

VISVESVARAYA TECHNOLOGICAL UNIVERSITY

“JnanaSangama”, Belgaum -590014, Karnataka.



LAB REPORT on

Artificial Intelligence

Submitted by

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



B.M.S. COLLEGE OF ENGINEERING

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CERTIFICATE

This is to certify that the Lab work entitled "**Artificial Intelligence**" carried out by **Nithin K Patil (1BM22CS184)**, who is bonafide student of **B.M.S. College of Engineering**. It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the academic semester September-2024 to February-2024. 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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Index

Sl. No.	Date	Experiment Title	Page No.
1	24-9-2024	Implement Tic –Tac –Toe Game Implement vacuum cleaner agent	3-10
2	1-10-2024	Implement 8 puzzle problems using Depth First Search (DFS) Implement Iterative deepening search algorithm	11-15
3	8-10-2024	Implement A* search algorithm	16-19
4	15-10-2024	Implement Hill Climbing search algorithm to solve N-Queens problem	20-23
5	22-10-2024	Simulated Annealing to Solve 8-Queens problem	24-26
6	29-10-2024	Create a knowledge base using propositional logic and show that the given query entails the knowledge base or not.	27-30
7	12-11-2024	Implement unification in first order logic	31-35
8	19-11-2024	Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning.	35-38
9	3-12-2024	Create a knowledge base consisting of first order logic statements and prove the given query using Resolution	39-42
10	3-12-2024	Implement Alpha-Beta Pruning.	43-46

Github Link:

https://github.com/Nithinkp20/AI_5D

1. Implement TIC-TAC-TOE

Algorithm:

CLASSEmate
Date _____
Page _____

Tic Tac Toe

Algo

Step 1: Make 3×3 matrix (Global declaration) and all values of matrix as -1.

Step 2: entering input as (row and column and replace with Step 3: run the check condition or check function (after every input run the check condition.)

Step 4: After user input, using random function to generate numbers from 0 to 2 for row and 0 to 2 for column and if the matrix $[x][y] == -1$ then replace -1 with 1 else generate again and check function for winner

Step 5: check function()

(check) function does it

if all any of the rows has all 0 or 1 then return true

~~else if all any of the columns has all 0 or 1 then return true~~

else if any of the columns has all 0 or 1 then return false

else if the diagonals of each matrix are all 1 or 0 then return true

else return false

Step 6: After every input run as function fill() to check if all the values on board.

iterate through the matrix if any value is not 1 then return false else return true.

Refer Algorithm

start number

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

```

```

        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
```

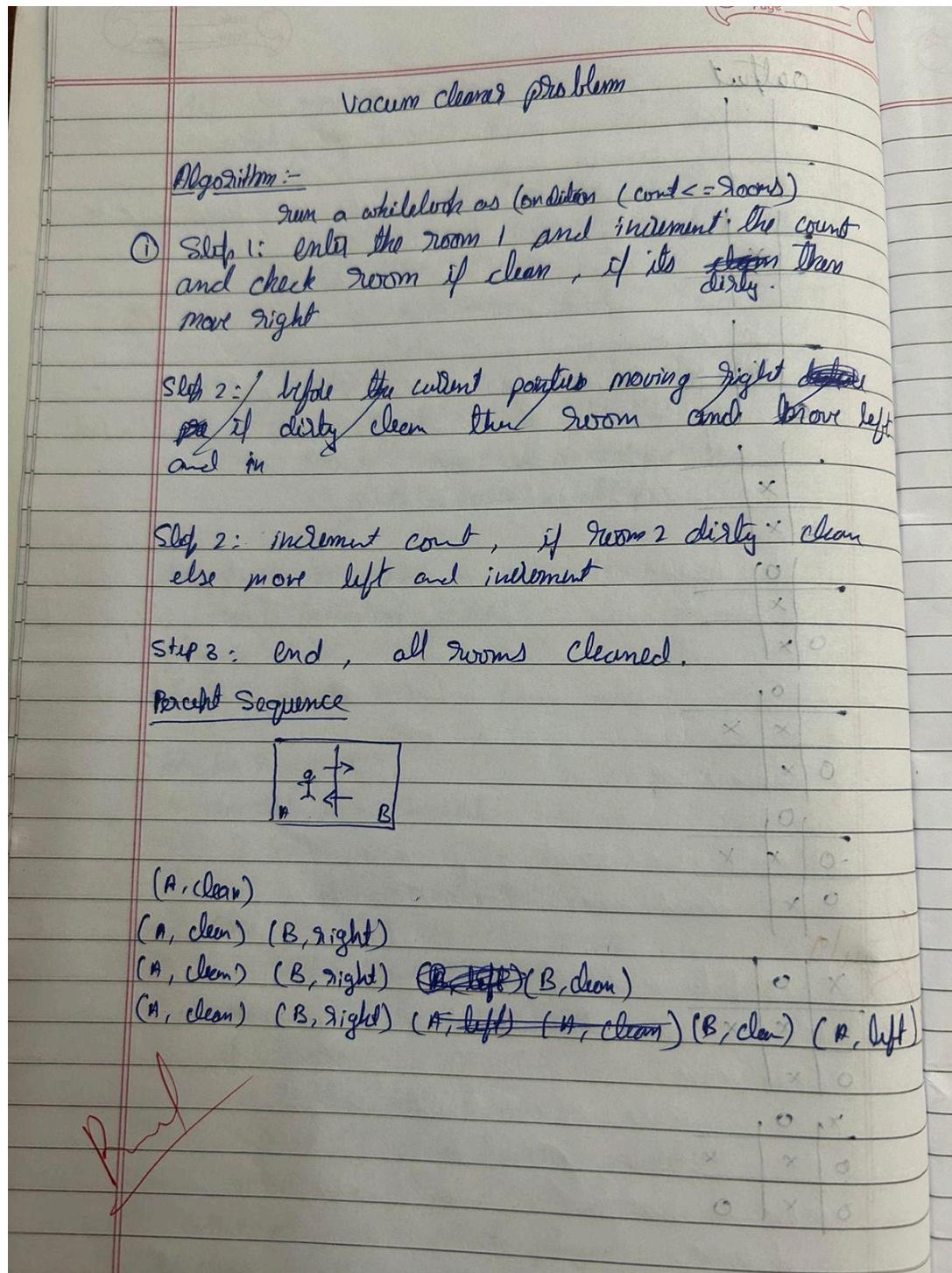
```
while not checkWin():  
    compMove()  
    playerMove()
```

```
X| |  
-+--  
| |  
-+--  
| |  
  
Enter position for 0:2  
X|0|  
-+--  
| |  
-+--  
| |  
  
X|0|  
-+--  
X| |  
-+--  
| |  
  
Enter position for 0:7  
X|0|  
-+--  
X| |  
-+--  
0| |
```

```
X|0|  
-+--  
X|X|  
-+--  
0| |  
  
Enter position for 0:6  
X|0|  
-+--  
X|X|0  
-+--  
0| |  
  
X|0|  
-+--  
X|X|0  
-+--  
0| |X  
  
Bot wins!  
Enter position for 0:$
```


2. Implement a vacuum cleaner agent.

Algorithm:



Code:

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

```

cost = 0

location_input = input("Enter Location of Vacuum (A or B): ").strip().upper()
status_input = input(f"Enter status of {location_input} (0 for Clean, 1 for Dirty): "
").strip()

other_location = 'B' if location_input == 'A' else 'A'
status_input_complement = input(f"Enter status of {other_location} (0 for Clean, 1 for Dirty): "
").strip()

print("Initial Location Condition:", 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 += 2
        print("Cost for CLEANING A:", 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:", cost)
        goal_state['B'] = '0'
        cost += 2
        print("COST for SUCK:", cost)
        print("Location B has been Cleaned.")

    else:
        print("Location B is already clean.")

elif location_input == 'B':

    print("Vacuum is placed in Location B")
    if status_input == '1':
        print("Location B is Dirty.")
        goal_state['B'] = '0'
        cost += 2
        print("COST for CLEANING B:",
        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:", cost)
    goal_state['A'] = '0'
    cost += 2
    print("COST for SUCK:", cost)
    print("Location A has been Cleaned.")
else:
    print("Location A is already clean.")

print("GOAL STATE:", goal_state)
print("Performance Measurement (Total Cost):", cost)
vacuum_world()

```

Output:

```

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

```

WEEK 2

1-10-2024

1. Solve 8-puzzle problem using DFS

Algorithm:

Lab - 3

Mahananday

- ① solve 8-puzzle sum using DFS and Manhattan distance.
- ② take input as 2D array and one spot as 0 (represents blank box).
- ③ for each possible move (right, left, top, down)
 - if state is already visited make another move
 - else make a move (right or left or up or down) calculate manhattan distance using the formula: $\text{sum} = \text{position(goal)} - \text{current position}$
- ④ check minimum sum and choose that particular move.
- ⑤ repeat the process until the goal is achieved.

DFS algo.

- ① make a node state represents the current state
- ② mark visited to the visited state
- ③ push the node into the stack
- ④ for each move check for visited
 - if visited
 - pop from stack and go to current state
 - make different move
 - else push the state in stack
- ⑤ break if the current state is the final state

DFS C program

Mahananday

WPS Office

Date _____

Page _____

DFS Algo:

1. create stack add starting state
2. create a visited array initialized empty
3. while stack is not empty;
 - current = pop top element of stack
 - if current == goal:
 - return solution
 - if current not in visited:
 - add current to visited
 - get all possible moves from current
 - move up down left right if possible
 - for each valid move make a state
 - add each new state to the stack if it is not in visited
- ④ if stack empty & no solution found return "no solution"

Code:

```
from collections import deque
def is_goal(state, goal_state):
    return state == goal_state
def get_neighbors(state):
    neighbors = []
```

```

index = state.index(0)
row, col = divmod(index, 3)
moves = [(-1, 0), (1, 0), (0, -1), (0, 1)]
for move in moves:
    new_row, new_col = row + move[0], col + move[1]
    if 0 <= new_row < 3 and 0 <= new_col < 3:
        new_index = new_row * 3 + new_col
        new_state = list(state)
        new_state[index], new_state[new_index] = new_state[new_index], new_state[index]
        neighbors.append(tuple(new_state))
return neighbors

def print_state(state):
    for i in range(0, 9,
3):
        print(state[i:i+3])
    print()

def dfs(start, goal):
    visited = set()
    stack = [(start, [])]
    while stack:
        current_state, path = stack.pop()
        if current_state in visited:
            continue
        visited.add(current_state)
        if is_goal(current_state, goal):
            return path + [current_state]
        for neighbor in get_neighbors(current_state):
            if neighbor not in visited:
                stack.append((neighbor, path + [current_state]))
    return None

def input_puzzle(prompt):
    print(prompt)
    puzzle = []
    for i in range(3):
        row = input(f"Enter row {i + 1} (3 numbers separated by spaces): ").split()
        puzzle.extend([int(x) for x in row])
    return tuple(puzzle)

```

```

def select_goal_state():
    print("Select a goal state:")
    print("1. Goal State:")
    print(" 0 1 2")
    print(" 3 4 5")
    print(" 6 7 8")
    print("2. Goal State:")
    print(" 1 2 3")
    print(" 4 5 6")
    print(" 7 8 0")
    choice = input("Enter 1 or 2: ")
    if choice == '1':
        return (0, 1, 2, 3, 4, 5, 6, 7, 8)
    else:
        return (1, 2, 3, 4, 5, 6, 7, 8, 0)

start_state = input_puzzle("Enter the start state (use 0 for the blank
space):") goal_state = select_goal_state()
print("\nSolving using DFS...")
dfs_solution = dfs(start_state,
goal_state) if dfs_solution:
    print("DFS Solution found! Steps:")
    for i, step in enumerate(dfs_solution):
        print(f"Step {i + 1}:")
        print_state(step)
else:
    print("No solution found using DFS.")

```

Output:

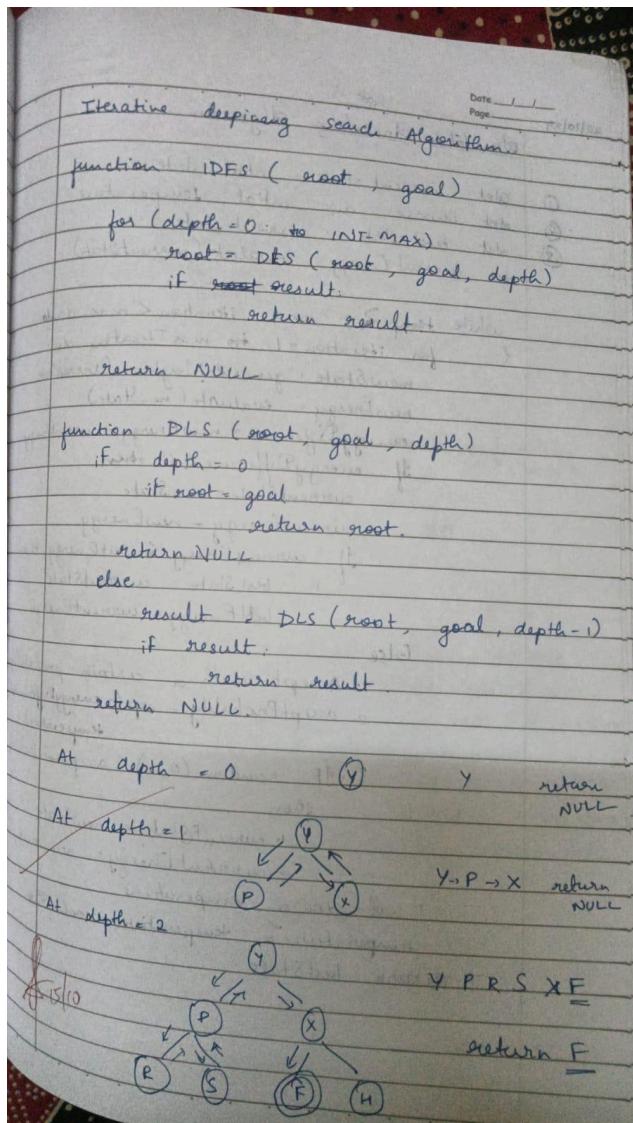
```

Enter the start state (use 0 for the blank space):
Enter row 1 (3 numbers separated by spaces): 1 2 3
Enter row 2 (3 numbers separated by spaces): 4 5 6
Enter row 3 (3 numbers separated by spaces): 0 7 8
Select a goal state:
1. Goal State:
 0 1 2
 3 4 5
 6 7 8
2. Goal State:
 1 2 3
 4 5 6
 7 8 0
Enter 1 or 2: 2
Solving using DFS...
DFS Solution found! Steps:
Step 1:
(1, 2, 3)
(4, 5, 6)
(0, 7, 8)
Step 2:
(1, 2, 3)
(4, 5, 6)
(7, 0, 8)
Step 3:
(1, 2, 3)
(4, 5, 6)
(7, 8, 0)

```

Implement iddfs:

Algorithm:



CODE:

```
def depth_limited_search(node, goal, depth, graph):
    """
    Perform Depth Limited Search to find the goal node.
    """
    if node == goal:
        return True
    if depth <= 0:
        return False
    for child in graph.get(node, []):
        if depth_limited_search(child, goal, depth - 1, graph):
```

```

        return True
    return False

def iterative_deepening_dfs(start, goal, max_depth, graph):
    """
    Perform Iterative Deepening Depth-First Search (IDDFS).
    """

    for depth in range(max_depth + 1):
        print(f'Depth: {depth}')
        if depth_limited_search(start, goal, depth, graph):
            return True
    return False

# Input graph from the user
graph = {}
num_edges = int(input("Enter the number of edges in the graph: "))
print("Enter the edges in the format 'node1 node2':")
for _ in range(num_edges):
    node1, node2 = input().split()
    if node1 not in graph:
        graph[node1] = []
    graph[node1].append(node2)

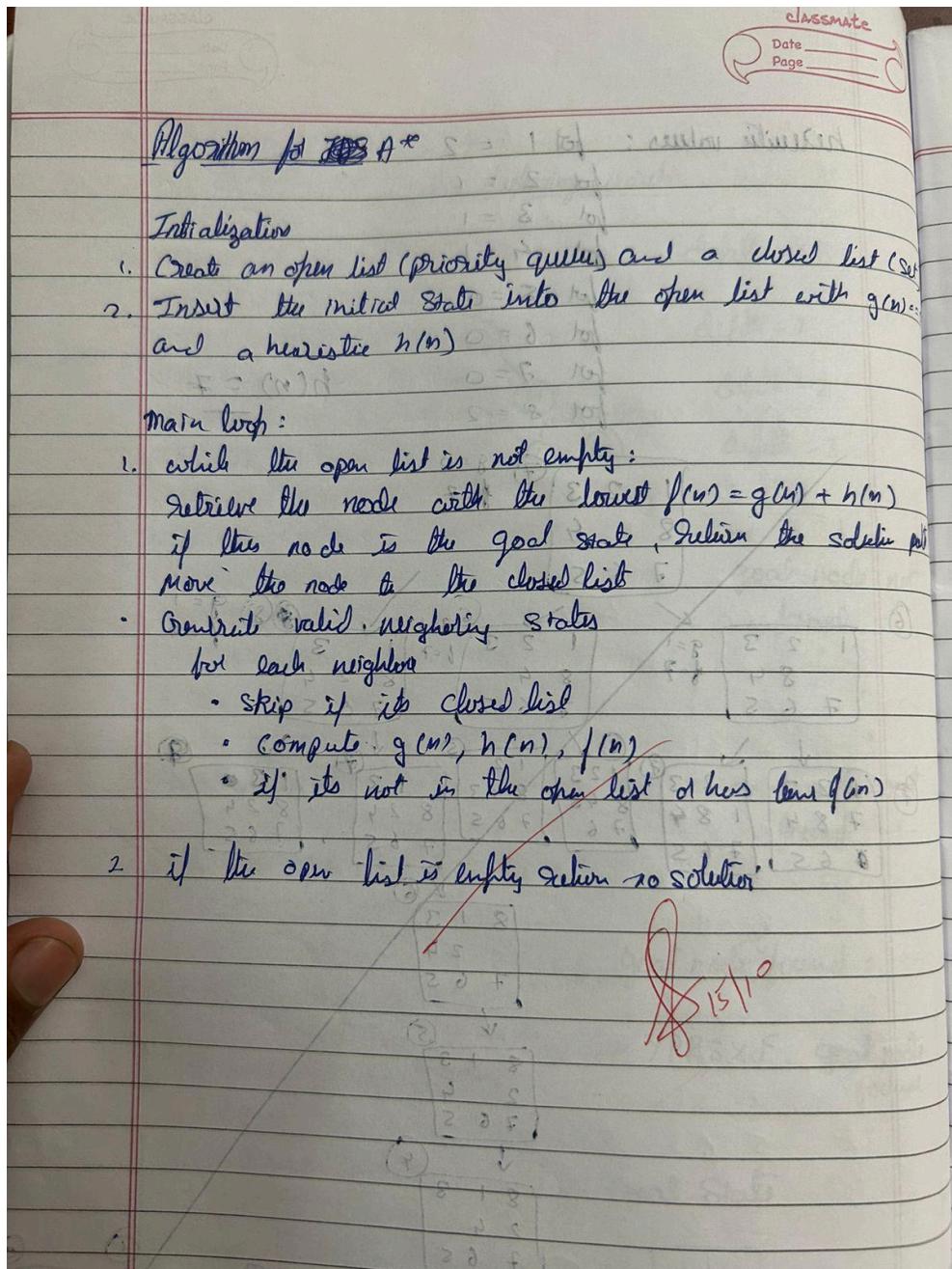
# Input start node, goal node, and maximum depth
start_node = input("Enter the start node: ")
goal_node = input("Enter the goal node: ")
max_depth = int(input("Enter the maximum depth: "))

# Perform IDDFS
found = iterative_deepening_dfs(start_node, goal_node, max_depth, graph)
if found:
    print(f'Goal node '{goal_node}' found!')
else:
    print(f'Goal node '{goal_node}' not found within depth {max_depth}.')

```

For 8-puzzle A* implementation, to calculate, $f(n)$:

1. Algorithm:



Code:

```
import heapq
def is_goal(state, goal_state):
    return state == goal_state
def get_neighbors(state):
```

```

neighbors = []
index = state.index(0)
row, col = divmod(index, 3)
moves = [(-1, 0), (1, 0), (0, -1), (0, 1)]
for move in moves:
    new_row, new_col = row + move[0], col + move[1]
    if 0 <= new_row < 3 and 0 <= new_col < 3:
        new_index = new_row * 3 + new_col
        new_state = list(state)
        new_state[index], new_state[new_index] = new_state[new_index], new_state[index]
        neighbors.append(tuple(new_state))
return neighbors

def misplaced_tiles(state, goal):
    return sum(1 for i in range(9) if state[i] != 0 and state[i] != goal[i])

def print_state(state):
    for i in range(0, 9,
3):
        print(state[i:i+3])
    print()

def a_star_level_wise(start, goal, heuristic):
    priority_queue = []
    heapq.heappush(priority_queue, (0, 0, start, []))
    visited = set()
    print("Level-wise output:")

    while priority_queue:
        f_n, g_n, current_state, path = heapq.heappop(priority_queue)
        if current_state in visited:
            continue
        visited.add(current_state)
        print(f"\nLevel {g_n} (g(n) = {g_n}):")
        print(f"f(n) = {f_n}, h(n) = {heuristic(current_state, goal)}")
        print_state(current_state)
        if is_goal(current_state, goal):
            return path + [current_state]
        neighbors = get_neighbors(current_state)
        for neighbor in neighbors:
            if neighbor not in visited:

```

```

g_new = g_n + 1
h_new = heuristic(neighbor, goal)
f_new = g_new + h_new
print(f" Adjacent Node (g(n) = {g_new}, h(n) = {h_new}, f(n) = {f_new}):")
print_state(neighbor)
heapq.heappush(priority_queue, (f_new, g_new, neighbor, path + [current_state]))
return None

def input_puzzle(prompt):
    print(prompt)
    puzzle = []
    for i in range(3):
        row = input(f"Enter row {i + 1} (3 numbers separated by spaces): ").split()
        puzzle.extend([int(x) for x in row])
    return tuple(puzzle)

start_state = input_puzzle("Enter the start state (use 0 for the blank space):")
goal_state = input_puzzle("Enter the goal state (use 0 for the blank space):")
heuristic = misplaced_tiles
print("\nSolving using A* Search with level-wise output...")
a_star_solution = a_star_level_wise(start_state, goal_state, heuristic)
if a_star_solution:
    print("A* Solution found! Steps:")
    for i, step in enumerate(a_star_solution):
        print(f"Step {i + 1}:")
        print_state(step)
else:
    print("No solution found using A*.")

```

Output:

```

Enter the start state (use 0 for the blank space):
Enter row 1 (3 numbers separated by spaces): 2 8 3
Enter row 2 (3 numbers separated by spaces): 1 6 4
Enter row 3 (3 numbers separated by spaces): 7 0 5
Enter the goal state (use 0 for the blank space):
Enter row 1 (3 numbers separated by spaces): 1 2 3
Enter row 2 (3 numbers separated by spaces): 8 0 4
Enter row 3 (3 numbers separated by spaces): 7 6 5

Solving using A* Search with level-wise output...
Level-wise output:

Level 0 (g(n) = 0):
f(n) = 0, h(n) = 4
(2, 8, 3)
(1, 6, 4)
(7, 0, 5)

Adjacent Node (g(n) = 1, h(n) = 3, f(n) = 4):
(2, 8, 3)
(1, 0, 4)
(7, 6, 5)

Adjacent Node (g(n) = 1, h(n) = 5, f(n) = 6):
(2, 8, 3)
(1, 6, 4)
(0, 7, 5)

```

```
Level 3 (g(n) = 3):
f(n) = 5, h(n) = 2
(0, 2, 3)
(1, 8, 4)
(7, 6, 5)

    Adjacent Node (g(n) = 4, h(n) = 1, f(n) = 5):
(1, 2, 3)
(0, 8, 4)
(7, 6, 5)

Level 4 (g(n) = 4):
f(n) = 5, h(n) = 1
(1, 2, 3)
(0, 8, 4)
(7, 6, 5)

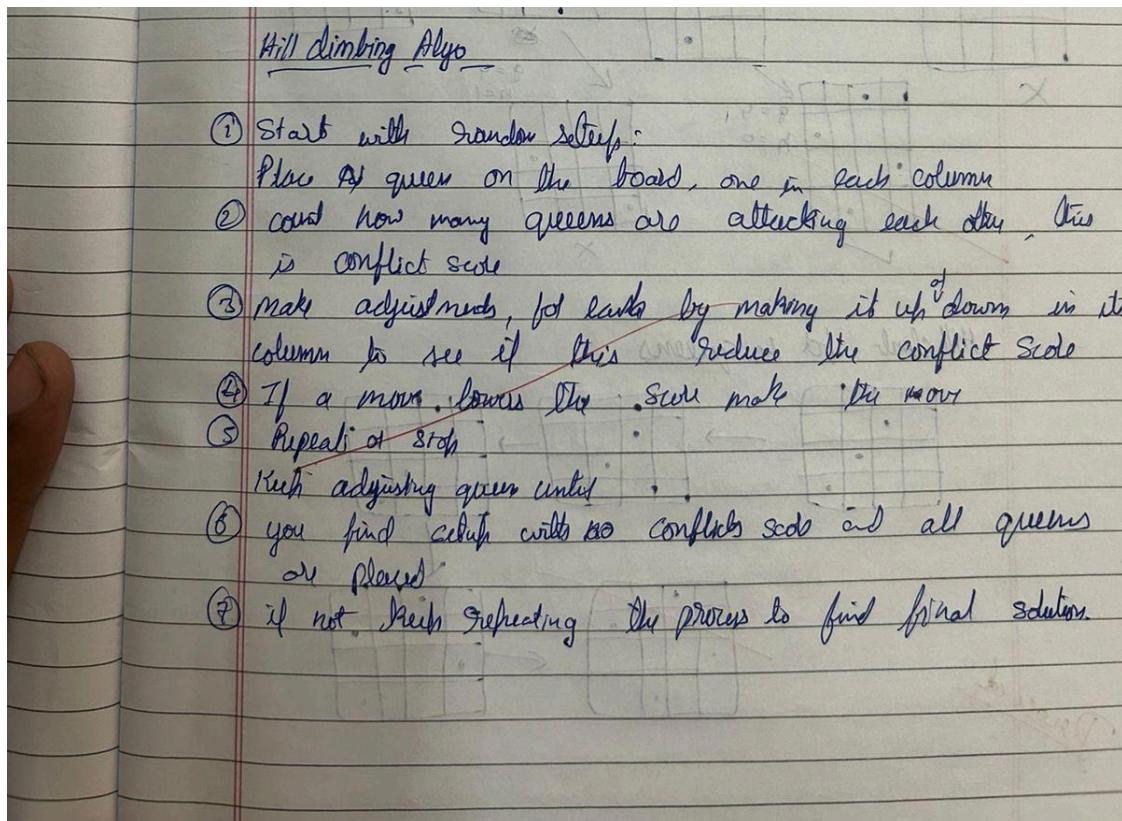
    Adjacent Node (g(n) = 5, h(n) = 2, f(n) = 7):
(1, 2, 3)
(7, 8, 4)
(0, 6, 5)

    Adjacent Node (g(n) = 5, h(n) = 0, f(n) = 5):
(1, 2, 3)
(8, 0, 4)
(7, 6, 5)

Level 5 (g(n) = 5):
f(n) = 5, h(n) = 0
(1, 2, 3)
(8, 0, 4)
(7, 6, 5)
```

Implement Hill Climbing search algorithm to solve N-Queens problem.

Algorithm:



Code:

```
def print_board(state):
    n = len(state)
    board = [['_' for _ in range(n)] for _ in
             range(n)] for col, row in enumerate(state):
        board[row][col] = 'Q'
    for row in board:
        print(
            ''.join(row)) print()
def calculate_cost(state):
    cost = 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):
                cost += 1
    return cost

def generate_neighbors(state):
    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] # Swap row positions of two
queens
                neighbors.append(new_state)
    return neighbors

def hill_climbing_4_queens(initial_state):
    n = 4

    current_state = initial_state
    current_cost = calculate_cost(current_state)

    print(f"Initial state: {current_state}, Cost: {current_cost}")
    print_board(current_state)

    steps = 0
    while current_cost != 0:
        steps += 1
```

```

neighbors = generate_neighbors(current_state)
neighbor_costs = [calculate_cost(neighbor) for neighbor in neighbors]

min_cost = min(neighbor_costs)
best_neighbor = neighbors[neighbor_costs.index(min_cost)]

print(f"Step {steps}: Best neighbor: {best_neighbor}, Cost: {min_cost}")
print_board(best_neighbor)

if min_cost < current_cost:
    current_state = best_neighbor
    current_cost = min_cost
else:
    print("Stuck at local maximum.")
    break

if current_cost == 0:
    print("Solution found:")
    print_board(current_state)
else:
    print("No solution found. Stuck at a local maximum.")

def get_user_input():
    print("Enter the initial positions of the queens on the board (0-based index for each column):")
    initial_state = []
    for col in range(4):
        row = int(input(f"Enter row position for column {col+1}: "))
        initial_state.append(row)
    return initial_state

def main():
    confirm = input("Run Hill Climbing for the 4-Queens problem? (yes/no): ").strip().lower()
    if confirm == 'yes':
        initial_state = get_user_input()
        hill_climbing_4_queens(initial_state)
    else:
        print("Operation
cancelled.") if __name__ == "__main__":
    main()

```

Output:

```
Enter the initial positions of the queens on the board (0-based index for each column):
Enter row position for column 1: 0
Enter row position for column 2: 0
Enter row position for column 3: 0
Enter row position for column 4: 0
Initial state: [0, 0, 0, 0], Cost: 6
Q Q Q Q
. . .
. . .
. . .

Step 1: Best neighbor: [0, 3, 0, 0], Cost: 3
Q . Q Q
. . .
. . .
. Q . .

Step 2: Best neighbor: [1, 3, 0, 0], Cost: 1
. . Q Q
Q . . .
. . .
. Q . .

Step 3: Best neighbor: [1, 3, 0, 2], Cost: 0
. . Q .
Q . . .
. . . Q
. Q . .

Solution found:
. . Q .
Q . . .
. . . Q
. Q . .
```

Simulated Annealing to Solve 8-Queens problem

Algorithm:

Simulated annealing

Algorithm for SA

```

1 set currState = initialState
2 Set currEnergy = eval
3 Set bestState = currState
4 Set bestEnergy = currEnergy
5 Set temp = initialTemp
6 while temp > 0 do
    1. for iIterations = 1 to maxIterations do
        1. newstate = generateNeighbor (currState)
        2. newEnergy = evaluate (newState)
        3. energyDifference = newEnergy - currEnergy
        4. if energyDifference < 0 then
            1. //Accept the new state
            2. currState = newState
            3. currEnergy < newEnergy
            4. if currEnergy < bestEnergy then
                1. bestState = currState
                2. bestEnergy = currEnergy
        5. Else
            1. //Accept with a certain probability
            2. acceptanceProbability = exp(-energyDifference / temperature)
            3. if random(0, 1) < acceptanceProbability then
                1. currState = newState
                2. currEnergy = newEnergy
            2. //cool down temperature
            3. temperature = temperature * coolingRate
    7. Return bestState

```

*Solved
22/10/24*

Code:

```

import random
import math
def calculate_conflicts(board):

```

```

n = len(board)
conflicts = 0

for i in range(n):
    for j in range(i + 1, n):
        if board[i] == board[j] or abs(board[i] - board[j]) == abs(i - j):
            conflicts += 1
return conflicts

def simulated_annealing(board, max_steps=1000, initial_temp=100, cooling_rate=0.99):
    current_conflicts = calculate_conflicts(board)
    temperature = initial_temp
    n = len(board)

    for step in range(max_steps):
        if current_conflicts == 0:
            return board

        col = random.randint(0, n - 1)
        new_row = random.randint(0, n - 1)

        new_board = board[:]
        new_board[col] = new_row
        new_conflicts = calculate_conflicts(new_board)

        delta = new_conflicts - current_conflicts
        if delta < 0 or random.uniform(0, 1) < math.exp(-delta / temperature):
            board = new_board
            current_conflicts = new_conflicts

        temperature *= cooling_rate

    return None

def main():
    n = int(input("Enter the number of queens (default is 8): ") or 8)
    print(f"Enter the positions of the queens as an array of size {n}:")
    print(f"(Example: 0,4,7,5,2,6,1,3 or space-separated values)")
    input_str = input().strip()

```

```

if ',' in input_str:
    board = list(map(int, input_str.split(',')))
else:
    board = list(map(int, input_str.split()))

if len(board) != n:
    print("Error: The number of positions must match the number of queens.")
    return

solution =
simulated_annealing(board) if
solution:
print("\nSolution found:")
for row in range(n):
    line = ['.'] * n
    line[solution[row]] = 'Q'
    print(" ".join(line))
else:
    print("No solution found.")

if __name__ == "__main__":
    main()

```

Output:

```

Enter the number of queens (default is 8): 8
Enter the positions of the queens as an array of size 8:
(Example: 0,4,7,5,2,6,1,3 or space-separated values)
0 4 7 5 2 6 1 3

```

Solution found:

```

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

```

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

Algorithm:

Lal - 7
Propositional Logic problems

KB: $\neg R_1 \vee \neg R_2 \vee \neg R_3 \vee \neg R_4 \vee \neg R_5 \vee \neg R_6 \vee \neg R_7$

- $R_1 \rightarrow$ Alice mother of Bob
- $R_2 \rightarrow$ Bob father of Charlie
- $R_3 \rightarrow$ A father is a parent
- $R_4 \rightarrow$ A mother is a parent
- $R_5 \rightarrow$ All parents have children
- $R_6 \rightarrow$ If someone is a parent, then children are siblings
- $R_7 \rightarrow$ Alice is married to David

Hypotheses:

- "Charlie is a sibling of Bob."

Entailment process:

- from the premise, Alice is the mother of Bob, so Alice is a parent
- Bob is the father of Charlie, so Charlie's parent is Bob
- from the premise, If someone is a parent, their children are siblings

$A \rightarrow B$ (Alice is mother of Bob)
 $B \rightarrow C$ (Bob is Charlie's father)
 $F \rightarrow P$ (Father is a parent)
 $M \rightarrow P$ (Mother is a parent)
 $P \rightarrow S$ (If someone is a parent, their children are siblings)
 $A \wedge B \rightarrow Q$ (If Alice is mother of Bob & Bob is father of Charlie, then Charlie is a sibling of Bob)

check for entailment

i) If A is true (Alice, Bob's mom) then B must

In tree ($\text{Bob is a father of Charlie}$) $A \rightarrow B$

\exists B is true then C (Bob is a parent) must be
true ($F \rightarrow P$) & M (Alice is a parent) must also
be true ($M \rightarrow P$)

\otimes \exists If both Alice & Charlie are parents (i.e $M \wedge F$ are
true) then S ($\text{their children are sibling}$) must be
true ($P \rightarrow S$)

since S is true (the hypothesis φ ("Charlie is sibling"))

Conclusion

using propositional logic, we can conclude that
"Charlie is a sibling of Bob" is entailed by KB.

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('p', 'q', 'r', 'kb', 'query')
    print('*' * 10)
    entails = True # Assumption: The Knowledge Base entails the query
    for comb in combinations:
        s = evaluatePostfix(toPostfix(kb), comb)
        f = evaluatePostfix(toPostfix(q), comb)
        print(comb[0], comb[1], comb[2], s, f)
        print('-' * 10)
        if s and not f:
            entails = False # Counterexample found
    return entails
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 the query.")  
else:  
    print("The Knowledge Base does not entail the query.")
```

Output:

```
Enter rule: p^q  
Enter the Query: r  
*****Truth Table Reference*****  
kb alpha  
*****  
True True  
-----  
True False  
-----  
The Knowledge Base does not entail query
```

Implement unification in first order logic.

Algorithm:

Lat 8
first order logic

Statement: "If all humans are mortal, all philosophers are human, and Socrates is a philosopher, then Socrates is mortal."

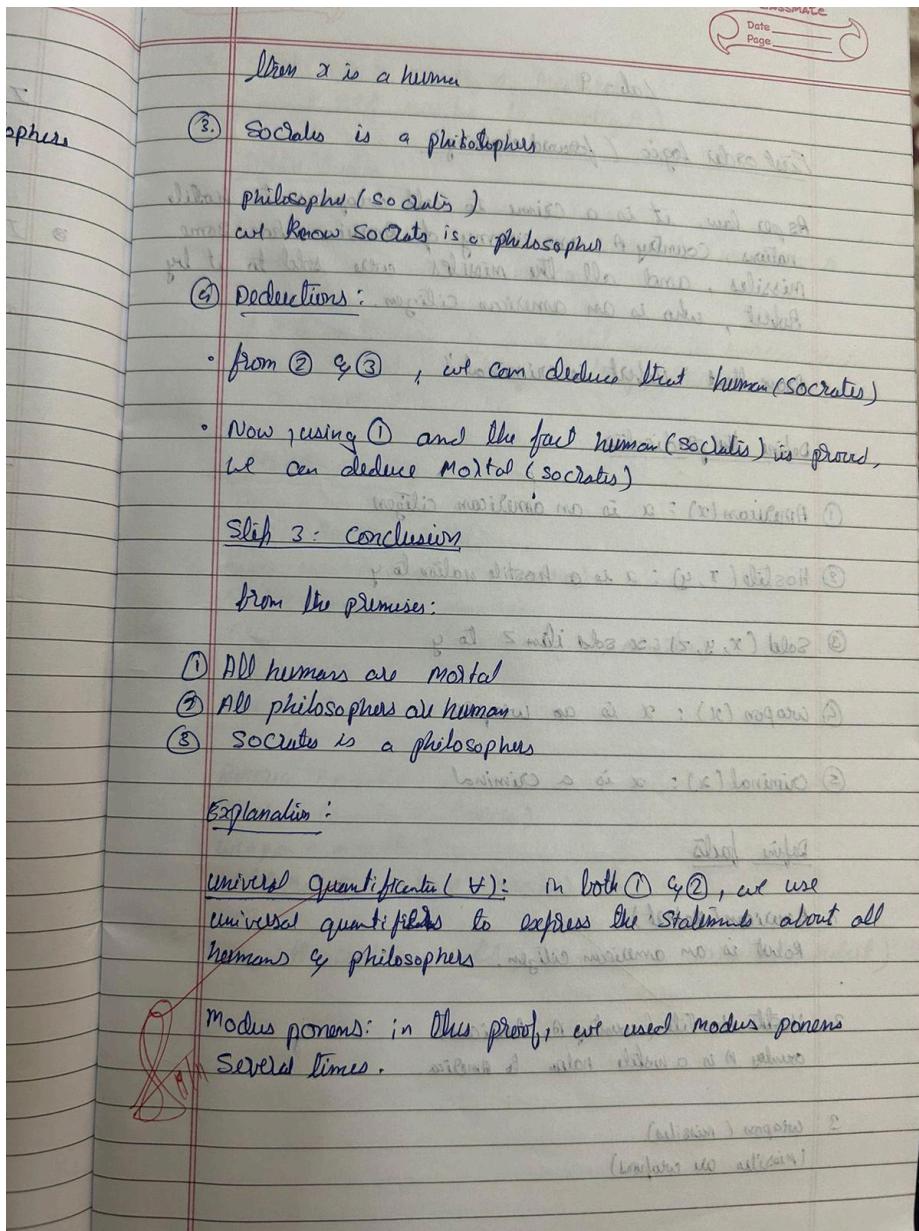
Step 1: For representation

- All humans are mortal:
 $\forall x (\text{human}(x) \rightarrow \text{mortal}(x))$
- All philosophers are humans:
 $\forall x (\text{Philosopher}(x) \rightarrow \text{human}(x))$
- Socrates is a philosopher:
 $\text{Philosopher}(\text{socrates})$

Prove the conclusion: Socrates is mortal or
 $\text{mortal}(\text{socrates})$

Step 2: Reasoning & Deductions

- All human are mortal
 $\forall x (\text{human}(x) \rightarrow \text{mortal}(x))$
 tells us that for any object x , if x is human, then x is mortal
- All philosophers are humans
 $\forall x (\text{Philosopher}(x) \rightarrow \text{human}(x))$
 tells us that for any object x , if x is a philosopher



Code:

```
def is_variable(x):
```

```
    """Check if x is a variable."""
```

```
    return isinstance(x, str) and x[0].islower()
```

```
def unify(x, y, subst):
```

```
    """Unify two terms x and y under a given substitution subst."""
```

```

print(f"Comparing: {x} with {y}")
if subst is None:
    return None
elif x == y:
    print(f"Both are equal: {x} == {y}")
    return subst
elif is_variable(x):
    return unify_variable(x, y, subst)
elif is_variable(y):
    return unify_variable(y, x, subst)
elif isinstance(x, tuple) and isinstance(y, tuple) and len(x) == len(y):
    for xi, yi in zip(x, y):
        subst = unify(xi, yi, subst)
    if subst is None:
        return None
    return subst
else:
    print(f"Cannot unify {x} and {y}")
    return None

def unify_variable(var, x, subst):
    """Handle variable unification."""
    if var in subst:
        print(f"Variable {var} is already in substitution. Resolving with {subst[var]}")
        return unify(subst[var], x, subst)
    elif occurs_check(var, x, subst):
        print(f"Occurs check failed: {var} occurs in {x}.")
        return None # Avoid infinite loops in recursive substitutions
    else:
        print(f"Adding substitution: {var} -> {x}")
        new_subst = subst.copy()
        new_subst[var] = x
        return new_subst

def occurs_check(var, x, subst):
    """Check if var occurs in x to avoid infinite substitution."""
    if var == x:
        return True
    elif isinstance(x, tuple):
        return any(occurs_check(var, xi, subst) for xi in x)
    elif is_variable(x) and x in subst:

```

```

        return occurs_check(var, subst[x], subst)
    else:
        return False

def parse_sentence_to_expression(sentence):
    """Convert an English sentence to a logical expression."""
    sentence = sentence.strip().replace("(, " ("").replace(")", " ) ").replace(", ", ", ")
    tokens = sentence.split()
    stack = []
    current = []
    for token in tokens:
        if token == "(":
            stack.append(current)
            current = []
        elif token == ")":
            if stack:
                last = stack.pop()
                last.append(tuple(current))
                current = last
        elif token == ",":
            continue
        else:
            current.append(token)
    return tuple(current) if len(current) == 1 else tuple(current)

def unification_with_explanation(expr1, expr2):
    """Perform unification on two expressions with step-by-step explanation."""
    print("\nStarting Unification Process...\n")
    subst = unify(expr1, expr2, {})
    if subst is not None:
        print("\nUnification\nSuccessful!")
        print("Substitution:", subst)
    else:
        print("\nUnification Failed!")

# Input from the user
print("Enter the logical expressions in English-like format.")
print("Example: Eats(x, Apple)")
sentence1 = input("Enter the first expression: ")
sentence2 = input("Enter the second expression: ")
# Parse sentences

```

```
expr1 = parse_sentence_to_expression(sentence1)
expr2 = parse_sentence_to_expression(sentence2)
# Perform unification with explanation
unification_with_explanation(expr1, expr2)
```

Output:

```
Enter the logical expressions in English-like format.
Example: Eats(x, Apple)
Enter the first expression: Works(x,y)
Enter the second expression: Works(Apple,Banana)

Starting Unification Process...

Comparing: ('Works', ('x', 'y')) with ('Works', ('Apple', 'Banana'))
Comparing: Works with Works
Both are equal: Works == Works
Comparing: ('x', 'y') with ('Apple', 'Banana')
Comparing: x with Apple
Adding substitution: x -> Apple
Comparing: y with Banana
Adding substitution: y -> Banana

Unification Successful!
Substitution: {'x': 'Apple', 'y': 'Banana'}
```

Create a KB consisting of first order logic statements and prove the following reasoning.

Lab - 9

First order logic (forward chaining)

As per law, it is a crime to sell weapons 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.

(Q) Prove that "Robert is criminal".

Define the predicates:

- ① American(x): x is an American citizen
- ② Hostile(x, y): x is a hostile nation to y
- ③ Sold(x, y, z): x sells item z to y
- ④ Weapon(x): x is a weapon
- ⑤ Criminal(x): x is a criminal

Define facts:

1. American(Robert) : Robert is an American citizen.
2. Hostile(Country A, America) : Country A is a hostile nation to America.
3. Weapon(Missiles) : Missiles are weapons.

Date _____
Page _____

1 Sold (Robert, Country B, Missiles) (missiles blocked)
(Robert sold missiles to country A.)

Define Rules

$\forall x, y \text{ American}(x) \wedge \text{Hostile}(y, \text{America}) \wedge \text{Weapon}(z) \wedge$
 $\text{Sold}(x, y, z) \rightarrow \text{Criminal}(x)$

If x is an American, y is a hostile nation to America, z is a weapon and x sold z to y , then x would go is a criminal.

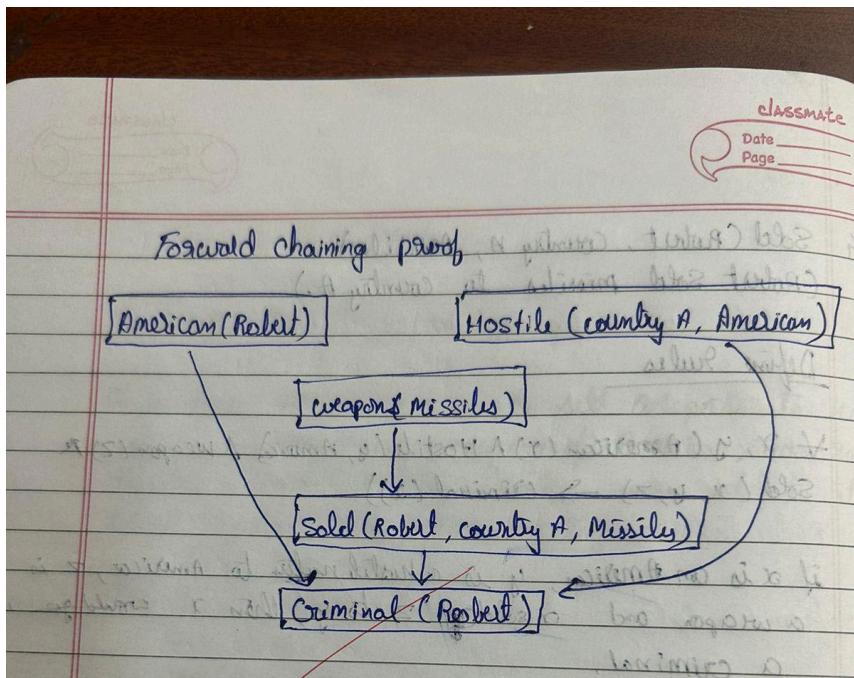
Forward Chaining

Fact 1: American(Robert)
Fact 2: Hostile(Country B, America)
Fact 3: Weapon(missiles)
Fact 4: Sold(Robert, Country B, missiles)

Applying rule

American(Robert)
Hostile(Country B, America)
Weapon(missiles)
~~Sold(Robert, Country B, missiles)~~

Since all conditions hold, we conclude Criminal(Robert)



Algorithm:

Code:

```

class ForwardChainingFOL:
    def __init__(self):
        self.facts = set() # Set of known facts
        self.rules = [] # List of rules in the form (premises, conclusion)
    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):
    """
    Unifies two facts if possible. Returns a substitution dictionary or None if unification fails.
    """
    if fact1 == fact2:
        return {} # No substitution needed
    if "(" in fact1 and "(" in fact2:
        # Split into predicate and arguments
        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
        # Unify arguments
        substitution = {}
        for a1, a2 in zip(args1, args2):
            if a1 != a2:
                if a1.islower(): # a1 is a variable
                    substitution[a1] = a2
                elif a2.islower(): # a2 is a variable
                    substitution[a2] = a1
                else: # Both are constants and different
                    return None
        return substitution
    return None
def apply_substitution(self, fact, substitution):
    """
    Applies a substitution to a fact and returns the substituted fact.
    """
    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
# Problem setup
fc = ForwardChainingFOL()
# Facts
fc.add_fact("American(Robert)")

```

```

fc.add_fact("Enemy(A,America)")
fc.add_fact("Owns(A,T1)")
fc.add_fact("Missile(T1)")
# Rules
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
goal = "Criminal(Robert)"
# Perform forward
chaining if
fc.forward_chain(goal):
    print(f"\nFinal result: Goal achieved: {goal}")
else:
    print("\nFinal result: Goal not achieved.")

```

Output:

```

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

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:
- Hostile(A)
- Sells(Robert,T1,A)
- American(Robert)
- Missile(T1)
- Enemy(A,America)
- Weapon(T1)
- Owns(A,T1)

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)

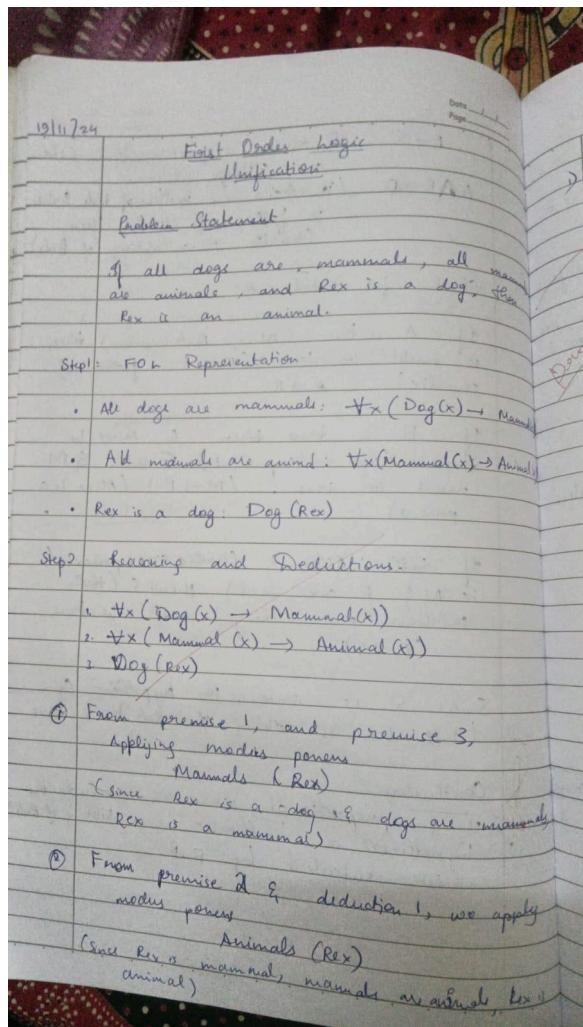
```

WEEK 9

03-12-2024

Write a proof tree generated using CNF.

Algorithm:



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

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'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({('likes', 'John', 'Peanuts
  ')})
  Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts'))} and frozenset({('likes', 'John', 'x'), ('not'
  , 'food(x)')})
  Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts'))} and frozenset({('alive', 'g'), ('killed', 'g
  ')})
  Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts'))} and frozenset({('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({('not', 'killed(k)'), ('not',
  'alive(k)')})
  Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts'))} and frozenset({('not', ('likes', 'John', 'Pea
  nuts'))})
  Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts'))} and frozenset({('not', 'eats(Anil, w)'), ('ea
  ts', 'Harry', 'w')})
  Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts'))} and frozenset({('likes', 'John', 'Peanuts')})
  Resolving clauses: frozenset({('food', 'z'), ('killed', 'y'), ('not', 'eats(y, z)')}) and frozenset({('li
  kes', 'John', 'x'), ('not', 'food(x)')})
  Resolving clauses: frozenset({('food', 'z'), ('killed', 'y'), ('not', 'eats(y, z)')}) and frozenset({('al
  ive', 'g'), ('killed', 'g')})
  Resolving clauses: frozenset({('food', 'z'), ('killed', 'y'), ('not', 'eats(y, z)')}) and frozenset({('ea
  ts', 'Anil', 'Peanuts')})
  Resolving clauses: frozenset({('food', 'z'), ('killed', 'y'), ('not', 'eats(y, z)')}) and frozenset({('al
  ive', 'Anil')})
  Resolving clauses: frozenset({('food', 'z'), ('killed', 'y'), ('not', 'eats(y, z)')}) and frozenset({('fo
  od', 'vegetables')})
  Resolving clauses: frozenset({('food', 'z'), ('killed', 'y'), ('not', 'eats(y, z)')}) and frozenset({('fo
  od', 'Apple')})
  Resolving clauses: frozenset({('food', 'z'), ('killed', 'y'), ('not', 'eats(y, z)')}) and frozenset({('no
  t', 'killed(k)'), ('not', 'alive(k)')})
  Resolving clauses: frozenset({('food', 'z'), ('killed', 'y'), ('not', 'eats(y, z)')}) and frozenset({('no
  t', ('likes', 'John', 'Peanuts'))})

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  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', 'vege
  tables')})
  Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('food', 'Apple'
  )})
  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({('not', 'eats(An
  il, w)'), ('eats', 'Harry', 'w')})
  Resolving clauses: frozenset({('not', 'killed(k)'), ('not', 'alive(k)')}) and frozenset({('likes', 'John
  ', 'Peanuts')})
  Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('likes', 'John', 'x
  '), ('not', 'food(x)')})
  Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('alive', 'g'), ('ki
  lled', 'g')})
  Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('eats', 'Anil', 'Pe
  anuts')})
  Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('food', 'z'), ('kil
  led', 'y'), ('not', 'eats(y, z)')})
  Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('alive', 'Anil')})
  Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('food', 'vegetables
  ')})
  Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('food', 'Apple')})
  Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('not', 'killed(k)')
  , ('not', 'alive(k)')})
  Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('not', 'eats(Anil,
  w)'), ('eats', 'Harry', 'w')})
  Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('likes', 'John', 'Pe
  anuts')})
  Resolving literal: ('not', ('likes', 'John', 'Peanuts')) with ('likes', 'John', 'Peanuts')
  Resulting Resolvent: frozenset()
Empty clause derived! The query is provable.
Query is provable.

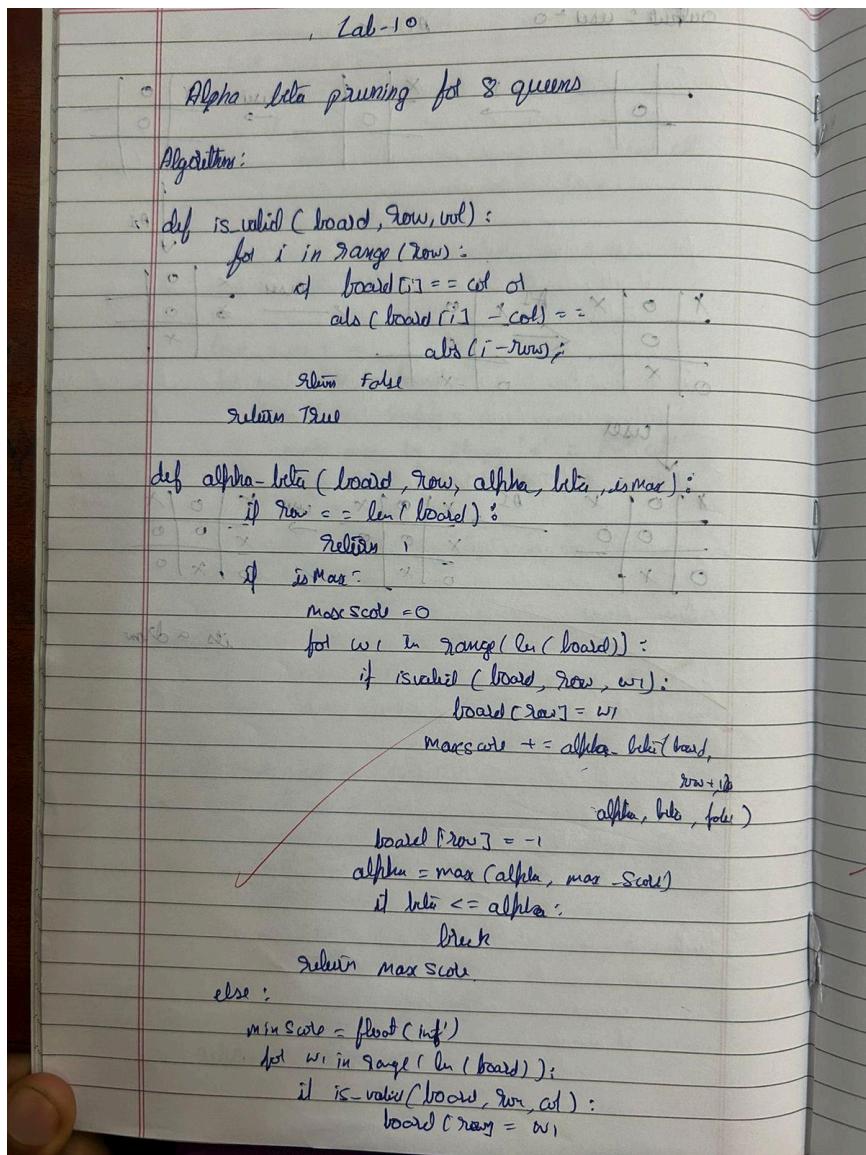
```

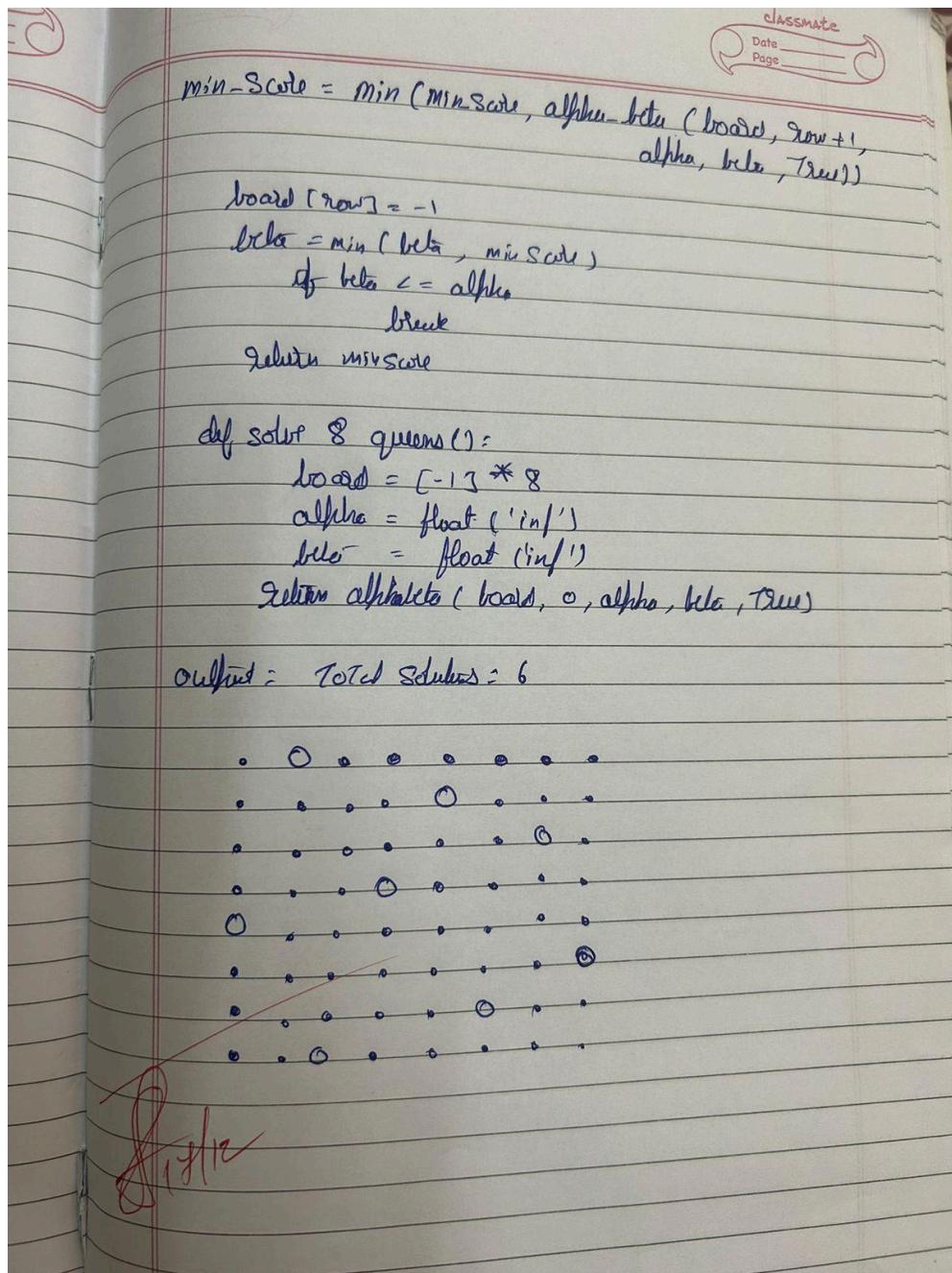
WEEK 10

3-12-2024

Implement Alpha Beta pruning.

Algorithm:





Code:

```

class AlphaBetaPruning:
  def __init__(self):
    self.pruned_branches = []
  def alpha_beta(self, node, depth, alpha, beta, maximizing_player):
    if isinstance(node, int):
      return node
    if maximizing_player:
      max_eval = float('-inf')
    else:
      min_eval = float('inf')
    for child in node.children:
      eval = self.alpha_beta(child, depth + 1, alpha, beta, not maximizing_player)
      if maximizing_player:
        if eval > max_eval:
          max_eval = eval
        if eval >= beta:
          self.pruned_branches.append(child)
          break
      else:
        if eval < min_eval:
          min_eval = eval
        if eval <= alpha:
          self.pruned_branches.append(child)
          break
    if maximizing_player:
      return max_eval
    else:
      return min_eval
  
```

```
for child in node:  
    eval = self.alpha_beta(child, depth - 1, alpha, beta, False)  
    max_eval = max(max_eval, eval)  
    alpha = max(alpha, eval)  
    if beta <= alpha:  
        self.pruned_branches.append(child)  
        break  
    return max_eval  
else:  
    min_eval = float('inf')
```

```

for child in node:
    eval = self.alpha_beta(child, depth - 1, alpha, beta, True)
    min_eval = min(min_eval, eval)
    beta = min(beta, eval)
    if beta <= alpha:
        self.pruned_branches.append(child)
        break
return min_eval

def run(self, game_tree):
    alpha = float('-inf')
    beta = float('inf')
    max_value = self.alpha_beta(game_tree, float('inf'), alpha, beta, True)
    return max_value, self.pruned_branches

def construct_tree_from_leaves(leaves):
    current_level = leaves
    while len(current_level) > 1:
        next_level = []
        for i in range(0, len(current_level), 2):
            if i + 1 < len(current_level):
                next_level.append([current_level[i], current_level[i + 1]])
            else:
                next_level.append(current_level[i])
        current_level = next_level
    return current_level[0]

def input_leaf_nodes():
    print("Enter the leaf nodes of the game tree separated by spaces (e.g., 3 5 6 9 1 4 7 10 11):")
    while True:
        try:
            leaves = list(map(int, input("Leaf nodes: ").split()))
            if len(leaves) >= 2:
                return leaves
            else:
                print("Please enter at least two leaf nodes.")
        except ValueError:
            print("Invalid input. Please enter integers only.") if __name__ == "__main__":
            leaves = input_leaf_nodes()
            game_tree = construct_tree_from_leaves(leaves)

```

```
abp = AlphaBetaPruning()
final_max_value, pruned_branches = abp.run(game_tree)
print(f"Final value of MAX node: {final_max_value}")
print(f"Subtrees pruned: {pruned_branches}")
```

Output:

```
Enter the leaf nodes of the game tree separated by spaces (e.g., 3 5 6 9 1 4 7 10 11):
Leaf nodes: 10 9 14 18 5 4 50 3
Final value of MAX node: 10
Subtrees pruned: [14, [5, 4]]
```