subterm in
term]
    return term


psi1 = ["P", "x", "y"]
psi2 = ["P", "a", "y"]

result = unify(psi1, psi2)
print("Unification Result:", result)

psi1 = ["P", "x", "y"]
psi2 = ["P", "x", "y"]

result = unify(psi1, psi2)
print("Unification Result:", result)

psi1 = ["P", "x", "y"]
psi2 = ["B", "x", "y"]

result = unify(psi1, psi2)
print("Unification Result:", result)

psi1 = ["P", "x", "y"]
psi2 = ["P", "a", "b"]

result = unify(psi1, psi2)
print("Unification Result:", result)

psi1 = ["P", "x", "y"]
psi2 = ["P", "x", "b"]

result = unify(psi1, psi2)
```

```
print("Unification Result:", result)
```

OUTPUT:

```
Unification Result: [('x', 'a')]
Unification Result: []
Unification Result: FAILURE
Unification Result: [('x', 'a'), ('y', 'b')]
Unification Result: [('y', 'b')]
```

LAB-08
Creating knowledge base of FOL and proving query using forward reasoning

ALGORITHM:

failure.
the result.
step, return

LAB-08

Project title :- Create a knowledge base consisting of FOL logic statements and prove the given query using forward reasoning.

Forward Reasoning Algorithm :-

function FOL-FC-ASK (KB, α) returns a substitution or false

inputs: KB, knowledge base, a set of first or definite clauses, α, the query, an atomic sentences.

local variables: new, the new sentence inferred on each iteration

repeat until new is empty
  new ← { }
  for each rule in KB do
    (p1 ∧ ... pn ⇒ q) ← STANDARDIZE-VARIABLES (rule)
    for each θ such that SUBST (θ, p1 ∧ ... ∧ pn)
        = SUBST (θ, p'1 ∧ ... ∧ p'n)
    for some p'1, ... p'n in KB
    q' ← SUBST (θ, q)
    if q' does not unify with some sentence already in KB or new then
      add q' to new
      φ ← UNIFY (q', α)
      if φ is not fail then return φ
  add new to KB
  return false.

PTO

Given case study :-

As per the law, it is a crime for an American to sell weapon to hostile nations. Country A, an enemy of America, has some missiles, and all the missiles were sold to it by Robert who is an American citizen. Prove that 'Robert is criminal'.

Representation in FOL

1. It is a crime for an american to sell weapon to hostile nations.
Let's say p, q, and r are variables.
American(p) ∧ Weapon(q) ∧ Sells(p, q, r) ∧ Hostile(r) ⇒ Criminal(p)

2. Country A has some missile.
∃x Owns(A, x) ∧ Missile(x).

Existential instantiation, introducing a new variable T1
Owns(A, T1)
Missile(T1)

3. All of the missiles was were sold to country A by Robert.
∀x Missile(x) ∧ Owns(A, x) ⇒ Sells(Robert, x, A)

4. Missiles are weapons
Missile(x) ⇒ Weapon(x)

5. Enemy of America is known as hostile.
∀x Enemy(x, America) ⇒ Hostile(x)

6. Robert is an American
American(Robert)

7. The country A, an enemy of America
Enemy(A, America).

output :

9> 'Criminal

forward

American

Nameeta. M.
3/12/24

r an American to
country A, an enemy of
all the missiles were
rica citizen.

to sell weapon to

Hostile(x) ⇒
riminal(p)

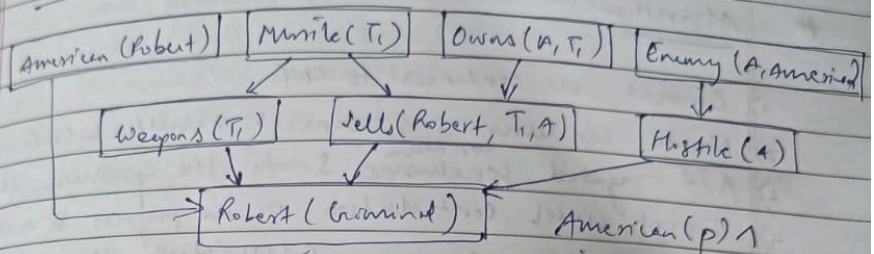
ew variable T_1

ntry A by Robert
bert, T_1, A)

output:

Is 'Criminal(Robert)' provable? True.

forward chaining proof



American(p) ∧
Weapon(q) ∧ Sells(p,q
∧ Hostiles ⇒ Criminal(p)

Namrata M.
3/12/2024

CODE:

```
class ForwardChainingFOL:
    def __init__(self):
        self.facts = set()
        self.rules = []

    def add_fact(self, fact):
        self.facts.add(fact)

    def add_rule(self, premises, conclusion):
        self.rules.append((premises, conclusion))

    def unify(self, fact1, fact2):

        if fact1 == fact2:
            return {}
        if "(" in fact1 and "(" in fact2:

            pred1, args1 = fact1.split("(", 1)
            pred2, args2 = fact2.split("(", 1)
            args1 = args1[:-1].split(",")
            args2 = args2[:-1].split(",")
            if pred1 != pred2 or len(args1) != len(args2):
                return None

            substitution = {}
            for a1, a2 in zip(args1, args2):
                if a1 != a2:
                    if a1.islower():
                        substitution[a1] = a2
                    elif a2.islower():
                        substitution[a2] = a1
                    else:
                        return None
            return substitution
        return None

    def apply_substitution(self, fact, substitution):

        if "(" in fact:
            pred, args = fact.split("(", 1)
```

```
            args = args[:-1].split(",")
            substituted_args = [substitution.get(arg, arg) for arg in
args]
            return f"{pred}({','.join(substituted_args)})"
        return fact

    def forward_chain(self, goal):
        iteration = 1
        while True:
            new_facts = set()
            print(f"\n=== Iteration {iteration} ===")
            print("Known Facts:")
            for fact in self.facts:
                print(f"  - {fact}")

            print("\nApplying rules...")
            rule_triggered = False

            for premises, conclusion in self.rules:
                substitutions = [{}]
                for premise in premises:
                    new_substitutions = []
                    for fact in self.facts:
                        for sub in substitutions:
                            unified =
self.unify(self.apply_substitution(premise, sub), fact)
                            if unified is not None:
                                new_substitutions.append({**sub,
**unified})
                    substitutions = new_substitutions
                for sub in substitutions:
                    inferred_fact =
self.apply_substitution(conclusion, sub)
                    if inferred_fact not in self.facts:
                        rule_triggered = True
                        print(f"Rule triggered: {premises} →
{conclusion}")
                        print(f"  New fact inferred:
{inferred_fact}")
                        new_facts.add(inferred_fact)

            if not new_facts:
                if not rule_triggered:
                    print("No rules triggered in this iteration.")
                print("No new facts inferred in this iteration.")
```

```
                break

            self.facts.update(new_facts)
            if goal in self.facts:
                print(f"\nGoal {goal} reached!")
                return True
            iteration += 1

        print("\nGoal not reached.")
        return False


fc = ForwardChainingFOL()

fc.add_fact("American(Robert)")
fc.add_fact("Enemy(A,America)")
fc.add_fact("Owns(A,T1)")
fc.add_fact("Missile(T1)")

fc.add_rule(["Missile(T1)"], "Weapon(T1)")
fc.add_rule(["Enemy(A,America)"], "Hostile(A)")
fc.add_rule(["Missile(p)", "Owns(A,p)"], "Sells(Robert,p,A)")
fc.add_rule(["American(p)", "Weapon(q)", "Sells(p,q,r)",
"Hostile(r)"], "Criminal(p)")

goal = "Criminal(Robert)"

if fc.forward_chain(goal):
    print(f"\nFinal result: Goal achieved: {goal}")
else:
    print("\nFinal result: Goal not achieved.")
```

OUTPUT:

=== Iteration 1 ===
Known Facts:
- Owns(A,T1)
- Enemy(A,America)
- Missile(T1)
- American(Robert)

Applying rules...
Rule triggered: ['Missile(T1)'] → Weapon(T1)
New fact inferred: Weapon(T1)

Rule triggered: ['Enemy(A,America)'] → Hostile(A)
  New fact inferred: Hostile(A)
Rule triggered: ['Missile(p)', 'Owns(A,p)'] → Sells(Robert,p,A)
  New fact inferred: Sells(Robert,T1,A)

=== Iteration 2 ===
Known Facts:
  - Missile(T1)
  - Weapon(T1)
  - American(Robert)
  - Owns(A,T1)
  - Hostile(A)
  - Sells(Robert,T1,A)
  - Enemy(A,America)

Applying rules...
Rule triggered: ['American(p)', 'Weapon(q)', 'Sells(p,q,r)', 'Hostile(r)'] → Criminal(p)
  New fact inferred: Criminal(Robert)

Goal Criminal(Robert) reached!

Final result: Goal achieved: Criminal(Robert)

LAB-09
Creating knowledge base of FOL and proving query using Resolution

ALGORITHM:

LAB-08

Project title :- Create a knowledge base of first order logic and solve query using resolution

Algorithm :-

1) Convert all sentences to CNF
2) Negate conclusion S & Convert result to CNF
3) Add negated conclusion S to the premise clauses
4) Repeat until contradiction or no progress is made
   a) Select 2 clauses (call them parent clauses)
   b) Release them together, performing all required unification
   c) If resolvent is the empty clause, a contradiction has been found.
   d) If not, add resolvent to the premises. If we succeed in step 4, we have proved the ~~conclusion~~ condition

Proof by Resolution :

Given the KB or Premise

a) John likes all kind of food
b) Apple & vegetables are food
c) Anything anyone eats and not killed is food
d) Anil eats peanuts and still Alive
e) Harry eats anything that Anil eats.
f) Anyone who is alive implies not killed
g) Anyone who is alive implies not killed
h) John likes peanuts

⇒ Representation in FOL

a) $\forall x : food(x) \rightarrow likes(John, x)$
b) $food(Apple) \wedge food(Vegetables)$
c) $\forall x \forall y : eats(x, y) \wedge \neg killed(x) \rightarrow food(y)$
d) $eats(Anil, peanuts) \wedge alive(Anil)$
e) $\forall x : eats(Anil, x) \rightarrow eats(Harry, x)$
f) $\forall x : \neg killed(x) \rightarrow alive(x)$
g) $\forall x : alive(x) \rightarrow \neg killed(x)$
h) $likes(John, Peanuts)$

Eliminate Implications

a) $\forall x \neg food(x) \vee likes(John, x)$
c) $\forall x \forall y \neg [eats(x, y) \wedge \neg killed(x)] \vee food(y)$
e) $\forall x \neg eats(Anil, x) \vee eats(Harry, x)$
f) $\forall x \neg [\neg killed(x)] \vee alive(x)$
g) $\forall x \neg alive(x) \vee \neg killed(x)$

→ Move negation ($\neg$) inwards

c) $\forall x \forall y \neg eats(x, y) \vee killed(x) \vee food(y)$
f) $\forall x killed(x) \vee alive(x)$

→ Standerize variables

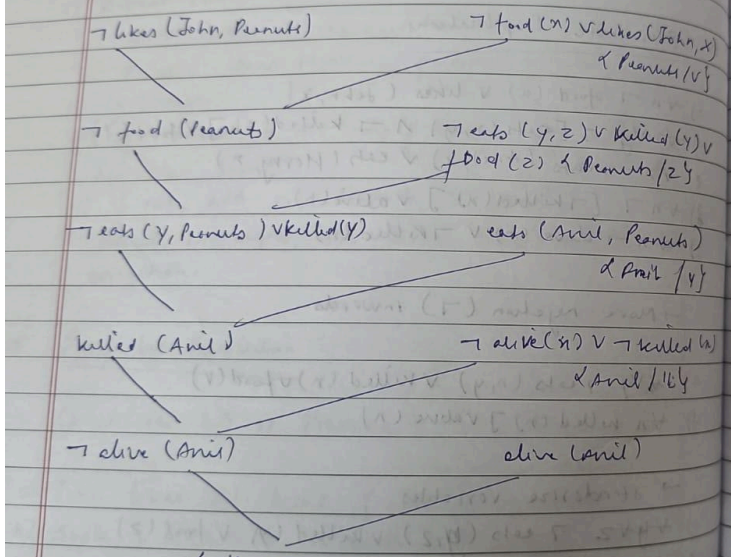
c) $\forall y \forall z \neg eats(y, z) \vee killed(y) \vee food(z)$
e) $\forall w \neg eats(Anil, w) \vee eats(Harry, w)$
f) $\forall g [killed(g)] \vee alive(g)$
g) $\forall k \neg alive(k) \vee \neg killed(k)$

→ Drop universal

a) $\neg food(x) \vee likes(John, x)$
b) $food(Apple)$
c) $food(Vegetables)$

c) food (vegetables)
d) ¬ eats (x z) ∨ killed (y) ∨ food (z)
e) eats (Anil, Peanuts)
f) alive (Anil)
g) ¬ eats (Anil, w) ∨ eats (Harry, w)
h) killed (y) ∨ alive (y)
i) ¬ alive (k) ∨ ¬ killed (k)

Prof :-



Project

Algorithm

↳ Alpha (α
path with
↳ Max wo
killed d
↳ In Both
which co
↳ Both n
same p
↳ Alpha(α
less tha

Problem.
Apply
node (H

CODE:

```
def negate(literal):
    """Return the negation of a literal."""
    if isinstance(literal, tuple) and literal[0] == "not":
        return literal[1]
    else:
        return ("not", literal)

def resolve(clause1, clause2):
    """Return the resolvent of two clauses."""
    resolvents = set()
    for literal1 in clause1:
        for literal2 in clause2:
            if literal1 == negate(literal2):
                resolvent = (clause1 - {literal1}) | (clause2 -
{literal2})
                print(f"    Resolving literal: {literal1} with
{literal2}")
                print(f"    Resulting Resolvent: {resolvent}")
                resolvents.add(frozenset(resolvent))
    return resolvents

def resolution_algorithm(KB, query):
    """Perform the resolution algorithm to check if the query can be
proven."""
    print("\n--- Step-by-Step Resolution Process ---")
    negated_query = negate(query)
    KB.append(frozenset([negated_query]))
    print(f"Negated Query Added to KB: {negated_query}")

    clauses = set(KB)

    step = 1
    while True:
        new_clauses = set()
        print(f"\nStep {step}: Resolving Clauses")
        for c1 in clauses:
            for c2 in clauses:
                if c1 != c2:
                    print(f"  Resolving clauses: {c1} and {c2}")
                    resolvent = resolve(c1, c2)
```

```
                    for res in resolvent:
                        if frozenset([]) in resolvent:
                            print("\nEmpty clause derived! The query
is provable.")
                            return True
                        new_clauses.add(res)

        if new_clauses.issubset(clauses):
            print("\nNo new clauses can be derived. The query is not
provable.")
            return False

        clauses.update(new_clauses)
        step += 1

KB = [
    frozenset([("not", "food(x)"), ("likes", "John", "x")]),
    frozenset([("food", "Apple")]),
    frozenset([("food", "vegetables")]),
    frozenset([("not", "eats(y, z)"), ("killed", "y"), ("food",
"z")]),
    frozenset([("eats", "Anil", "Peanuts")]),
    frozenset([("alive", "Anil")]),
    frozenset([("not", "eats(Anil, w)"), ("eats", "Harry", "w")]),
    frozenset([("killed", "g"), ("alive", "g")]),
    frozenset([("not", "alive(k)"), ("not", "killed(k)")]),
    frozenset([("likes", "John", "Peanuts")])
]


query = ("likes", "John", "Peanuts")

result = resolution_algorithm(KB, query)
if result:
    print("\nQuery is provable.")
else:
    print("\nQuery is not provable.")
```

OUTPUT:

--- Step-by-Step Resolution Process ---
Negated Query Added to KB: ('not', ('likes', 'John', 'Peanuts'))

Step 1: Resolving Clauses

Resolving clauses: frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')}) and frozenset({('alive', 'Anil')})
Resolving clauses: frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')}) and frozenset({('food', 'vegetables')})
Resolving clauses: frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')}) and frozenset({('food', 'Apple')})
Resolving clauses: frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')}) and frozenset({('eats', 'Anil', 'Peanuts')})
Resolving clauses: frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')}) and frozenset({('alive', 'g'), ('killed', 'g')})
Resolving clauses: frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')}) and frozenset({('not', 'killed(k)'), ('not', 'alive(k)')})
Resolving clauses: frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')}) and frozenset({('likes', 'John', 'Peanuts')})
Resolving clauses: frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')}) and frozenset({('not', 'eats(Anil, w)'), ('eats', 'Harry', 'w')})
Resolving clauses: frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
Resolving clauses: frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')}) and frozenset({('likes', 'John', 'x'), ('not', 'food(x)')})
Resolving clauses: frozenset({('alive', 'Anil')}) and frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')})
Resolving clauses: frozenset({('alive', 'Anil')}) and frozenset({('food', 'vegetables')})
Resolving clauses: frozenset({('alive', 'Anil')}) and frozenset({('food', 'Apple')})
Resolving clauses: frozenset({('alive', 'Anil')}) and frozenset({('eats', 'Anil', 'Peanuts')})
Resolving clauses: frozenset({('alive', 'Anil')}) and frozenset({('alive', 'g'), ('killed', 'g')})
Resolving clauses: frozenset({('alive', 'Anil')}) and frozenset({('not', 'killed(k)'), ('not', 'alive(k)')})
Resolving clauses: frozenset({('alive', 'Anil')}) and frozenset({('likes', 'John', 'Peanuts')})
Resolving clauses: frozenset({('alive', 'Anil')}) and frozenset({('not', 'eats(Anil, w)'), ('eats', 'Harry', 'w')})
Resolving clauses: frozenset({('alive', 'Anil')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
Resolving clauses: frozenset({('alive', 'Anil')}) and frozenset({('likes', 'John', 'x'), ('not', 'food(x)')})
Resolving clauses: frozenset({('food', 'vegetables')}) and frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')})
Resolving clauses: frozenset({('food', 'vegetables')}) and frozenset({('alive', 'Anil')})
Resolving clauses: frozenset({('food', 'vegetables')}) and frozenset({('food', 'Apple')})
Resolving clauses: frozenset({('food', 'vegetables')}) and frozenset({('eats', 'Anil', 'Peanuts')})
Resolving clauses: frozenset({('food', 'vegetables')}) and frozenset({('alive', 'g'), ('killed', 'g')})
Resolving clauses: frozenset({('food', 'vegetables')}) and frozenset({('not', 'killed(k)'), ('not', 'alive(k)')})
Resolving clauses: frozenset({('food', 'vegetables')}) and frozenset({('likes', 'John', 'Peanuts')})
Resolving clauses: frozenset({('food', 'vegetables')}) and frozenset({('not', 'eats(Anil, w)'), ('eats', 'Harry', 'w')})

Resolving clauses: frozenset({('food', 'vegetables')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
Resolving clauses: frozenset({('food', 'vegetables')}) and frozenset({('likes', 'John', 'x'), ('not', 'food(x)')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('alive', 'Anil')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('food', 'vegetables')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('eats', 'Anil', 'Peanuts')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('alive', 'g'), ('killed', 'g')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('not', 'killed(k)'), ('not', 'alive(k)')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('likes', 'John', 'Peanuts')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('not', 'eats(Anil, w)'), ('eats', 'Harry', 'w')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('likes', 'John', 'x'), ('not', 'food(x)')})
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')})
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('alive', 'Anil')})
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('food', 'vegetables')})
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('food', 'Apple')})
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('alive', 'g'), ('killed', 'g')})
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('not', 'killed(k)'), ('not', 'alive(k)')})
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('likes', 'John', 'Peanuts')})
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('not', 'eats(Anil, w)'), ('eats', 'Harry', 'w')})
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('likes', 'John', 'x'), ('not', 'food(x)')})
Resolving clauses: frozenset({('alive', 'g'), ('killed', 'g')}) and frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')})
Resolving clauses: frozenset({('alive', 'g'), ('killed', 'g')}) and frozenset({('alive', 'Anil')})
Resolving clauses: frozenset({('alive', 'g'), ('killed', 'g')}) and frozenset({('food', 'vegetables')})
Resolving clauses: frozenset({('alive', 'g'), ('killed', 'g')}) and frozenset({('food', 'Apple')})
Resolving clauses: frozenset({('alive', 'g'), ('killed', 'g')}) and frozenset({('eats', 'Anil', 'Peanuts')})
Resolving clauses: frozenset({('alive', 'g'), ('killed', 'g')}) and frozenset({('not', 'killed(k)'), ('not', 'alive(k)')})
Resolving clauses: frozenset({('alive', 'g'), ('killed', 'g')}) and frozenset({('likes', 'John', 'Peanuts')})

Resolving clauses: frozenset({('alive', 'g'), ('killed', 'g')}) and frozenset({('not', 'eats(Anil, w)'), ('eats', 'Harry', 'w')})
Resolving clauses: frozenset({('alive', 'g'), ('killed', 'g')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
Resolving clauses: frozenset({('alive', 'g'), ('killed', 'g')}) and frozenset({('likes', 'John', 'x'), ('not', 'food(x)')})
Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')})
Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('alive', 'Anil')})
Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('food', 'vegetables')})
Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('food', 'Apple')})
Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('eats', 'Anil', 'Peanuts')})
Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('alive', 'g'), ('killed', 'g')})
Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('likes', 'John', 'Peanuts')})
Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('not', 'eats(Anil, w)'), ('eats', 'Harry', 'w')})
Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('likes', 'John', 'x'), ('not', 'food(x)')})
Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')})
Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('alive', 'Anil')})
Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('food', 'vegetables')})
Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('food', 'Apple')})
Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('eats', 'Anil', 'Peanuts')})
Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('alive', 'g'), ('killed', 'g')})
Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', 'killed(k)'), ('not', 'alive(k)')})
Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', 'eats(Anil, w)'), ('eats', 'Harry', 'w')})
Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
Resolving literal: ('likes', 'John', 'Peanuts') with ('not', ('likes', 'John', 'Peanuts'))
Resulting Resolvent: frozenset()

Empty clause derived! The query is provable. Query is provable.

LAB-10
Alpha-Beta pruning algorithm

ALGORITHM:

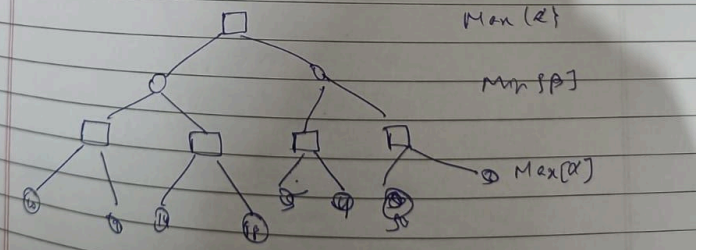
Project title :- Implement Alpha-Beta pruning

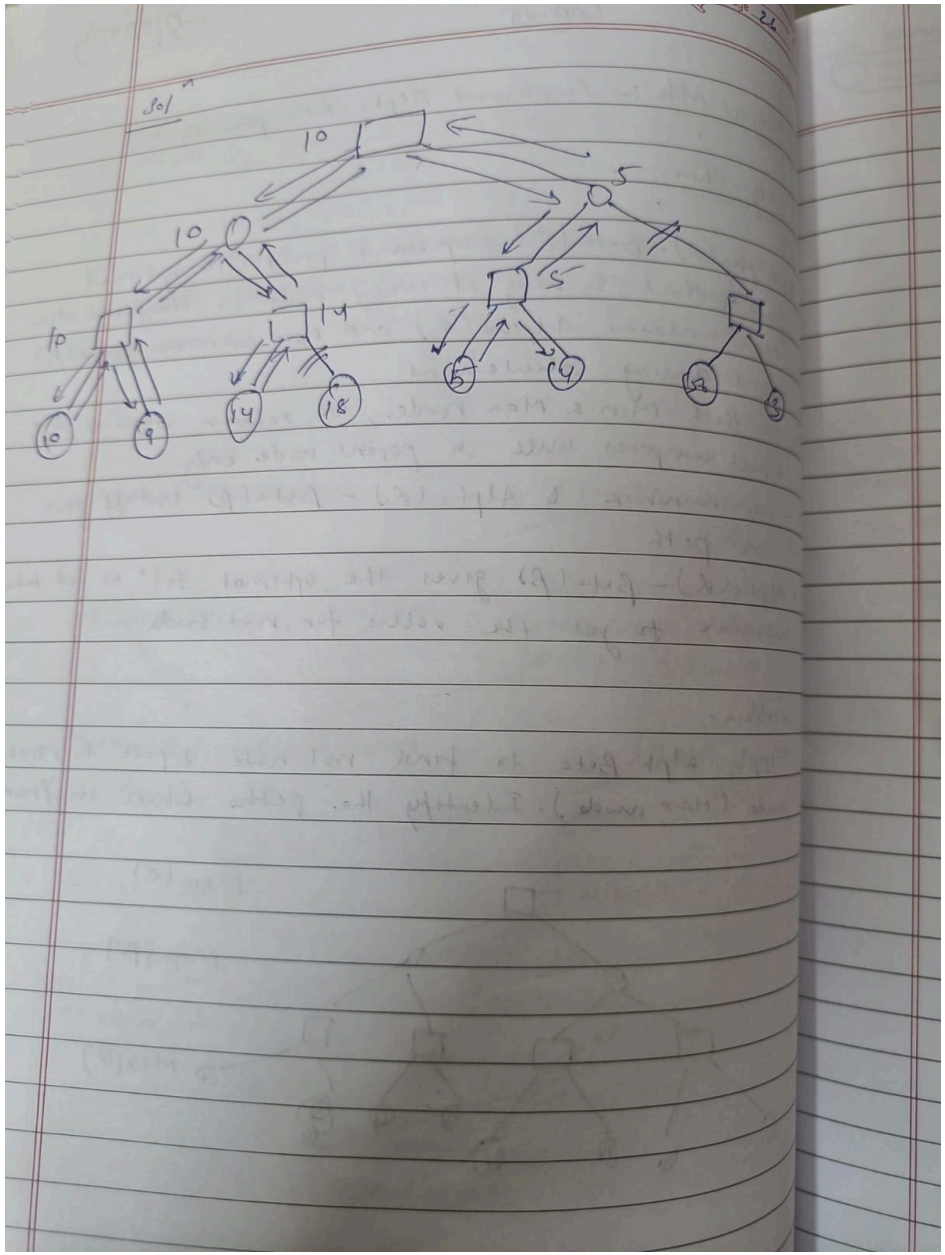
Algorithm :-

- Alpha(α) - Beta(β) proposes to find the optimal path without looking at every node in the game tree
- Max contains Alpha(α) and Min contains Beta(β) bound during calculations
- In Both Min & Max node, we return when α ≥ β which compares with its parent node only.
- Both minimax & Alpha(α) - Beta(β) cut-off give same path
- Alpha(α) - Beta(β) gives the optimal solution as it takes less time to get the value for root node.

Problem.

Apply alph-Beta to find root node & path to root node (MAX node). Identify the paths which are pruned




Sol
10
10
5
5
10
14
10
9
14
18
5
4
17
3

CODE:

```
def alpha_beta_search(state):
    def max_value(state, alpha, beta, path):
        print(f"MAX: Visiting state {state}, alpha={alpha},
beta={beta}")
        if terminal_test(state):
            print(f"MAX: Terminal state {state} has utility
{utility(state)}")
            return utility(state), path
        v = float('-inf')
        best_path = []
        for action in actions(state):
            result_state = result(state, action)
            value, new_path = min_value(result_state, alpha, beta,
path + [action])
            print(f"MAX: From state {state}, action {action} →
value={value}")
            if value > v:
                v = value
                best_path = new_path
            if v >= beta:
                print(f"MAX: Pruning at state {state} with value={v}
≥ beta={beta}")
                return v, best_path
            alpha = max(alpha, v)
        print(f"MAX: Returning value={v} for state {state}")
        return v, best_path

    def min_value(state, alpha, beta, path):
        print(f"MIN: Visiting state {state}, alpha={alpha},
beta={beta}")
        if terminal_test(state):
            print(f"MIN: Terminal state {state} has utility
{utility(state)}")
            return utility(state), path
        v = float('inf')
        best_path = []
        for action in actions(state):
            result_state = result(state, action)
            value, new_path = max_value(result_state, alpha, beta,
path + [action])
```

```
            print(f"MIN: From state {state}, action {action} →
value={value}")
            if value < v:
                v = value
                best_path = new_path
            if v <= alpha:
                print(f"MIN: Pruning at state {state} with value={v}
≤ alpha={alpha}")
                return v, best_path
            beta = min(beta, v)
        print(f"MIN: Returning value={v} for state {state}")
        return v, best_path

    print("Starting Alpha-Beta Search...\n")
    final_value, final_path = max_value(state, float('-inf'),
float('inf'), [state])
    return final_value, final_path


def terminal_test(state):
    return state in terminal_states

def utility(state):
    return terminal_states[state]

def actions(state):
    return game_tree.get(state, [])

def result(state, action):
    return action

game_tree = {
    'A': ['B', 'C'],
    'B': ['D', 'E'],
    'C': ['F', 'G'],
    'D': ['H','I'],
    'E': ['J','K'],
    'F': ['L','M'],
    'G': ['N','O'],
    'H':[],
    'I':[],
    'J':[],
    'K':[],
    'L':[],
    'M':[],
```

```
    'N':[],
    'O':[]
}

terminal_states = {
    'H': 10,
    'I': 9,
    'J': 14,
    'K': 18,
    'L': 5,
    'M': 4,
    'N': 50,
    'O': 3
}

final_value, final_path = alpha_beta_search('A')
print("\n--- Final Results ---")
print(f"The final utility value is: {final_value}")
print(f"The final path taken is: {final_path}")
```

OUTPUT:

Starting Alpha-Beta Search...

MAX: Visiting state A, alpha=-inf, beta=inf
MIN: Visiting state B, alpha=-inf, beta=inf
MAX: Visiting state D, alpha=-inf, beta=inf
MIN: Visiting state H, alpha=-inf, beta=inf
MIN: Terminal state H has utility 10
MAX: From state D, action H → value=10
MIN: Visiting state I, alpha=10, beta=inf
MIN: Terminal state I has utility 9
MAX: From state D, action I → value=9
MAX: Returning value=10 for state D
MIN: From state B, action D → value=10
MAX: Visiting state E, alpha=-inf, beta=10
MIN: Visiting state J, alpha=-inf, beta=10
MIN: Terminal state J has utility 14
MAX: From state E, action J → value=14
MAX: Pruning at state E with value=14 ≥ beta=10
MIN: From state B, action E → value=14
MIN: Returning value=10 for state B
MAX: From state A, action B → value=10
MIN: Visiting state C, alpha=10, beta=inf

MAX: Visiting state F, alpha=10, beta=inf
MIN: Visiting state L, alpha=10, beta=inf
MIN: Terminal state L has utility 5
MAX: From state F, action L → value=5
MIN: Visiting state M, alpha=10, beta=inf
MIN: Terminal state M has utility 4
MAX: From state F, action M → value=4
MAX: Returning value=5 for state F
MIN: From state C, action F → value=5
MIN: Pruning at state C with value=5 ≤ alpha=10
MAX: From state A, action C → value=5
MAX: Returning value=10 for state A

--- Final Results ---
The final utility value is: 10

The final path taken is: ['A', 'B', 'D', 'H']