VISVESVARAYA TECHNOLOGICAL UNIVERSITY

“JnanaSangama”, Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

Vaibhav Urs A N(1BM22CS315)

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
Sep-2024 to Jan-2025

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 **Vaibhav Urs A N(1BM22CS315),** who is a bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. 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.

Prof. Prameetha Pai Associate Professor Department of CSE, BMSCE	Dr. Kavitha Sooda Professor & HOD Department of CSE, BMSCE

Github Link: https://github.com/VaibhavUrs/AI

Table of contents

Program 1 - Tic Tac toe

<u>Algorithm</u>

04/10/24

LAB - 1

<u>TIC TAC TOE Game</u>

```
function minimax (node, depth, isMaximizing Player):
if node is a terminal state:
return evaluate (node)

if isMaximizing Player:
 best Value = -infinity
for each child in node:
Value = minimax (child, depth +1, false)
best Value = max (best Value, value)
 return bestValue
else:
  bestValue = +infinity
  for each child in node:
  Value = minimax (child, depth +1, true)
   bestValue = min (best Value, value)
   return bestValue
```

11/10/24

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])2

    print('-+-+-')

    print(board[7] + '|' + board[8] + '|' + board[9])

    print('\n')


def spaceFree(pos):

    return board[pos] == ' '


def checkWin():

    win_conditions = [

        (1, 2, 3), (4, 5, 6), (7, 8, 9),  # Rows

        (1, 4, 7), (2, 5, 8), (3, 6, 9),  # Columns

        (1, 5, 9), (3, 5, 7)  # Diagonals

    ]

    for a, b, c in win_conditions:

        if board[a] == board[b] == board[c] and board[a] != ' ':

            return True

    return False
```

```
def checkMoveForWin(move):
    win_conditions = [
        (1, 2, 3), (4, 5, 6), (7, 8, 9),
        (1, 4, 7), (2, 5, 8), (3, 6, 9),
        (1, 5, 9), (3, 5, 7)
    ]
    for a, b, c in win_conditions:
        if board[a] == board[b] == move and board[a] != ' ':
            return True
    return False


def checkDraw():
    return all(board[key] != ' ' for key in board.keys())


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)


player = 'O'
bot = 'X'


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


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)


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

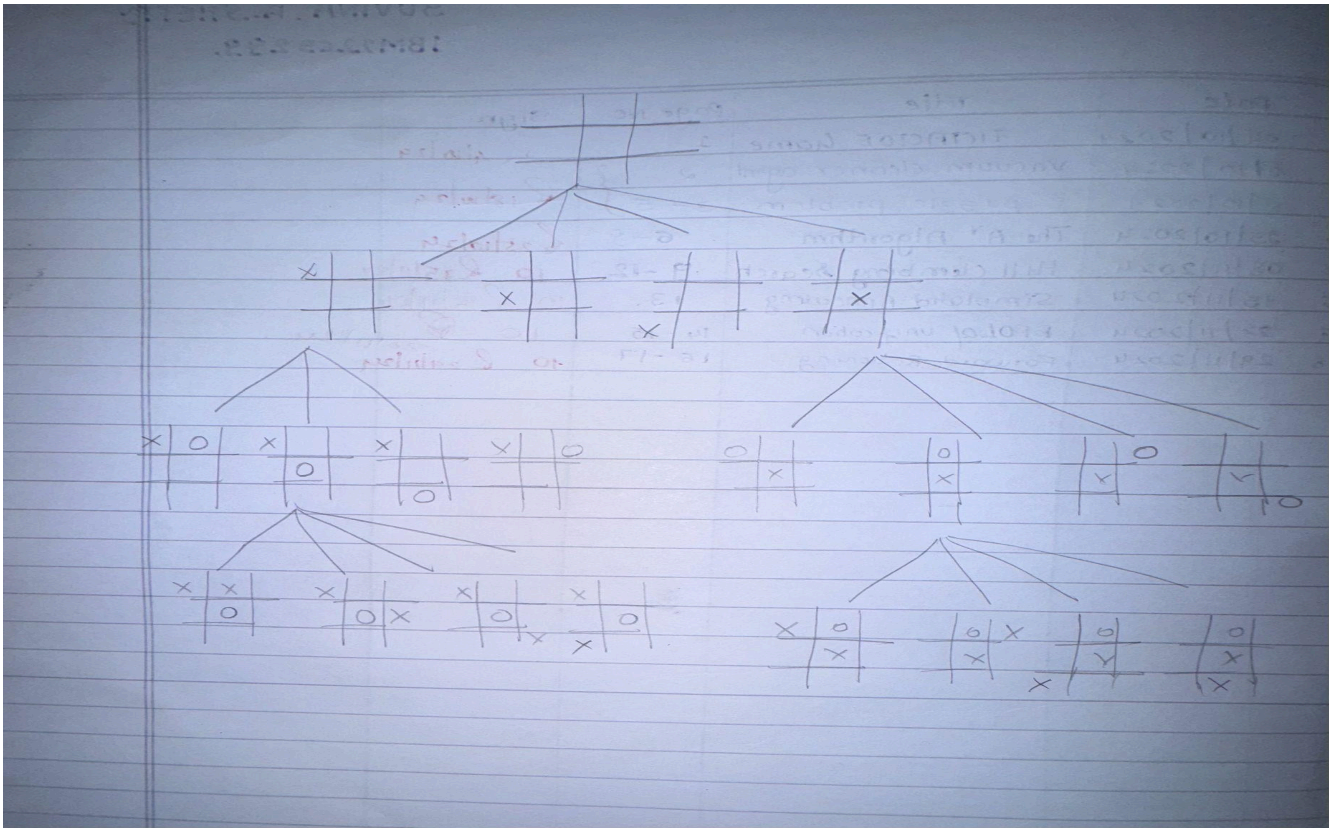
```
    elif checkDraw():
        return 0

    if isMaximizing:
        bestScore = -1000
        for key in board.keys():
            if board[key] == ' ':
                board[key] = bot
                score = minimax(board, False)
                board[key] = ' '
                bestScore = max(score, bestScore)
        return bestScore
    else:
        bestScore = 1000
        for key in board.keys():
            if board[key] == ' ':
                board[key] = player
                score = minimax(board, True)
                board[key] = ' '
                bestScore = min(score, bestScore)
        return bestScore

print("\nVAIBHAV URS A N")
print("1BM22CS315\n")

while not checkWin() and not checkDraw():
    compMove()
    if checkWin() or checkDraw():
```

```
        break

    playerMove()
```

Output Snapshot

```
Vaibhav Urs A N
USN:1BM22CS315

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


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


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


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

State Space Tree



Program 2 - 8 Puzzle Using BFS

<u>Algorithm</u>

18/10/24

3

8 Puzzle problem using BFS & DFS

BFS

Let fringe be a list containing the initial state.
Loop
    if fringe is empty return failure
    Node ← remove-first(fringe)
  if Node is a goal
    then return the path from Initial state to Node
  else generate all successors of Node, and
    add generated nodes to the back of fringe
End Loop

Code

```
#BFS
from collections import deque

class PuzzleState:
    def __init__(self, board, zero_position, path=[]):
        self.board = board
        self.zero_position = zero_position
        self.path = path

    def is_goal(self):
        return self.board == [1, 2, 3, 4, 5, 6, 7, 8, 0]

    def get_possible_moves(self):
        moves = []
        row, col = self.zero_position
        directions = [(0, 1), (1, 0), (0, -1), (-1, 0)]  # Right, Down, Left, Up

        for dr, dc in directions:
            new_row, new_col = row + dr, col + dc
            if 0 <= new_row < 3 and 0 <= new_col < 3:
                new_board = self.board[:]
                # Swap zero with the adjacent tile
                new_board[row * 3 + col], new_board[new_row * 3 + new_col] = new_board[new_row
* 3 + new_col], new_board[row * 3 + col]
                moves.append(PuzzleState(new_board, (new_row, new_col), self.path + [new_board]))
        return moves

def bfs(initial_state):
    queue = deque([initial_state])
    visited = set()

    while queue:
        current_state = queue.popleft()
        # Show the current board
        print("Current Board State:")
        print_board(current_state.board)
        print()

        if current_state.is_goal():
```

```
            return current_state.path
        visited.add(tuple(current_state.board))

        for next_state in current_state.get_possible_moves():
            if tuple(next_state.board) not in visited:
                queue.append(next_state)

    return None

def print_board(board):
    for i in range(3):
        print(board[i * 3:i * 3 + 3])

def main():
    print("Enter the initial state of the 8-puzzle (use 0 for the blank tile, e.g., '1 2 3 4 5 6 7 8 0'): ")
    user_input = input()
    initial_board = list(map(int, user_input.split()))

    if len(initial_board) != 9 or set(initial_board) != set(range(9)):
        print("Invalid input! Please enter 9 numbers from 0 to 8.")
        return

    zero_position = initial_board.index(0)
    initial_state = PuzzleState(initial_board, (zero_position // 3, zero_position % 3))
    solution_path = bfs(initial_state)

    if solution_path is None:
        print("No solution found.")
    else:
        print("Solution found in", len(solution_path), "steps.")
        for step in solution_path:
            print_board(step)
            print()

if __name__ == "__main__":
    main()

print("-------------")
print("\nVAIBHAV URS A N ")
print("1BM22CS315\n")
```

Output Snapshot

```
Enter the initial state of the 8-puzzle (use 0 for the blank tile, e.g., '1 2 3 4 5 6 7 8 0'):
1 2 3 4 0 6 7 5 8
Current Board State:
[1, 2, 3]
[4, 0, 6]
[7, 5, 8]

Current Board State:
[1, 2, 3]
[4, 6, 0]
[7, 5, 8]

Current Board State:
[1, 2, 3]
[4, 5, 6]
[7, 0, 8]

Current Board State:
[1, 2, 3]
[0, 4, 6]
[7, 5, 8]
```

```
Solution found in 2 steps.
[1, 2, 3]
[4, 5, 6]
[7, 0, 8]

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

-------------
Vaibhav Urs A N
1BM22CS315
```

State Space Tree

18/10/2024

state space tree

start state : 1 2 3
4 5 6
0 7 8

Goal state : 1 2 3
4 5 6
7 8 0

For BFS

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

[1 2 3]
[4 5 6]
[7 0 8]
(move up)

↓

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

↓

[1 2 3]
[4 5 6]
[7 8 0]
(Goal state)

[1 2 3]
[4 5 0]
[4 0 6]
(move left)

↓

[1 2 3]
[4 5 6]
[0 7 8]
(move Down)

1 2 3
4 0 6
0 7 8
(move Right)

↓

[1 2 3]
[4 5 6]
[7 0 8]
(move down)

8 puzzle using DFS

DFS

Let fringe be a list containing the initial state
Loop
  if fringe is empty return failure
  Node ← remove-first (fringe)
  if Node is a goal
   then return the path from initial state to Node
  else generate all successors of Node and
   add generated node to the front of fringe
End loop

```
Vaibhav Urs A N
1BM22CS315
---------
Enter the initial state of the puzzle:
Enter row 1 (space-separated numbers, use 0 for empty space): 1 2 3
Enter row 2 (space-separated numbers, use 0 for empty space): 4 0 5
Enter row 3 (space-separated numbers, use 0 for empty space): 7 8 6
Enter the goal state of the puzzle:
Enter row 1 (space-separated numbers, use 0 for empty space): 1 2 3
Enter row 2 (space-separated numbers, use 0 for empty space): 4 5 6
Enter row 3 (space-separated numbers, use 0 for empty space): 7 8 0
Solution found in 30 moves:
[1, 2, 3]
[4, 0, 5]
[7, 8, 6]

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

Code

```
from collections import deque

print("\nVAIBHAV URS A N ")
print("1BM22CS315\n")
print("--------")

def get_user_input(prompt):
    board = []
    print(prompt)
    for i in range(3):
        row = list(map(int, input(f"Enter row {i + 1} (space-separated numbers, use 0 for empty space): 
").split()))
        board.append(row)
    return board

def is_solvable(board):
    flattened_board = [tile for row in board for tile in row if tile != 0]
    inversions = 0
    for i in range(len(flattened_board)):
        for j in range(i + 1, len(flattened_board)):
            if flattened_board[i] > flattened_board[j]:
                inversions += 1
    return inversions % 2 == 0

class PuzzleState:
    def __init__(self, board, moves=0, previous=None):
        self.board = board
        self.empty_tile = self.find_empty_tile()
        self.moves = moves
        self.previous = previous

    def find_empty_tile(self):
        for i in range(3):
            for j in range(3):
```

```
                if self.board[i][j] == 0:
                    return (i, j)

    def is_goal(self, goal_state):
        return self.board == goal_state

    def get_possible_moves(self):
        row, col = self.empty_tile
        possible_moves = []
        directions = [(1, 0), (-1, 0), (0, 1), (0, -1)]  # down, up, right, left
        for dr, dc in directions:
            new_row, new_col = row + dr, col + dc
            if 0 <= new_row < 3 and 0 <= new_col < 3:
                # Make the move
                new_board = [row[:] for row in self.board]  # Deep copy
                new_board[row][col], new_board[new_row][new_col] = new_board[new_row][new_col],
new_board[row][col]
                possible_moves.append(PuzzleState(new_board, self.moves + 1, self))
        return possible_moves

def dfs(initial_state, goal_state):
    stack = [initial_state]
    visited = set()
    while stack:
        current_state = stack.pop()
        # If we find the goal, return the state
        if current_state.is_goal(goal_state):
            return current_state
        # Convert board to a tuple for the visited set
        state_tuple = tuple(tuple(row) for row in current_state.board)
        # If we've already visited this state, skip it
        if state_tuple not in visited:
            visited.add(state_tuple)
            for next_state in current_state.get_possible_moves():
                stack.append(next_state)
    return None  # No solution found
```

```python
def print_solution(solution):
    path = []
    while solution:
        path.append(solution.board)
        solution = solution.previous
    for state in reversed(path):
        for row in state:
            print(row)
        print()

if __name__ == "__main__":
    # Get user input for initial and goal states
    initial_board = get_user_input("Enter the initial state of the puzzle:")
    goal_board = get_user_input("Enter the goal state of the puzzle:")

    if is_solvable(initial_board):
        initial_state = PuzzleState(initial_board)
        solution = dfs(initial_state, goal_board)
        if solution:
            print("Solution found in", solution.moves, "moves:")
            print_solution(solution)
        else:
            print("No solution found.")
    else:
        print("This puzzle is unsolvable.")
```

Output Snapshot

```
Vaibhav Urs A N
1BM22CS315
--------
Enter the initial state of the puzzle:
Enter row 1 (space-separated numbers, use 0 for empty space): 1 2 3
Enter row 2 (space-separated numbers, use 0 for empty space): 4 0 5
Enter row 3 (space-separated numbers, use 0 for empty space): 7 8 6
Enter the goal state of the puzzle:
Enter row 1 (space-separated numbers, use 0 for empty space): 1 2 3
Enter row 2 (space-separated numbers, use 0 for empty space): 4 5 6
Enter row 3 (space-separated numbers, use 0 for empty space): 7 8 0
Solution found in 30 moves:
[1, 2, 3]
[4, 0, 5]
[7, 8, 6]

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

StateSpaceTree

18/10/2024

For DFS

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

↓ move up

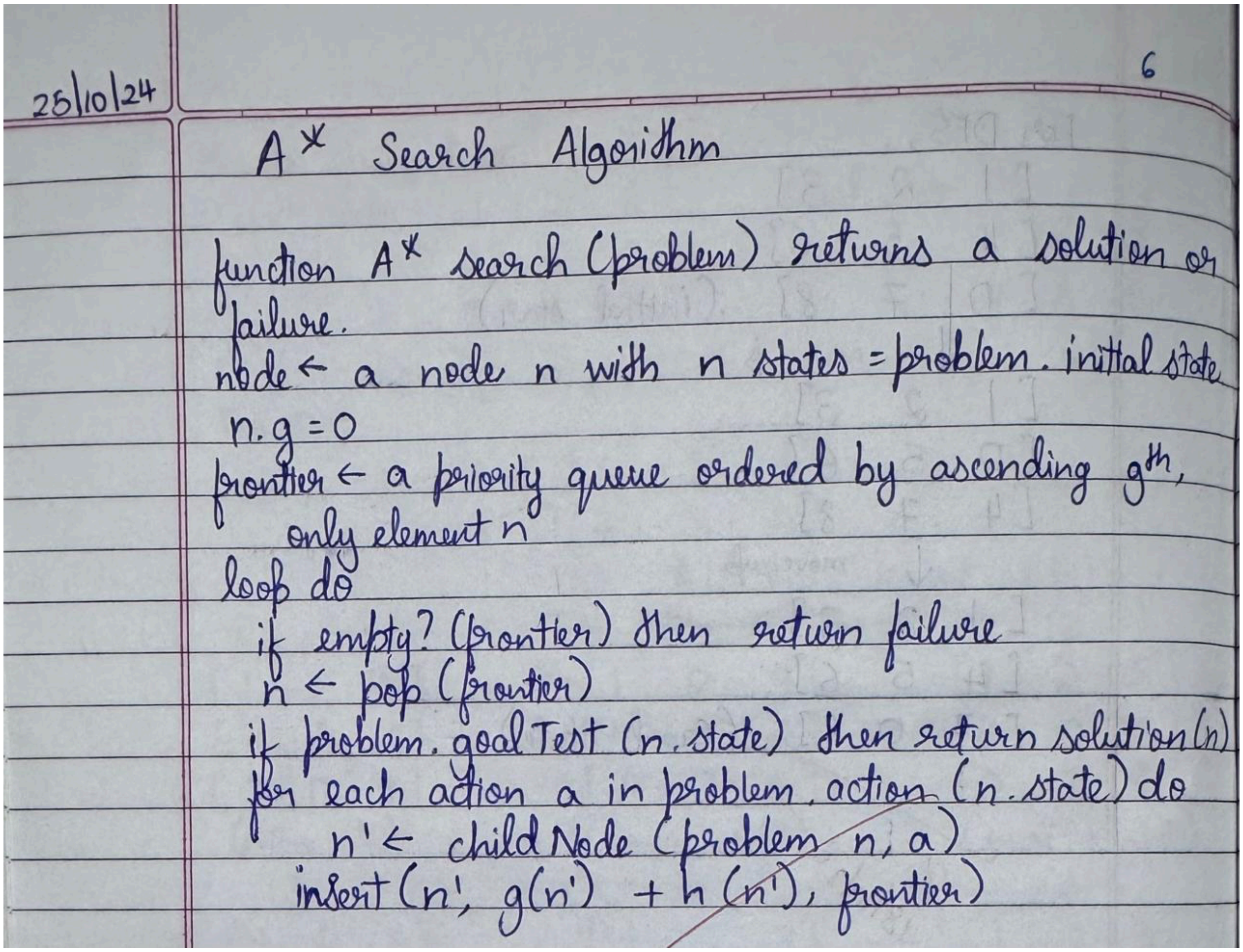
$$\begin{bmatrix} 1 & 2 & 3 \\ 0 & 5 & 6 \\ 4 & 7 & 8 \end{bmatrix}$$

↓ move up

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

18/10/2024

Program 03 - 8 Puzzle Using A* Algorithm



25/10/24 6

A* Search Algorithm

function A* search (problem) returns a solution or failure.
node ← a node n with n states = problem.initial state
n.g = 0
frontier ← a priority queue ordered by ascending g^{th}, only element n
loop do
if empty? (frontier) then return failure
n ← pop (frontier)
if problem.goalTest (n.state) then return solution(n)
for each action a in problem.action (n.state) do
n' ← childNode (problem, n, a)
insert (n', g(n') + h(n'), frontier)

<u>Code</u>

MANHATTAN DISTANCE

```
#Manhattan Distance
import heap


class Node:
    def __init__(self, position, parent=None):
        self.position = position
        self.parent = parent
        self.g = 0  # Cost from start to this node
        self.h = 0  # Heuristic cost from this node to target
        self.f = 0  # Total cost

    def __lt__(self, other):
```

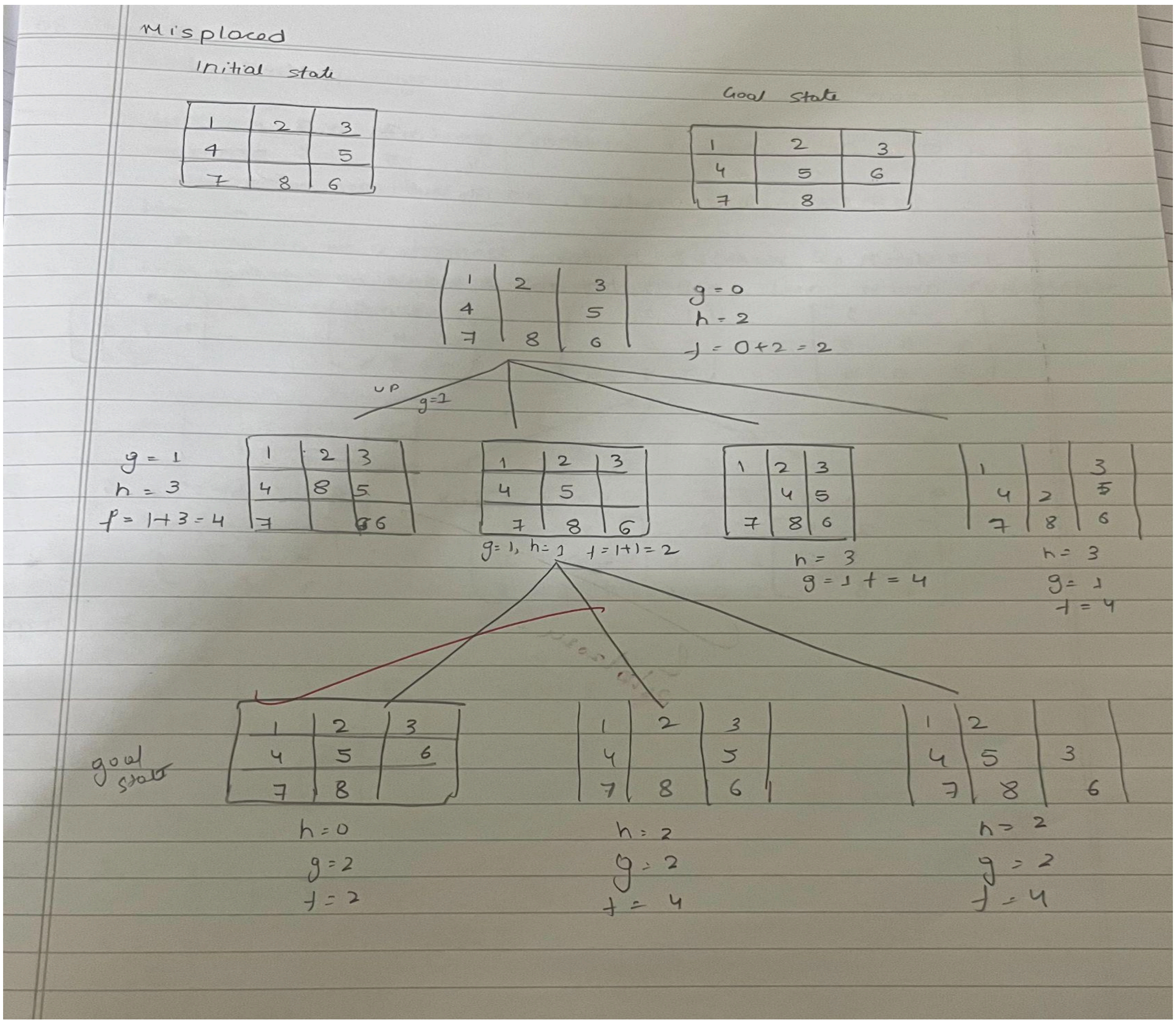
```
        return self.f < other.f

def heuristic(a, b):
    # Manhattan distance
    return abs(a[0] - b[0]) + abs(a[1] - b[1])

def astar(start, goal, grid):
    open_list = []
    closed_list = set()
    start_node = Node(start)
    goal_node = Node(goal)
    heapq.heappush(open_list, start_node)

    while open_list:
        current_node = heapq.heappop(open_list)
        closed_list.add(current_node.position)

        # Goal check
        if current_node.position == goal:
            path = []
            while current_node:
                path.append(current_node.position)
                current_node = current_node.parent
            return path[::-1]  # Return reversed path

        # Generate neighbors
        neighbors = [
            (current_node.position[0] + dx, current_node.position[1] + dy)
            for dx, dy in [(-1, 0), (1, 0), (0, -1), (0, 1)]
        ]

        for next_position in neighbors:
            # Check if within bounds and not a wall (assuming 0 is free space)
            if (0 <= next_position[0] < len(grid) and
                0 <= next_position[1] < len(grid[0]) and
                grid[next_position[0]][next_position[1]] == 0):
```

```
            if next_position in closed_list:
                continue

            neighbor_node = Node(next_position, current_node)
            neighbor_node.g = current_node.g + 1
            neighbor_node.h = heuristic(next_position, goal)
            neighbor_node.f = neighbor_node.g + neighbor_node.h

            # Check if this neighbor is already in the open list
            if any(neighbor.position == neighbor_node.position and neighbor.f <= neighbor_node.f for
neighbor in open_list):
                continue

            heapq.heappush(open_list, neighbor_node)

    return []  # Return empty path if no path found

# Example usage
if __name__ == "__main__":
    grid = [
        [0, 0, 0, 0, 0],
        [0, 1, 1, 1, 0],
        [0, 0, 0, 0, 0],
        [0, 1, 1, 0, 0],
        [0, 0, 0, 0, 0]
    ]
    start = (0, 0)
    goal = (4, 4)
    path = astar(start, goal, grid)
    print("Path from start to goal:", path)
    print("\nVAIBHAV URS A N ")
    print("1BM22CS315\n")
```

Output Snapshot

```
Path from start to goal: [(0, 0), (1, 0), (2, 0), (2, 1), (2, 2), (2, 3), (3, 3), (4, 3), (4, 4)]
Vaibhav Urs A N
1BM22CS315
```

State Space Tree



MISPLACED TILES

```
import heapq


class PuzzleState:
    def __init__(self, board, g=0):
        self.board = board
        self.g = g  # Cost from start to this state
        self.zero_pos = board.index(0)  # Position of the empty space

    def h(self):
        # Calculate the number of misplaced tiles (Misplaced Tile Heuristic)
        return sum(1 for i in range(9) if self.board[i] != 0 and self.board[i] != i + 1)

    def f(self):
        return self.g + self.h()

    def get_neighbors(self):
        neighbors = []
        x, y = divmod(self.zero_pos, 3)
        directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]  # Up, Down, Left, Right
        for dx, dy in directions:
            new_x, new_y = x + dx, y + dy
            if 0 <= new_x < 3 and 0 <= new_y < 3:
                new_zero_pos = new_x * 3 + new_y
                new_board = self.board[:]
                # Swap zero with the neighboring tile
                new_board[self.zero_pos], new_board[new_zero_pos] = new_board[new_zero_pos],
new_board[self.zero_pos]
                neighbors.append(PuzzleState(new_board, self.g + 1))
```

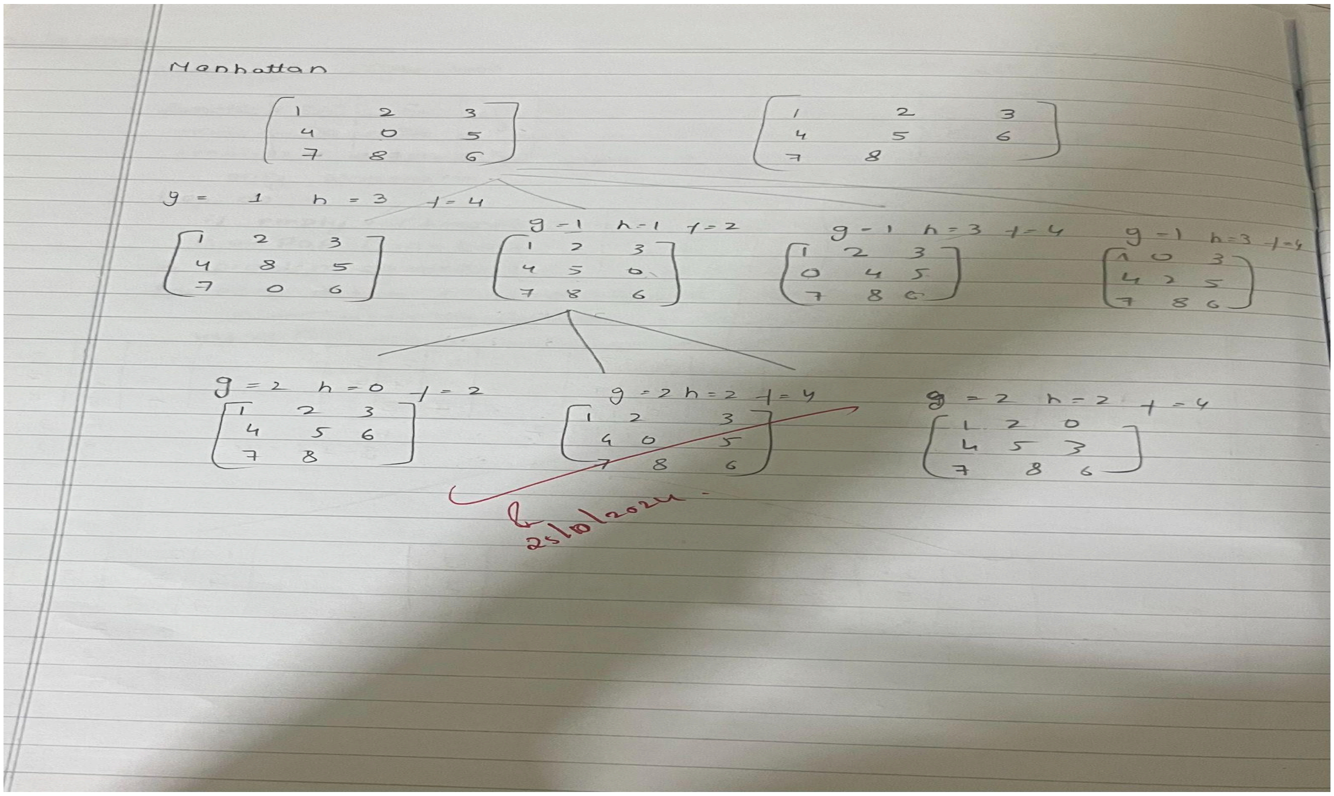
```
        return neighbors


def a_star(initial_state, goal_state):
    open_set = []
    heapq.heappush(open_set, (initial_state.f(), 0, initial_state))  # Add a unique identifier (0 in this case)
    came_from = {}
    g_score = {tuple(initial_state.board): 0}

    while open_set:
        current_f, _, current = heapq.heappop(open_set)

        if current.board == goal_state:
            return reconstruct_path(came_from, current)

        for neighbor in current.get_neighbors():
            neighbor_tuple = tuple(neighbor.board)
            tentative_g_score = g_score[tuple(current.board)] + 1

            if neighbor_tuple not in g_score or tentative_g_score < g_score[neighbor_tuple]:
                came_from[neighbor_tuple] = current
                g_score[neighbor_tuple] = tentative_g_score
                heapq.heappush(open_set, (neighbor.f(), neighbor.g, neighbor))

    return None  # No solution found


def reconstruct_path(came_from, current):
    path = []
    while current is not None:
        path.append(current.board)
```

```
        current = came_from.get(tuple(current.board), None)
    return path[::-1]


# Example usage
if __name__ == "__main__":
    initial_state = PuzzleState([1, 2, 3, 4, 5, 6, 0, 7, 8])
    goal_state = [1, 2, 3, 4, 5, 6, 7, 8, 0]
    solution = a_star(initial_state, goal_state)

    if solution:
        for step in solution:
            print(step)
    else:
        print("No solution found")

    print("VAIBHAV URS A N ")
    print("1BM22CS315")
```

<u>Output Snapshot</u>

```
[1, 2, 3, 4, 5, 6, 0, 7, 8]
[1, 2, 3, 4, 5, 6, 7, 0, 8]
[1, 2, 3, 4, 5, 6, 7, 8, 0]
Vaibhav Urs A N
1BM22CS315
```

State Space Tree



Program 4 - Vacuum Cleaner

<u>Algorithm</u>

18/10/24 LAB - 02 2

Implement vacuum cleaner agent

Algorithm:

1. Initialize the agent starting (x,y)

2. Loop until all cells are clean
    a. Perceive the current cell
    b. If the cell is dirty:
        i. clean the current cell
    c. Else:
        i. check surrounding cells (up, down, left, right) to see if any one is dirty.
        ii. Move to the next dirty cell (using a strategy such as BFS, DFS or random movement.
    d. If no dirty cell are perceived. Stop (All cells are clean).

3. End

Code

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

    location_input = input("Enter Location of Vacuum: ")
    status_input = input("Enter status of " + location_input + " (0 for Clean, 1 for Dirty): ")
    status_input_complement = input("Enter status of other room (0 for Clean, 1 for Dirty): ")

    print("Initial Location Condition: " + str(goal_state))

    if location_input == 'A':
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            goal_state['A'] = '0'
            cost += 1
            print("Cost for CLEANING A: " + str(cost))
            print("Location A has been Cleaned.")

        if status_input_complement == '1':
            print("Location B is Dirty.")
            print("Moving right to Location B.")
            cost += 1
            print("COST for moving RIGHT: " + str(cost))
            goal_state['B'] = '0'
            cost += 1
            print("COST for SUCK: " + str(cost))
            print("Location B has been Cleaned.")
        else:
            print("No action needed; Location B is already clean.")
    else:
        print("Location A is already clean.")
        if status_input_complement == '1':
            print("Location B is Dirty.")
            print("Moving RIGHT to Location B.")
```

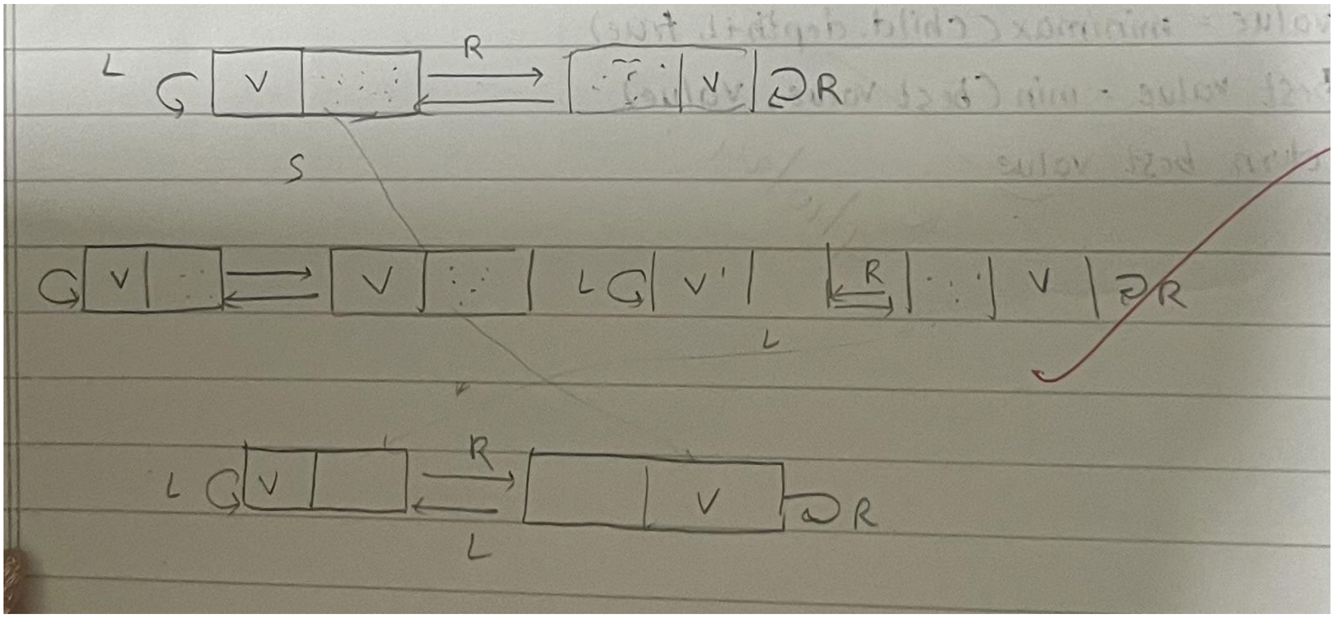
```
        cost += 1
        print("COST for moving RIGHT: " + str(cost))
        goal_state['B'] = '0'
        cost += 1
        print("COST for SUCK: " + str(cost))
        print("Location B has been Cleaned.")
    else:
        print("No action needed; Location B is already clean.")

if location_input == 'B':
    print("Vacuum is placed in Location B")
    if status_input == '1':
        print("Location B is Dirty.")
        goal_state['B'] = '0'
        cost += 1
        print("COST for CLEANING B: " + str(cost))
        print("Location B has been Cleaned.")

    if status_input_complement == '1':
        print("Location A is Dirty.")
        print("Moving LEFT to Location A.")
        cost += 1
        print("COST for moving LEFT: " + str(cost))
        goal_state['A'] = '0'
        cost += 1
        print("COST for SUCK: " + str(cost))
        print("Location A has been Cleaned.")
    else:
        print("No action needed; Location A is already clean.")
else:
    print("Location B is already clean.")
    if status_input_complement == '1':
        print("Location A is Dirty.")
        print("Moving LEFT to Location A.")
        cost += 1
        print("COST for moving LEFT: " + str(cost))
```

```
            goal_state['A'] = '0'
            cost += 1
            print("COST for SUCK: " + str(cost))
            print("Location A has been Cleaned.")
        else:
            print("No action needed; Location A is already clean.")

    print("GOAL STATE: ")
    print(goal_state)
    print("Performance Measurement: " + str(cost))
    print("\nVAIBHAV URS A N ")
    print("1BM22CS299\n")

vacuum_world()
```

Output Snapshot

```
Enter Location of Vacuum: 3
Enter status of 3 (0 for Clean, 1 for Dirty): 1
Enter status of other room (0 for Clean, 1 for Dirty): 1
Initial Location Condition: {'A': '0', 'B': '0'}
Location A is already clean.
Location B is Dirty.
Moving RIGHT to Location B.
COST for moving RIGHT: 1
COST for SUCK: 2
Location B has been Cleaned.
Location B is already clean.
Location A is Dirty.
Moving LEFT to Location A.
COST for moving LEFT: 3
COST for SUCK: 4
Location A has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 4
Vaibhav Urs A N
1BM22CS315
```

State Space Tree



Program-05 Hill Climbing

Algorithm

08/11/24

9

Hill - Climbing Search Algorithm

function Hill - Climbing (problem) return a state that is a local maxima

current ← Make node (problem. Initial - State)

loop do

neighbour ← a highest - valued successor of current

if neighbour . value ≤ current value the return current state

current ← neighbour

Code

```
import random


def print_board(board, n):
    """Prints the current state of the board."""
    for row in range(n):
        line = ""
        for col in range(n):
            if board[col] == row:
                line += " Q "
            else:
                line += " . "
        print(line)
    print()
```

```python
def calculate_conflicts(board, n):
    """Calculates the number of conflicts (attacks) between queens."""
    conflicts = 0
    for i in range(n):
        for j in range(i + 1, n):
            # Check if queens are in the same row or diagonal
            if board[i] == board[j] or abs(board[i] - board[j]) == abs(i - j):
                conflicts += 1
    return conflicts

def get_best_neighbor(board, n):
    """
    Finds the best neighboring board with the fewest conflicts.
    Returns the best board and its conflict count.
    """
    current_conflicts = calculate_conflicts(board, n)
    best_board = board[:]
    best_conflicts = current_conflicts
    neighbors = []

    for col in range(n):
        original_row = board[col]
        for row in range(n):
            if row == original_row:
                continue
            # Move queen to a new row and calculate conflicts
            board[col] = row
            new_conflicts = calculate_conflicts(board, n)
            neighbors.append((board[:], new_conflicts))
        # Restore the original row before moving to the next column
        board[col] = original_row

    # Sort neighbors by the number of conflicts (ascending)
    neighbors.sort(key=lambda x: x[1])
    if neighbors:
        best_neighbor = neighbors[0]
```

```
        if best_neighbor[1] < best_conflicts:
            return best_neighbor
    return board, current_conflicts

def hill_climbing_with_restarts(n, initial_board, max_restarts=100):
    """
    Performs Hill Climbing with random restarts to solve the N-Queens problem.
    Returns the final board configuration and its conflict count.
    """
    current_board = initial_board[:]
    current_conflicts = calculate_conflicts(current_board, n)

    print("Initial board:")
    print_board(current_board, n)
    print(f"Initial conflicts: {current_conflicts}\n")

    steps = 0
    restarts = 0

    while current_conflicts > 0 and restarts < max_restarts:
        new_board, new_conflicts = get_best_neighbor(current_board, n)

        steps += 1
        print(f"Step {steps}:")
        print_board(new_board, n)
        print(f"Conflicts: {new_conflicts}\n")

        if new_conflicts < current_conflicts:
            current_board = new_board
            current_conflicts = new_conflicts
        else:
            # If no better neighbor is found, perform a random restart
            restarts += 1
            print(f"Restarting... (Restart number {restarts})\n")
            current_board = [random.randint(0, n-1) for _ in range(n)]
            current_conflicts = calculate_conflicts(current_board, n)
```

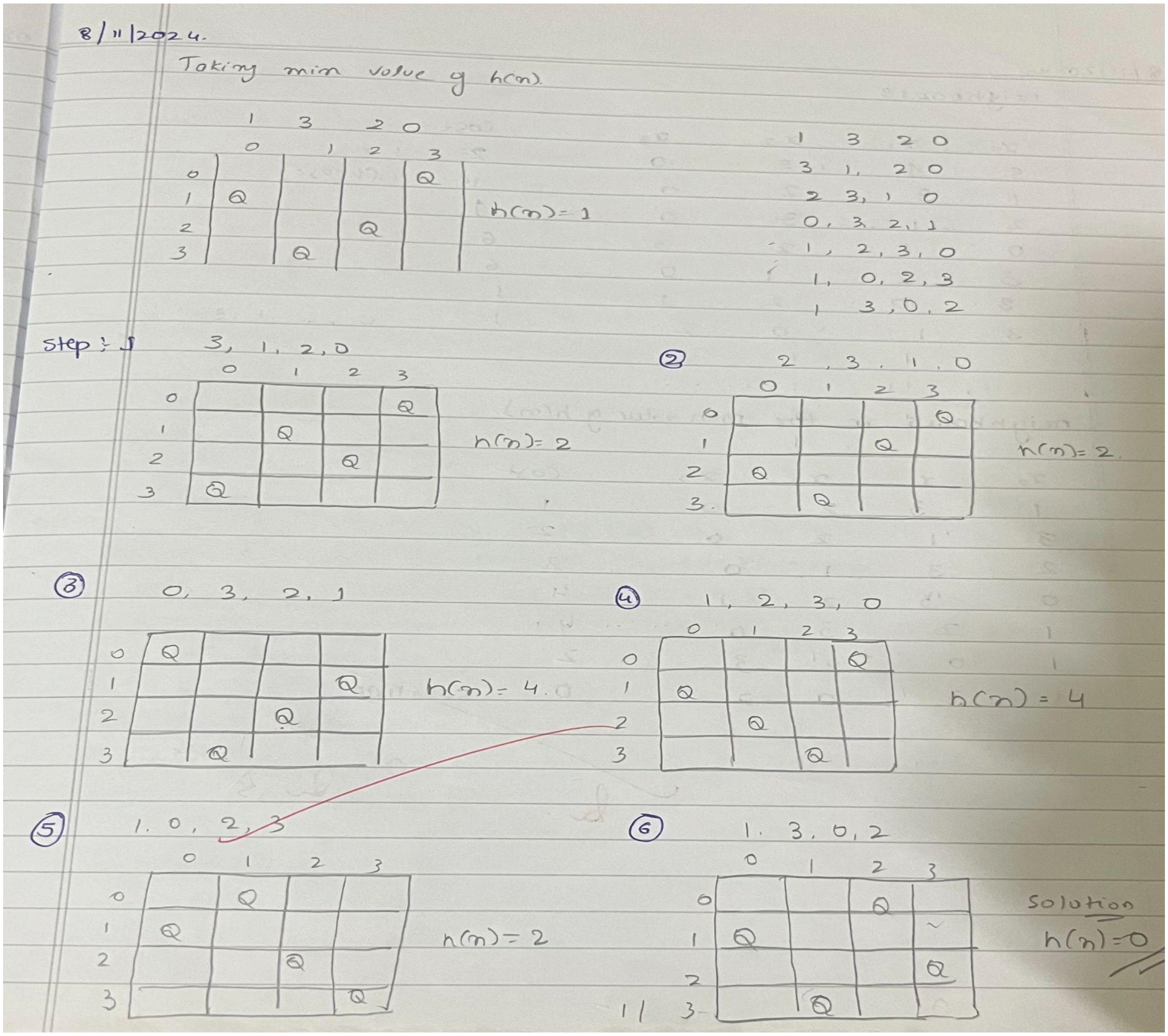
```
        print("New initial board:")
        print_board(current_board, n)
        print(f"Conflicts: {current_conflicts}\n")

    return current_board, current_conflicts

# Main function
def main():
    n = 4
    print("Enter the initial positions of queens (row numbers from 0 to 3 for each column):")
    initial_board = []
    for i in range(n):
        while True:
            try:
                row = int(input(f"Column {i}: "))
                if 0 <= row < n:
                    initial_board.append(row)
                    break
                else:
                    print(f"Please enter a number between 0 and {n-1}.")
            except ValueError:
                print("Invalid input. Please enter an integer.")

    solution, conflicts = hill_climbing_with_restarts(n, initial_board)

    print("Final solution:")
    print_board(solution, n)
    if conflicts == 0:
        print("A solution was found with no conflicts!")
    else:
        print(f"No solution was found after {100} restarts. Final number of conflicts: {conflicts}")

if __name__ == "__main__":
    main()
print("VAIBHAV URS A N ")
print("1BM22CS315")
```

OUTPUT

```
Enter the initial positions of queens (row numbers from 0 to 3 for each column):
Column 0: 3
Column 1: 1
Column 2: 2
Column 3: 0
Initial board:
 .  .  .  Q
 .  Q  .  .
 .  .  Q  .
 Q  .  .  .

Initial conflicts: 2

Step 1:
 .  .  .  Q
 .  Q  .  .
 .  .  Q  .
 Q  .  .  .

Conflicts: 2

Restarting... (Restart number 1)

New initial board:
 .  .  Q  .
 .  .  .  .
 .  .  .  .
 Q  Q  .  Q

Conflicts: 3
```

```
Step 3:
 .  .  Q  .
 Q  .  .  .
 .  .  .  Q
 .  Q  .  .

Conflicts: 0

Final solution:
 .  .  Q  .
 Q  .  .  .
 .  .  .  Q
 .  Q  .  .

A solution was found with no conflicts!
Vaibhav Urs A N
1BM22CS315
```

State Space Tree



Program-06 Simulated Annealing

Algorithm

15/11/24 13

Simulated Annealing

```
function current ← initial state
 T ← a large positive value
 while T>0 do
    next ← a random neighbour of current
    DE ← current.cost - next.cost
    If ΔE > 0 then
     current ← next
   else
     current ← next with probability P = e^(ΔE/T)
   end if
   decrease T
end while
return current
```

Code

```
import random
import math

def print_board(board, n):
    """Prints the current state of the board."""
    for row in range(n):
        line = ""
        for col in range(n):
            if board[col] == row:
                line += " Q "  # Queen is represented by "Q"
            else:
                line += " . "  # Empty space represented by "."
        print(line)
    print()

def calculate_conflicts(board, n):
    """Calculates the number of conflicts (attacks) between queens."""
    conflicts = 0
    for i in range(n):
        for j in range(i + 1, n):
            # Check if queens are in the same row or diagonal
            if board[i] == board[j] or abs(board[i] - board[j]) == abs(i - j):
                conflicts += 1
    return conflicts

def simulated_annealing(n, initial_temp=1000, cooling_rate=0.995, max_iterations=10000):
    """Simulated Annealing algorithm to solve N-Queens with detailed steps."""
    # Initial random board configuration (one queen in each column)
    board = [random.randint(0, n - 1) for _ in range(n)]
    current_conflicts = calculate_conflicts(board, n)
    temperature = initial_temp
    iteration = 0
```

```
print("Initial board:")
print_board(board, n)
print(f"Initial conflicts: {current_conflicts}\n")

while current_conflicts > 0 and iteration < max_iterations:
    # Generate a neighboring state by moving a queen to another row in its column
    col = random.randint(0, n - 1)
    original_row = board[col]
    new_row = random.randint(0, n - 1)
    while new_row == original_row:
        new_row = random.randint(0, n - 1)  # Ensure we are moving the queen to a new row
    board[col] = new_row

    # Calculate the number of conflicts in the new configuration
    new_conflicts = calculate_conflicts(board, n)

    # Display the current step, board, and conflicts
    print(f"Iteration {iteration + 1}:")
    print(f"Temperature: {temperature:.2f}")
    print(f"Trying to move queen in column {col} from row {original_row} to row {new_row}")
    print_board(board, n)
    print(f"New conflicts: {new_conflicts}, Current conflicts: {current_conflicts}")

    # If the new state has fewer conflicts, accept it.
    # If the new state has more conflicts, accept it with a certain probability.
    if new_conflicts < current_conflicts or random.random() < math.exp((current_conflicts -
new_conflicts) / temperature):
        current_conflicts = new_conflicts
        print("Move accepted.\n")
    else:
        # If no improvement, revert the move
        board[col] = original_row
        print("Move rejected. Reverting to previous state.\n")

    # Reduce the temperature according to the cooling schedule
```

```
        temperature *= cooling_rate

        iteration += 1

    return board, current_conflicts

def main():
    # Input dynamic parameters
    print("Welcome to the N-Queens Problem Solver using Simulated Annealing!")
    n = int(input("Enter the size of the board (N): "))
    initial_temp = float(input("Enter the initial temperature (e.g., 1000): "))
    cooling_rate = float(input("Enter the cooling rate (e.g., 0.995): "))
    max_iterations = int(input("Enter the maximum number of iterations (e.g., 10000): "))
    print("Vaibhav Urs A N")
    print("1BM22CS315")

    solution, conflicts = simulated_annealing(n, initial_temp, cooling_rate, max_iterations)

    print("Final solution:")
    print_board(solution, n)
    if conflicts == 0:
        print("A solution was found with no conflicts!")
    else:
        print(f"No solution was found after {max_iterations} iterations. Final number of conflicts:
{conflicts}")

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

Output Snapshot

```
Welcome to the N-Queens Problem Solver using Simulated Annealing!
Enter the size of the board (N): 4
Enter the initial temperature (e.g., 1000): 1000
Enter the cooling rate (e.g., 0.995): 0.99
Enter the maximum number of iterations (e.g., 10000): 200
Vaibhav Urs A N
1BM22CS315
Initial board:
 Q  .  .  Q
 .  Q  Q  .
 .  .  .  .
 .  .  .  .

Initial conflicts: 4

Iteration 1:
Temperature: 1000.00
Trying to move queen in column 2 from row 1 to row 0
 Q  .  Q  Q
 .  Q  .  .
 .  .  .  .
 .  .  .  .

New conflicts: 5, Current conflicts: 4
Move accepted.

Iteration 2:
Temperature: 990.00
Trying to move queen in column 1 from row 1 to row 0
 Q  Q  Q  Q
 .  .  .  .
 .  .  .  .
 .  .  .  .

New conflicts: 6, Current conflicts: 5
Move accepted.
```

State Space Tree

O/P

Enter the size of the board (N) : 4
Enter the initial temperature (e.g, 1000 :) : 1000
Enter the cooling rate (eg. 0.995) : 0.99 :
Enter the maximum number of iteration (eg. 10000) : 200
Initial board:

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

Final state :

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

Program-07 Unification in first order logic

Algorithm

22/1/24

14

Implement Unification using FOL

Algorithm:

Step-1: If Ψ_1 or Ψ_2 is a variable or constant, then
a). If Ψ_1 and Ψ_2 are identical, then return NIL
b). Else if Ψ_1 is a variable,
a. then if Ψ_1 occurs in Ψ_2, then return FAILURE
b. else return $\{(\Psi_2 / \Psi_1)\}$
c). Else if Ψ_2 is a variable,
a. then if Ψ_2 occurs in Ψ_1, then return FAILURE
b. else return $\{(\Psi_1 / \Psi_2)\}$
d). else return FAILURE

Step-2: If the initial predicate symbol in Ψ_1 and Ψ_2 is not same, then return FAILURE.

Step-3: If Ψ_1 and Ψ_2 have different number of arguments then return FAILURE

Step-4: Set substitution set (SBST) to NIL

Step-5: For i=1 to number of elements in Ψ_1
a). call unify function with i^{th} element of Ψ_1 and i^{th} element of Ψ_2 and put result into S.
b). If S = failure then return FAILURE
c). If S ≠ NIL then do,
a. apply S to the remainder of both L1 and L2
b. subset = append (S, subset)

Step-6: return subset

Executed

Code

```
import ast
from typing import Union, List, Dict, Tuple
from collections import deque

# Define Term Classes
class Term:
    def substitute(self, subs: Dict[str, 'Term']) -> 'Term':
        raise NotImplementedError

    def occurs(self, var: 'Variable') -> bool:
        raise NotImplementedError

    def __eq__(self, other):
        raise NotImplementedError

    def __str__(self):
        raise NotImplementedError

class Variable(Term):
    def __init__(self, name: str):
        self.name = name

    def substitute(self, subs: Dict[str, Term]) -> Term:
        if self.name in subs:
            return subs[self.name].substitute(subs)
        return self

    def occurs(self, var: 'Variable') -> bool:
        return self.name == var.name

    def __eq__(self, other):
        return isinstance(other, Variable) and self.name == other.name

    def __str__(self):
```

```python
        return self.name

class Constant(Term):
    def __init__(self, name: str):
        self.name = name

    def substitute(self, subs: Dict[str, Term]) -> Term:
        return self

    def occurs(self, var: 'Variable') -> bool:
        return False

    def __eq__(self, other):
        return isinstance(other, Constant) and self.name == other.name

    def __str__(self):
        return self.name

class Function(Term):
    def __init__(self, name: str, args: List[Term]):
        self.name = name
        self.args = args

    def substitute(self, subs: Dict[str, Term]) -> Term:
        substituted_args = [arg.substitute(subs) for arg in self.args]
        return Function(self.name, substituted_args)

    def occurs(self, var: 'Variable') -> bool:
        return any(arg.occurs(var) for arg in self.args)

    def __eq__(self, other):
        return (
            isinstance(other, Function) and
            self.name == other.name and
            len(self.args) == len(other.args) and
            all(a == b for a, b in zip(self.args, other.args))
```

```
    )

    def __str__(self):
        return f"{self.name}({', '.join(str(arg) for arg in self.args)})"

def parse_expression(expr: List) -> Term:
    if not isinstance(expr, list) or not expr:
        raise ValueError("Expression must be a non-empty list")

    func_name = expr[0]
    args = expr[1:]

    parsed_args = []
    for arg in args:
        if isinstance(arg, list):
            parsed_args.append(parse_expression(arg))
        elif isinstance(arg, str):
            if arg[0].islower():
                parsed_args.append(Variable(arg))
            elif arg[0].isupper():
                parsed_args.append(Constant(arg))
            else:
                raise ValueError(f"Invalid argument format: {arg}")
        else:
            raise ValueError(f"Unsupported argument type: {arg}")

    return Function(func_name, parsed_args)

def unify_terms(term1: Term, term2: Term) -> Union[Dict[str, Term], str]:
    # Initialize substitution set S
    S: Dict[str, Term] = {}

    # Initialize the equation list
    equations: deque[Tuple[Term, Term]] = deque()
    equations.append((term1, term2))
```

```
    while equations:
        s, t = equations.popleft()
        s = s.substitute(S)
        t = t.substitute(S)

        if s == t:
            continue
        elif isinstance(s, Variable):
            if t.occurs(s):
                return "FAILURE"
            S[s.name] = t
            # Apply the substitution to existing substitutions
            for var in S:
                S[var] = S[var].substitute({s.name: t})
        elif isinstance(t, Variable):
            if s.occurs(t):
                return "FAILURE"
            S[t.name] = s
            for var in S:
                S[var] = S[var].substitute({t.name: s})
        elif isinstance(s, Function) and isinstance(t, Function):
            if s.name != t.name or len(s.args) != len(t.args):
                return "FAILURE"
            for s_arg, t_arg in zip(s.args, t.args):
                equations.append((s_arg, t_arg))
        elif isinstance(s, Constant) and isinstance(t, Constant):
            if s.name != t.name:
                return "FAILURE"
            # else, they are equal; continue
        else:
            return "FAILURE"

    return S

def format_substitution(S: Dict[str, Term]) -> str:
    if not S:
```

```
        return "{}"
    return "{ " + ", ".join(f"{var} = {term}" for var, term in S.items()) + " }"

def unify(expression1: List, expression2: List) -> Union[Dict[str, Term], str]:
    try:
        term1 = parse_expression(expression1)
        term2 = parse_expression(expression2)
    except ValueError as e:
        return f"FAILURE: {e}"

    result = unify_terms(term1, term2)

    return result

def main():
    print("=== Unification Algorithm ===\n")
    print("Please enter the expressions in list format.")
    print("Example: [\"Eats\", \"x\", \"Apple\"]\n")

    try:
        expr1_input = input("Enter Expression 1: ")
        expression1 = ast.literal_eval(expr1_input)
        if not isinstance(expression1, list):
            raise ValueError("Expression must be a list.")

        expr2_input = input("Enter Expression 2: ")
        expression2 = ast.literal_eval(expr2_input)
        if not isinstance(expression2, list):
            raise ValueError("Expression must be a list.")

    except (SyntaxError, ValueError) as e:
        print(f"Invalid input format: {e}")
        return

    result = unify(expression1, expression2)
```

```
    if isinstance(result, str):
        print("\nUnification Result:")
        print(result)
    else:
        print("\nUnification Successful:")
        print(format_substitution(result))

if __name__ == "__main__":
    main()
print("VAIBHAV URS A N")
print("1BM22CS315 \n")
```

Output Snapshot

```
=== Unification Algorithm ===

Please enter the expressions in list format.
Example: ["Eats", "x", "Apple"]

Enter Expression 1: ["Eats", "x", "Apple"]
Enter Expression 2: ["Eats", "Banana", "y"]

Unification Successful:
{ x = Banana, y = Apple }
Vaibhav Urs A N
1BM22CS315
```

State Space Tree

22/4/2024

Output

please enter the expressions in list Format
Example: ["Eats", "x", "Apple"]

Enter Expoession 1: ["Eats", "x", "Apple"]
Enter Expression 2: ["Eats", "bananna", "Y"]

unification successful
{x = banbonna Y = Apple}.

22/4/24

Program-8 Forward Reasoning

Algorithm

16

29/11/24

Forward Reasoning Algorithm

Algorithm:

function FOL-FC-ASK (KB, α) returns substitution or false
inputs: KB, the Knowledge base, a set of first order definite clauses; α, the query, an atomic sentence
local variables: new, the new sentences inferred on each iteration, repeat until new is empty.

new ← {}
for each rule in KB do
$(P_1 \wedge \ldots \wedge P_n) \Rightarrow q_i)$ ← STANALONE - VARIABLE (rule)
for each θ such that SUBST $(\theta, P_1 \wedge \ldots \wedge P_n)$
= SUBST $(\theta, P_1' \wedge \ldots \wedge P'_n)$ for some $P_1', \ldots, P'_n$ in KB
If q' does not unify with some sentence already in KB or new then add q' to new
ϕ ← UNIFY (q_i', α)
if ϕ is not fail then return ϕ
add new to KB
return false

Code

```
def fol_fc_ask(KB, query):
    """
    Implements the Forward Chaining algorithm.
    :param KB: The knowledge base, a list of first-order definite clauses.
    :param query: The query, an atomic sentence.
    :return: True if the query can be proven, otherwise False.
    """
    inferred = set()  # Keep track of inferred facts
    agenda = [fact for fact in KB if not fact.get('premises')]  # Initial facts
    rules = [rule for rule in KB if rule.get('premises')]  # Rules with premises


    # Debugging output: Initial agenda and inferred facts
    print(f"Initial agenda: {[fact['conclusion'] for fact in agenda]}")
    print(f"Initial inferred: {inferred}")


    while agenda:
        fact = agenda.pop(0)
        print(f"\nProcessing fact: {fact['conclusion']}")
```

```
        # Check if this fact matches the query
        if fact['conclusion'] == query:
            print(f"Found query match: {fact['conclusion']}")
            return True

        # Infer new facts if this fact hasn't been inferred before
        if fact['conclusion'] not in inferred:
            inferred.add(fact['conclusion'])
            print(f"Inferred facts: {inferred}")

            # Process rules that match this fact as a premise
            for rule in rules:
                if fact['conclusion'] in rule['premises']:
                    print(f"Rule premise satisfied: {rule['premises']} -> {rule['conclusion']}")
                    rule['premises'].remove(fact['conclusion'])  # Remove satisfied premise
                    if not rule['premises']:  # All premises satisfied
                        new_fact = {'conclusion': rule['conclusion']}
                        agenda.append(new_fact)  # Add new fact to agenda
                        print(f"New fact inferred: {new_fact['conclusion']}")
```

```
        # Debugging output after each iteration
        print(f"Current agenda: {[fact['conclusion'] for fact in agenda]}")
        print(f"Current inferred: {inferred}")

    # If the loop finishes without finding the query
    print(f"Query {query} not found.")
    return False


# Example Knowledge Base
KB = [
    {'premises': [], 'conclusion': 'American(Robert)'},
    {'premises': [], 'conclusion': 'Missile(T1)'},
    {'premises': [], 'conclusion': 'Owns(A, T1)'},
    {'premises': [], 'conclusion': 'Enemy(A, America)'},
    {'premises': ['Missile(T1)'], 'conclusion': 'Weapon(T1)'},
    {'premises': ['American(Robert)', 'Weapon(T1)', 'Sells(Robert, T1, A)', 'Hostile(A)'], 'conclusion':
'Criminal(Robert)'},
    {'premises': ['Owns(A, T1)', 'Enemy(A, America)'], 'conclusion': 'Hostile(A)'},
    {'premises': [], 'conclusion': 'Sells(Robert, T1, A)'}
```

```
]



# Query

query = 'Criminal(Robert)'



# Run the algorithm

result = fol_fc_ask(KB, query)

print("Final Result:", result)

print("VAIBHAV URS A N")

print("1BM22CS315")
```

OutputSnapshot

```
Processing fact: Enemy(A, America)
Inferred facts: {'Missile(T1)', 'Enemy(A, America)', 'Owns(A, T1)', 'American(Robert)'}
Rule premise satisfied: ['Enemy(A, America)'] -> Hostile(A)
New fact inferred: Hostile(A)
Current agenda: ['Sells(Robert, T1, A)', 'Weapon(T1)', 'Hostile(A)']
Current inferred: {'Missile(T1)', 'Enemy(A, America)', 'Owns(A, T1)', 'American(Robert)'}

Processing fact: Sells(Robert, T1, A)
Inferred facts: {'Enemy(A, America)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'American(Robert)'}
Rule premise satisfied: ['Weapon(T1)', 'Sells(Robert, T1, A)', 'Hostile(A)'] -> Criminal(Robert)
Current agenda: ['Weapon(T1)', 'Hostile(A)']
Current inferred: {'Enemy(A, America)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'American(Robert)'}

Processing fact: Weapon(T1)
Inferred facts: {'Enemy(A, America)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'American(Robert)'}
Rule premise satisfied: ['Weapon(T1)', 'Hostile(A)'] -> Criminal(Robert)
Current agenda: ['Hostile(A)']
Current inferred: {'Enemy(A, America)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'American(Robert)'}

Processing fact: Hostile(A)
Inferred facts: {'Enemy(A, America)', 'Hostile(A)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'American(Robert)'}
Rule premise satisfied: ['Hostile(A)'] -> Criminal(Robert)
New fact inferred: Criminal(Robert)
Current agenda: ['Criminal(Robert)']
Current inferred: {'Enemy(A, America)', 'Hostile(A)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'American(Robert)'}

Processing fact: Criminal(Robert)
Found query match: Criminal(Robert)
Final Result: True
```

```
Processing fact: Hostile(A)
Inferred facts: {'Hostile(A)', 'Owns(A, T1)', 'American(Robert)', 'Weapon(T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'Enemy(A, America)'}
Rule premise satisfied: ['Hostile(A)'] -> Criminal(Robert)
New fact inferred: Criminal(Robert)
Current agenda: ['Criminal(Robert)']
Current inferred: {'Hostile(A)', 'Owns(A, T1)', 'American(Robert)', 'Weapon(T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'Enemy(A, America)'}

Processing fact: Criminal(Robert)
Found query match: Criminal(Robert)

Final Result: True
Vaibhav Urs A N
1BM22CS315
```

State Space Tree

ut processing fact: Criminal (Robert)
Found Query match : Criminal (Robert)
Final Result : True.

20/11/24.

Program - 9 Create a knowledge base using propositional logic and show that the given query entails the knowledge base or not.

Algorithm

20/12/24 20

Initialize knowledge base with propositional logic statements.

Algorithm:

```
if forward_chaining (knowledge_base, query):
    print("Query is entailed by the knowledge base")
else:
    print("Query is not entailed by the knowledge base")
function forward chaining (knowledge_base, query):
  initialize agenda with known facts from knowledge base
  while agenda is not empty:
    pop a fact from agenda
    if fact matches query:
      return True
    for each rule in knowledge base:
      if fact satisfies a rule's premis:
        add the rule's conclusion to agenda
  return False
```

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: ")  # Knowledge Base (KB)
  q = input("Enter the Query: ")  # 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)  # Evaluate KB
    f = evaluatePostfix(toPostfix(q), comb)  # Evaluate Query
    print(s, f)
    print('-' * 10)

    if s and not f:  # If KB is True and query is False, KB does not entail query
      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]])  # Push the truth value from the combination
      elif i == '~':
          val1 = stack.pop()
          stack.append(not val1)  # Negation
      else:
          val1 = stack.pop()
          val2 = stack.pop()
          stack.append(_eval(i, val2, val1))  # Evaluate AND or OR
  return stack.pop()

def _eval(i, val1, val2):
  if i == '^':
      return val2 and val1  # AND
  return val2 or val1  # OR

# Main Program
input_rules()
ans = entailment()

print("VAIBHAV URS A N")
print("1BM22CS315")

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

OutputSnapshot

```
Enter rule: (p^q)vr
Enter the Query: p
**********Truth Table Reference**********
kb alpha
**********
True True
----------
True True
----------
True True
----------
False True
----------
True False
----------
VAIBHAV URS A N
1BM22CS315
The Knowledge Base does not entail the query
```

Program - 10 Write a proof tree generated using Resolution

Algorithm

20/12/24

18

Convert a given first order logic statement resolution.

Algorithm:

→ Convert all sentences to CNF

→ Negate conclusion S and convert result to CNF.

→ Add negated conclusion S to the premise clauses.

→ Repeat until contradiction or no progress is made:

a. Select 2 clauses (all of them parent clauses)

b. Resolve them together, performing all required unifications.

c. If resolvent is the empty clause, a contradiction has been found (i.e. S follows from the previous)

d. If not, add resolvent to the premises.

If we suceed in step 4, we have proved the conclusion

Code

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

# Function to resolve two clauses
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

# Function to perform resolution on the KB and query with detailed output
def resolution_algorithm(KB, query):
  """Perform the resolution algorithm to check if the query can be proven."""
  print("\n--- Step-by-Step Resolution Process ---")
  # Add the negation of the query to the knowledge base
  negated_query = negate(query)
  KB.append(frozenset([negated_query]))
  print(f"Negated Query Added to KB: {negated_query}")

  # Initialize the set of clauses to process
  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  # Empty clause found, contradiction, query is provable
                        new_clauses.add(res)

        if new_clauses.issubset(clauses):
            print("\nNo new clauses can be derived. The query is not provable.")
            return False  # No new clauses, query is not provable

        clauses.update(new_clauses)
        step += 1

# Knowledge Base (KB) from the image facts
KB = [
    frozenset([("not", "food(x)"), ("likes", "John", "x")]),  # 1
    frozenset([("food", "Apple")]),  # 2
    frozenset([("food", "vegetables")]),  # 3
    frozenset([("not", "eats(y, z)"), ("killed", "y"), ("food", "z")]),  # 4
    frozenset([("eats", "Anil", "Peanuts")]),  # 5
    frozenset([("alive", "Anil")]),  # 6
    frozenset([("not", "eats(Anil, w)"), ("eats", "Harry", "w")]),  # 7
    frozenset([("killed", "g"), ("alive", "g")]),  # 8
    frozenset([("not", "alive(k)"), ("not", "killed(k)")]),  # 9
    frozenset([("likes", "John", "Peanuts")])  # 10
]

# Query to prove
query = ("likes", "John", "Peanuts")

# Perform resolution to check if the query is provable
```

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

print("\nVAIBHAV URS A N”)
print("1BM22CS315")
```

Output Snapshot

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

Step 1: Resolving Clauses
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', 'alive(k)'), ('not', 'killed(k)')})
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('food', 'z'), ('killed', 'y'), ('not', 'eats(y, z)')})
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', 'eats(Anil, w)'), ('eats', 'Harry', 'w')})
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', 'food(x)'), ('likes', 'John', 'x')})
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('alive', 'Anil')})
    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.
  VAIBHAV URS A N
  1BM22CS315
```

Program - 11 Alpha-Beta values generated to identify the final value of MAX node and subtrees pruned for a given Game tree using the Alpha-Beta pruning algorithm

Algorithm

20/12/24

Implement Alpha - Beta Pruning

Algorithm:

→ Alpha (α) - Beta (β) proposes to compute and find the optimal path without looking at every node in the game tree.

→ Max contains alpha (α) and min contains Beta (β) bound during the calculation

→ In both min and max node we have return when $\alpha \geq \beta$ which compares with its parent node only.

→ Both minmax and alpha (α) - Beta (β) cut-off give same path.

→ Alpha (α) - Beta (β) gives optimal solution as it takes less time to get the value for the root node.

Code

```
import math

# Alpha-Beta Pruning Algorithm
def alpha_beta_search(depth, index, is_max, values, alpha, beta, target_depth):
  """Recursive function for Alpha-Beta Pruning."""
  # Base case: If the target depth is reached, return the leaf node value
  if depth == target_depth:
      return values[index]

  if is_max:
      # Maximizer's turn
      best = -math.inf
      for i in range(2):
          val = alpha_beta_search(depth + 1, index * 2 + i, False, values, alpha, beta, target_depth)
          best = max(best, val)
          alpha = max(alpha, best)
          if beta <= alpha:
              break  # Prune remaining branches
      return best
  else:
      # Minimizer's turn
      best = math.inf
      for i in range(2):
          val = alpha_beta_search(depth + 1, index * 2 + i, True, values, alpha, beta, target_depth)
          best = min(best, val)
          beta = min(beta, best)
          if beta <= alpha:
              break  # Prune remaining branches
      return best

def main():
  # User Input: Values of leaf nodes
  print("Enter the values of leaf nodes separated by spaces:")
  values = list(map(int, input().split()))

  # Calculate depth of the game tree
```

```
    target_depth = math.log2(len(values))
    if target_depth != int(target_depth):
        print("Error: The number of leaf nodes must be a power of 2.")
        return
    target_depth = int(target_depth)

    # Run Alpha-Beta Pruning
    result = alpha_beta_search(0, 0, True, values, -math.inf, math.inf, target_depth)

    # Display the result
    print(f"The optimal value determined by Alpha-Beta Pruning is: {result}")

print("VAIBHAV URS A N")
print("1BM22CS315\n")

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

Output Snapshot

```
VAIBHAV URS A N
1BM22CS315

Enter the values of leaf nodes separated by spaces:
10 9 14 18 5 4 50 3
The optimal value determined by Alpha-Beta Pruning is: 10
```