VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

Gopika Pushparajan (1BM23CS101)

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-2025 to Jan-2026

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 **Gopika Pushparajan (1BM23CS101),** 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. Sheetal V A Assistant Professor Department of CSE, BMSCE	**Dr. Kavitha Sooda** Professor & HOD Department of CSE, BMSCE

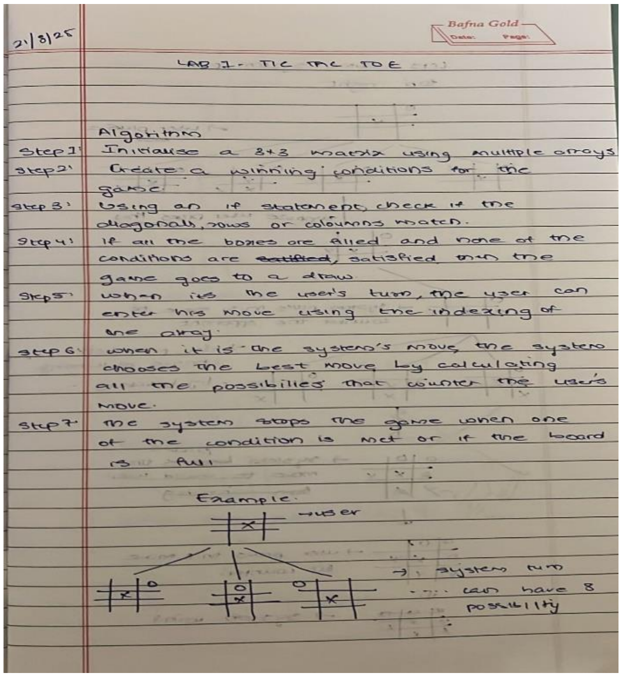
Index

Github Link:
https://github.com/gopikapushparajan/ailab

Program 1

Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

Algorithm:



21/8/25

LAB 1 - TIC TAC TOE

Algorithm

Step 1: Initialise a 3+3 matrix using multiple arrays

Step 2: Create a winning conditions for the game

Step 3: Using an if statement, check if the diagonals, rows or coloumns match.

Step 4: If all the boxes are filled and none of the conditions are ~~satified~~, satisfied then the game goes to a draw

Step 5: when its the user's turn, the user can enter his move using the indexing of the array

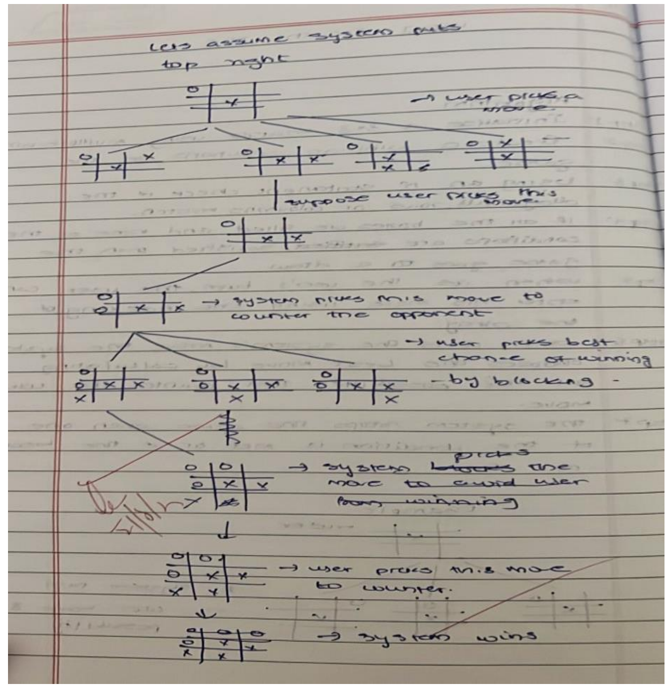
Step 6: when it is the system's move, the system chooses the best move by calculating all the possibilies that counter the user's move.

Step 7: The system stops the game when one of the condition is met or if the board is full

Example

→ user

→ system turn can have 8 possibility



Lets assume system puts top right

→ user picks a move

suppose user picks this move

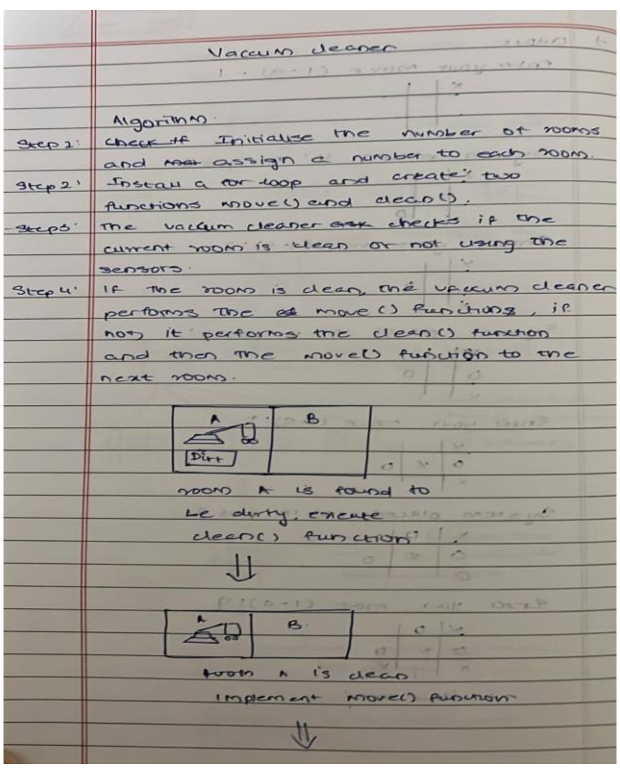
→ system picks this move to counter the opponent

→ user picks best chance of winning - by blocking -

→ system ~~blocks~~ picks the move to avoid user ~~from winning~~

→ user picks this move to counter.

→ system wins



Vaccum cleaner

Algorithm

Step 1: ~~Check if~~ Initialise the number of rooms and ~~that~~ assign a number to each room.

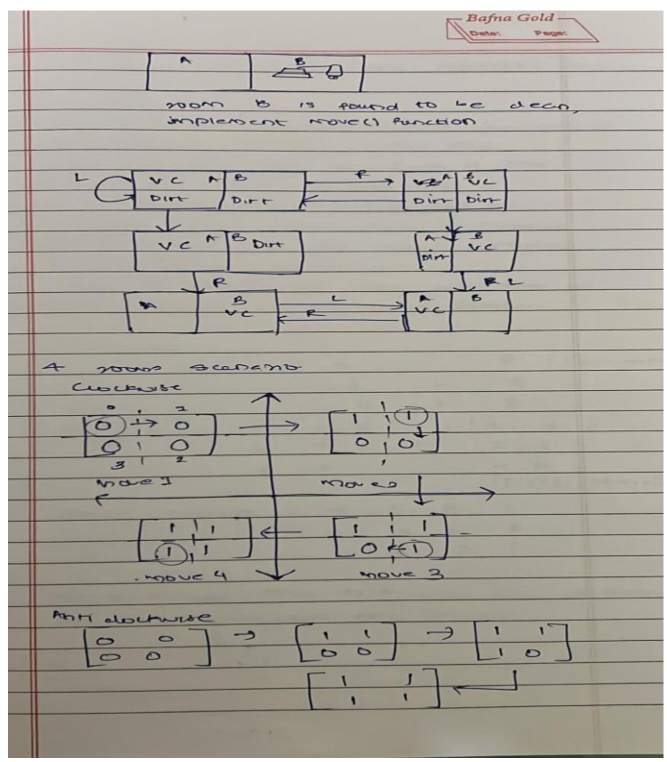
Step 2: Install a for loop and create two functions move() and clean().

Step 3: The vaccum cleaner ~~ask~~ checks if the current room is clean or not using the sensors.

Step 4: If the room is clean, the vaccum cleaner performs the ~~a~~ move() functions, if not, it performs the clean() function and then the move() function to the next room.

room A is found to be dirty, execute clean() function

room A is clean implement move() function



room B is found to be clean, implement move() function

4 rooms scenario

Clockwise

move 1

move 2

move 3

move 4

Anti clockwise

Code:

Tic Tac Toe:

```
def computer_move():
    best_move = minimax_recurse(game_board, active_player, 0)
    print("The best move is ", best_move)
    make_move(game_board, best_move, active_player)

    print("COMPUTER MOVE DONE")

def minimax_recurse(game_board, player, depth):

    winner = is_winner(game_board)
    if winner == active_player:
        return 1
    elif winner is not None and winner != active_player:
        return -1
    elif len(get_move_list(game_board)) == 0:
        return 0

    if player == player1:
        other_player = player2
    else:
        other_player = player1

    if player == active_player:
        alpha = -1
    else:
        alpha = 1

    movelist = get_move_list(game_board)
    best_move = None

    for move in movelist:
        board2 = [list(row) for row in game_board] # Create a copy of the board

        make_move(board2, move, player)

        subalpha = minimax_recurse(board2, other_player, depth + 1)

        if player == active_player:
            if depth == 0 and alpha <= subalpha:
                best_move = move
            alpha = max(alpha, subalpha)
            if alpha == 1: # Alpha-beta pruning
                if depth == 0:
                  return best_move
```

```
            return alpha

        else:
          alpha = min(alpha, subalpha)
          if alpha == -1: # Alpha-beta pruning
            return alpha

    if depth == 0:
      return best_move
    return alpha


# BOARD FUNCTIONS
game_board = [['1','2','3'],['4','5','6'],['7','8','9']] # Changed to strings to avoid confusion with available moves
def print_board(board) :

    for row in board :
      print(row)

def make_move(game_board, player_move, active_player):

    x = 0
    y = 0
    try:
      player_move = int(player_move)
    except ValueError:
      print("Invalid input. Please enter a number.")
      return game_board

    if player_move == 1 :
      x = 0
      y = 0
    elif player_move == 2 :
      x = 0
      y = 1
    elif player_move == 3 :
      x = 0
      y = 2
    elif player_move == 4 :
      x = 1
      y = 0
    elif player_move == 5 :
      x = 1
      y = 1
    elif player_move == 6 :
      x = 1
      y = 2
```

```
    elif player_move == 7 :
        x = 2
        y = 0
    elif player_move == 8 :
        x = 2
        y = 1
    elif player_move == 9 :
        x = 2
        y = 2
    else :
        print ("value is out of range")
        return game_board


    if game_board[x][y] == "O" or game_board[x][y] == "X" :
        print("move not available")
        return game_board

    game_board[x][y] = str(active_player)
    return game_board

def is_winner(board):
    for i in range (0,3) :
        if board[i][0] == player1 and board[i][1] == player1 and board[i][2] == player1 :
            return player1

        if board[i][0] == player2 and board[i][1] == player2 and board[i][2] == player2 :
            return player2

    # checking for columns
    for i in range(0,3):
        if board[0][i] == player1 and board[1][i] == player1 and board[2][i] == player1:
            return player1
        if board[0][i] == player2 and board[1][i] == player2 and board[2][i] == player2:
            return player2

    # checking for diagonals
    if board[0][0] == player1 and board[1][1] == player1 and board[2][2] == player1 :
        return player1
    if board[0][0] == player2 and board[1][1] == player2 and board[2][2] == player2 :
        return player2

    if board[2][0] == player1 and board[1][1] == player1 and board[0][2] == player1 :
        return player1
    if board[2][0] == player2 and board[1][1] == player2 and board[0][2] == player2 :
        return player2

    return None
```

```
def get_move_list (game_board) :

    move = []

    for row in game_board :
        for i in row :
            if i.isdigit():
                move.append(int(i))
    return move

# Main Loop
player1 = "X"
player2 = "O"
print_board(game_board)
while True :
    active_player = player1
    # this is for player move
    print(get_move_list(game_board))
    player_move = input("Please insert your move >>> ")
    game_board = make_move(game_board,player_move,active_player)
    print_board(game_board)

    if is_winner(game_board) == player1 :
        print("Player1 is the winner")
        break
    if is_winner(game_board) == player2 :
        print("Player2 is the winner")
        break
    if len(get_move_list(game_board)) == 0:
        print("It's a tie!")
        break

    print(get_move_list(game_board))
    # computer time
    active_player = player2
    computer_move()
    print_board(game_board)

    if is_winner(game_board) == player1 :
        print("Player1 is the winner")
        break
    if is_winner(game_board) == player2 :
        print("Player2 is the winner")
        break
    if len(get_move_list(game_board)) == 0:
        print("It's a tie!")
        break
```

Vacuum Cleaner:

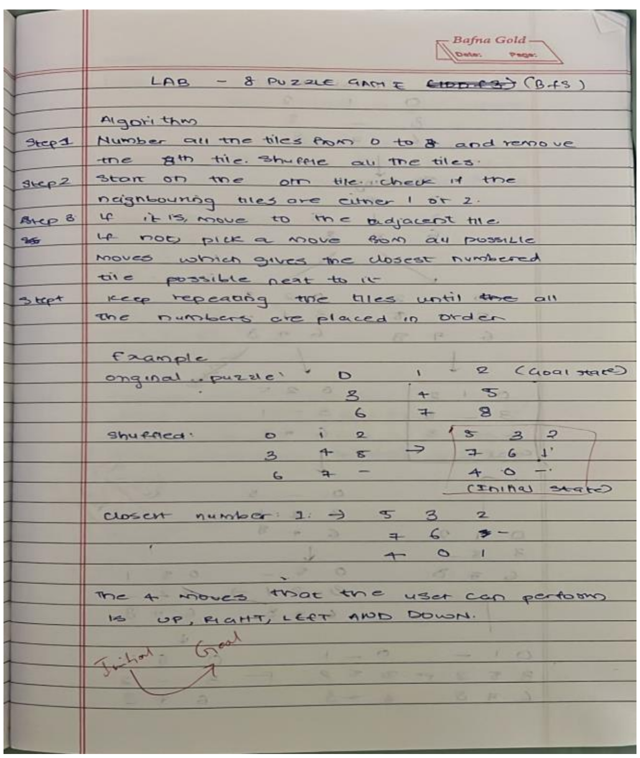
```
import random

def vacuum_cleaner_agent(location, status_A, status_B):
    """
    Simulates a simple vacuum cleaner agent in a two-location environment (A and B).
    Args:
        location (str): The current location of the vacuum ('A' or 'B').
        status_A (str): The cleanliness status of location A ('Dirty' or 'Clean').
        status_B (str): The cleanliness status of location B ('Dirty' or 'Clean').
    Returns:
        tuple: A tuple containing the updated location and statuses after the agent's action.
    """
    print(f"Vacuum cleaner is at {location}.")

    if location == 'A':
        if status_A == 'Dirty':
            print("Location A is Dirty. Sucking dirt...")
            status_A = 'Clean'
            print("Location A is now Clean.")
            # Move to B after cleaning A
            print("Moving to Location B.")
            return 'B', status_A, status_B
        else:
            print("Location A is Clean. Moving to Location B.")
            return 'B', status_A, status_B
    elif location == 'B':
        if status_B == 'Dirty':
            print("Location B is Dirty. Sucking dirt...")
            status_B = 'Clean'
            print("Location B is now Clean.")
            # Move to A after cleaning B
            print("Moving to Location A.")
            return 'A', status_A, status_B
        else:
            print("Location B is Clean. Moving to Location A.")
            return 'A', status_A, status_B

# Initializing the environment
initial_location = random.choice(['A', 'B'])
initial_status_A = random.choice(['Dirty', 'Clean'])
initial_status_B = random.choice(['Dirty', 'Clean'])

print(f"Initial state: Vacuum at {initial_location}, A is {initial_status_A}, B is {initial_status_B}\n")

current_location, current_status_A, current_status_B = initial_location, initial_status_A,
```

```
initial_status_B

# Running the simulation until both locations are clean
while current_status_A == 'Dirty' or current_status_B == 'Dirty':
    current_location, current_status_A, current_status_B = vacuum_cleaner_agent(
        current_location, current_status_A, current_status_B
    )
    print(f"Current state: Vacuum at {current_location}, A is {current_status_A}, B is
{current_status_B}\n")

print("Both locations are clean. Vacuum cleaner has finished its task.")
```

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)
Implement Iterative deepening search algorithm

Algorithm:



Bafna Gold Date: Page:

LAB - 8 PUZZLE GAME ~~[illegible]~~ (BFS)

Algorithm

Step 1 Number all the tiles from 0 to 8 and remove the 8th tile. Shuffle all the tiles.

Step 2 Start on the om tile. Check if the neighbouring tiles are either 1 or 2.

Step 3 If it is, move to the adjacent tile.
If not, pick a move from all possible moves which gives the closest numbered tile possible next to it.

Step 4 Keep repeating the tiles until ~~the~~ all the numbers are placed in order.

Example

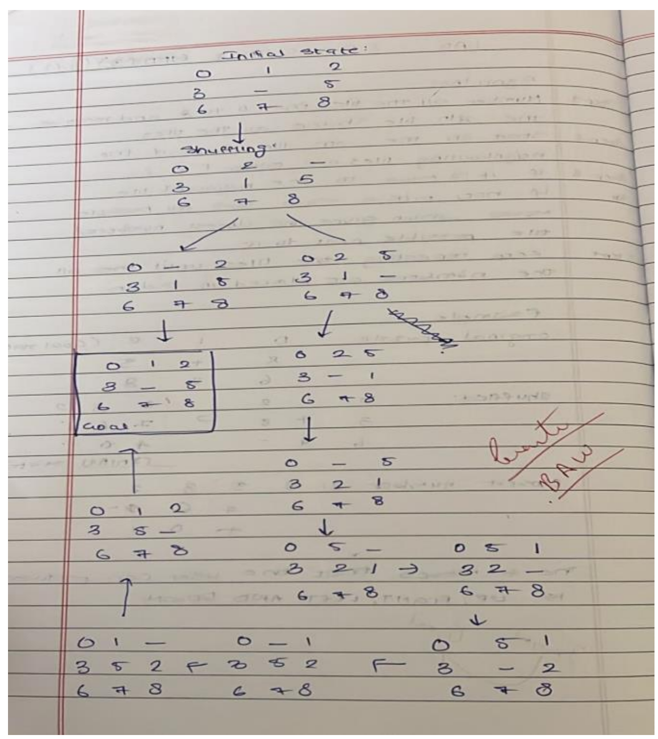
original puzzle: 0 1 2 (Goal state)
3 4 5
6 7 8

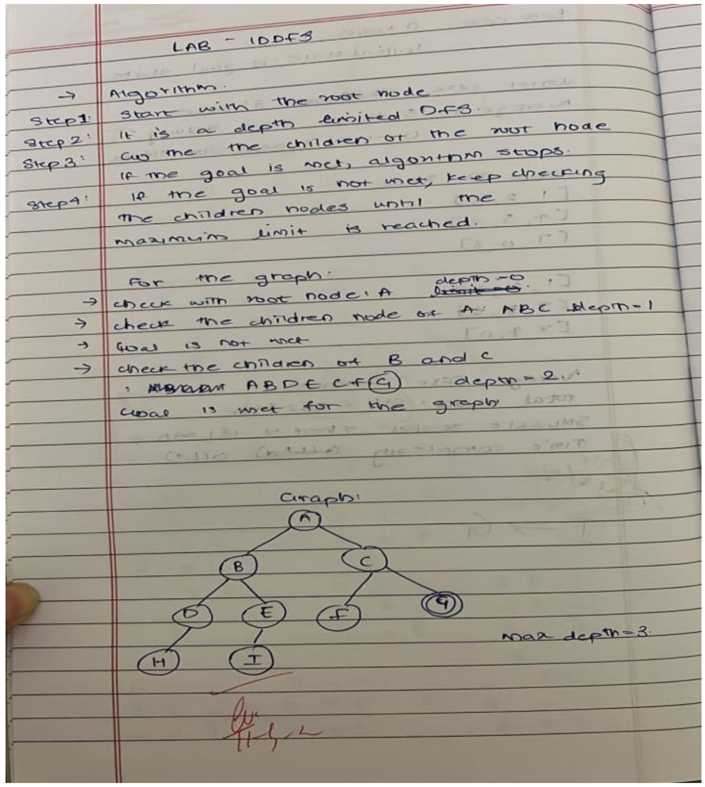
shuffled: 0 1 2 → 5 3 2
3 4 5 → 7 6 1
6 7 – → 4 0 –
(Initial state)

closest number 1: → 5 3 2
7 6 –
4 0 1

The 4 moves that the user can perform is UP, RIGHT, LEFT AND DOWN.

Initial Goal




LAB - IDDFS

→ Algorithm:

Step1: Start with the root node

Step2: It is a depth limited DFS.

Step3: Go the the children of the root node

If the goal is met, algorithm stops.

Step4: If the goal is not met, keep checking the children nodes until the maximum limit is reached.

For the graph:

→ check with root node: A depth = 0

→ check the children node of A: ABC depth = 1

→ Goal is not met

→ check the children of B and C

: ABDECFG depth = 2

Goal is met for the graph

Code:

BFS

```
# Import necessary libraries
from collections import deque

# Define the dimensions of the puzzle
N = 3

# Class to represent the state of the puzzle
class PuzzleState:
    def __init__(self, board, x, y, depth):
        self.board = board
        self.x = x
        self.y = y
        self.depth = depth

# Possible moves: Left, Right, Up, Down
row = [0, 0, -1, 1]
col = [-1, 1, 0, 0]

# Function to check if the current state is the goal state
def is_goal_state(board):
    goal = [[1, 2, 3], [4, 5, 6], [7, 8, 0]]
    return board == goal
```

```
# Function to check if a move is valid
def is_valid(x, y):
    return 0 <= x < N and 0 <= y < N

# Function to print the puzzle board
def print_board(board):
    for row in board:
        print(' '.join(map(str, row)))
    print('--------')

# BFS function to solve the 8-puzzle problem
def solve_puzzle_bfs(start, x, y):
    q = deque()
    visited = set()

    # Enqueue initial state
    q.append(PuzzleState(start, x, y, 0))
    visited.add(tuple(map(tuple, start)))

    while q:
        curr = q.popleft()

        # Print the current board state
        print(f'Depth: {curr.depth}')
        print_board(curr.board)

        # Check if goal state is reached
        if is_goal_state(curr.board):
            print(f'Goal state reached at depth {curr.depth}')
            return

        # Explore all possible moves
        for i in range(4):
            new_x = curr.x + row[i]
            new_y = curr.y + col[i]

            if is_valid(new_x, new_y):
                new_board = [row[:] for row in curr.board]
                new_board[curr.x][curr.y], new_board[new_x][new_y] = new_board[new_x][new_y],
new_board[curr.x][curr.y]

                # If this state has not been visited before, push to queue
                if tuple(map(tuple, new_board)) not in visited:
                    visited.add(tuple(map(tuple, new_board)))
                    q.append(PuzzleState(new_board, new_x, new_y, curr.depth + 1))

    print('No solution found (BFS Brute Force reached depth limit)')
```

```
# Driver Code
if __name__ == '__main__':
    start = [[1, 2, 3], [4, 0, 5], [6, 7, 8]]  # Initial state
    x, y = 1, 1

    print('Initial State:')
    print_board(start)

    solve_puzzle_bfs(start, x, y)
```

IDDFS:

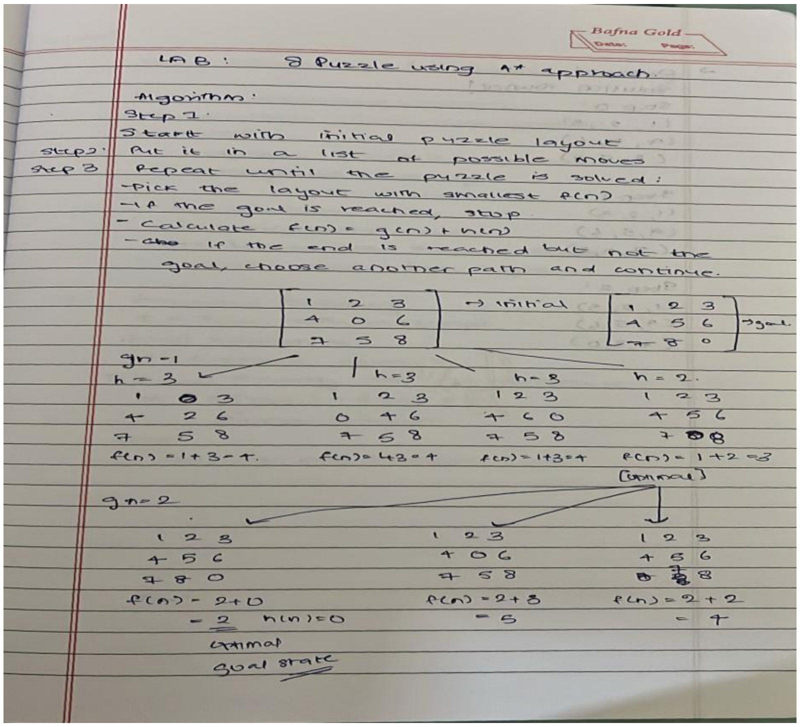
```
from collections import deque

# Goal state
GOAL = (1, 2, 3,
        4, 5, 6,
        7, 8, 0)

# Moves: up, down, left, right
MOVES = {
    'U': -3,
    'D':  3,
    'L': -1,
    'R':  1
}

def is_valid_move(pos, move):
    """Check if blank can move in given direction."""
    if move == 'U' and pos < 3: return False
    if move == 'D' and pos > 5: return False
    if move == 'L' and pos % 3 == 0: return False
    if move == 'R' and pos % 3 == 2: return False
    return True

def neighbors(state):
    """Generate valid neighbor states from current state."""
    new_states = []
    pos = state.index(0)  # blank position
    for move, offset in MOVES.items():
        if is_valid_move(pos, move):
            new_pos = pos + offset
            new_state = list(state)
            new_state[pos], new_state[new_pos] = new_state[new_pos], new_state[pos]
            new_states.append((tuple(new_state), move))
    return new_states
```

```
def dls(state, depth, visited, path):
    """Depth-limited DFS."""
    if state == GOAL:
        return path
    if depth == 0:
        return None
    visited.add(state)

    for neighbor, move in neighbors(state):
        if neighbor not in visited:
            result = dls(neighbor, depth - 1, visited, path + [move])
            if result is not None:
                return result
    return None

def iddfs(start, max_depth=50):
    """Iterative Deepening DFS."""
    for depth in range(max_depth):
        visited = set()
        path = dls(start, depth, visited, [])
        if path is not None:
            return path
    return None

# --- MAIN PROGRAM ---
if __name__ == "__main__":
    print("Enter the start state of the 8-puzzle (use 0 for blank):")
    nums = []
    for i in range(9):
        nums.append(int(input(f"Tile {i+1}: ")))
    start = tuple(nums)

    solution = iddfs(start, max_depth=30)
    if solution:
        print(f"\nSolution found in {len(solution)} moves:")
        print(" -> ".join(solution))
    else:
        print("No solution found within depth limit.")
```

Program 3

Implement A* search algorithm

Algorithm:



Bafna Gold

LAB : 8 Puzzle using A* approach.

Algorithm:

Step 1:
Start with initial puzzle layout
Step 2: Put it in a list of possible moves
Step 3 Repeat until the puzzle is solved:
- Pick the layout with smallest f(n)
- If the goal is reached, stop
- Calculate f(n) = g(n) + h(n)
- If the end is reached but not the goal, choose another path and continue.

Code:

```
import heapq
from termcolor import colored

# Class to represent the state of the 8-puzzle
class PuzzleState:
    def __init__(self, board, parent, move, depth, cost):
        self.board = board  # The puzzle board configuration
        self.parent = parent  # Parent state
        self.move = move  # Move to reach this state
        self.depth = depth  # Depth in the search tree
        self.cost = cost  # Cost (depth + heuristic)

    def __lt__(self, other):
        return self.cost < other.cost

# Function to display the board in a visually appealing format
def print_board(board):
    print("+---+---+---+")
    for row in range(0, 9, 3):
        row_visual = "|"
        for tile in board[row:row + 3]:
```

```
            if tile == 0:  # Blank tile
                row_visual += f" {colored(' ', 'cyan')} |"
            else:
                row_visual += f" {colored(str(tile), 'yellow')} |"
        print(row_visual)
        print("+---+---+---+")

# Goal state for the puzzle
goal_state = [1, 2, 3, 4, 5, 6, 7, 8, 0]

# Possible moves for the blank tile (up, down, left, right)
moves = {
    'U': -3,  # Move up
    'D': 3,   # Move down
    'L': -1,  # Move left
    'R': 1    # Move right
}

# Function to calculate the heuristic (Manhattan distance)
def heuristic(board):
    distance = 0
    for i in range(9):
        if board[i] != 0:
            x1, y1 = divmod(i, 3)
            x2, y2 = divmod(board[i] - 1, 3)
            distance += abs(x1 - x2) + abs(y1 - y2)
    return distance

# Function to get the new state after a move
def move_tile(board, move, blank_pos):
    new_board = board[:]
    new_blank_pos = blank_pos + moves[move]
    new_board[blank_pos], new_board[new_blank_pos] = new_board[new_blank_pos],
new_board[blank_pos]
    return new_board

# A* search algorithm
def a_star(start_state):
    open_list = []
    closed_list = set()
    heapq.heappush(open_list, PuzzleState(start_state, None, None, 0, heuristic(start_state)))

    while open_list:
        current_state = heapq.heappop(open_list)

        if current_state.board == goal_state:
            return current_state
```

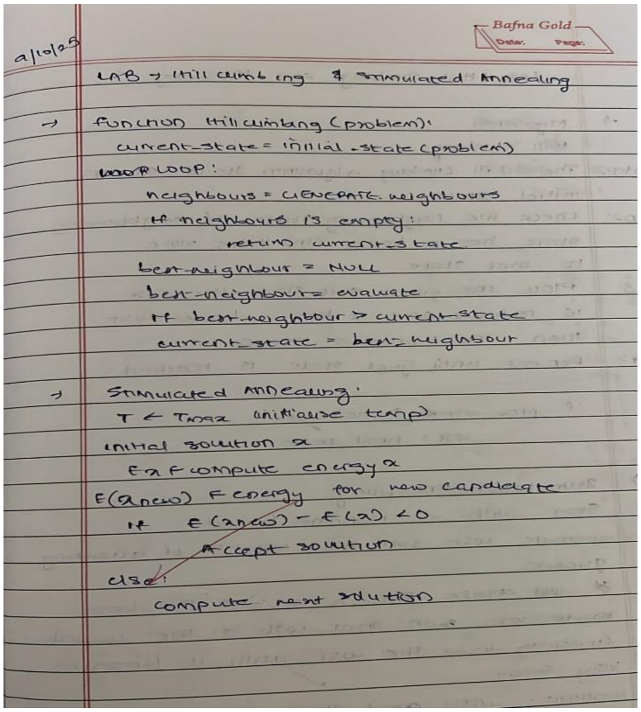
```
        closed_list.add(tuple(current_state.board))

        blank_pos = current_state.board.index(0)

        for move in moves:
            if move == 'U' and blank_pos < 3:  # Invalid move up
                continue
            if move == 'D' and blank_pos > 5:  # Invalid move down
                continue
            if move == 'L' and blank_pos % 3 == 0:  # Invalid move left
                continue
            if move == 'R' and blank_pos % 3 == 2:  # Invalid move right
                continue

            new_board = move_tile(current_state.board, move, blank_pos)

            if tuple(new_board) in closed_list:
                continue

            new_state = PuzzleState(new_board, current_state, move, current_state.depth + 1,
current_state.depth + 1 + heuristic(new_board))
            heapq.heappush(open_list, new_state)

    return None

# Function to print the solution path
def print_solution(solution):
    path = []
    current = solution
    while current:
        path.append(current)
        current = current.parent
    path.reverse()

    for step in path:
        print(f"Move: {step.move}")
        print_board(step.board)

# Initial state of the puzzle
initial_state = [1, 2, 3, 4, 0, 5, 6, 7, 8]

# Solve the puzzle using A* algorithm
solution = a_star(initial_state)

# Print the solution
if solution:
    print(colored("Solution found:", "green"))
    print_solution(solution)
```

```
else:
    print(colored("No solution exists.", "red"))
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:

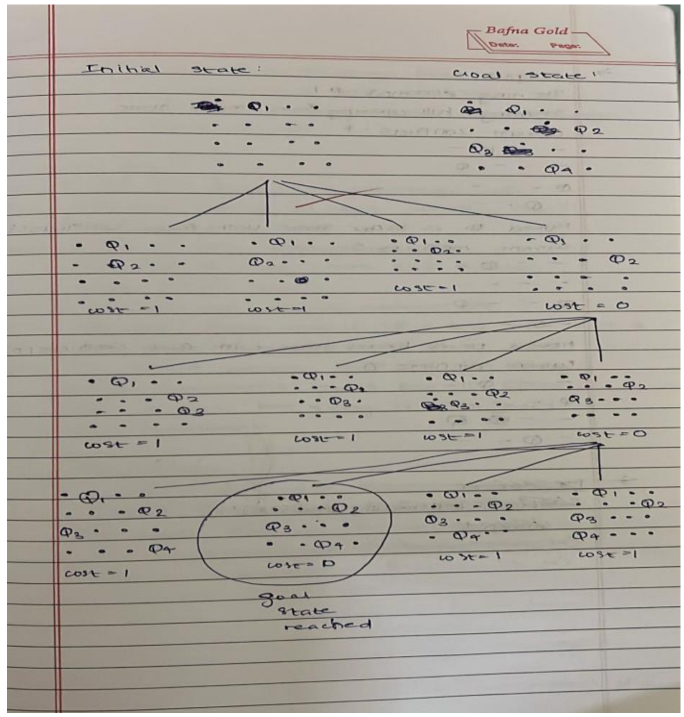


9/10/25

LAB → Hill climbing & Simulated Annealing

→ function Hillclimbing (problem):
current_state = initial_state (problem)
LOOP:
neighbours = GENERATE neighbours
if neighbours is empty:
return current_state
best_neighbour = NULL
best_neighbour = evaluate
if best_neighbour > current_state
current_state = best_neighbour

→ Simulated Annealing:
T ← Tmax (initialise temp)
initial solution x
Ex ← compute energy x
E(xnew) ← energy for new candidate
if E(xnew) − E(x) < 0
Accept solution
else:
compute next solution



Code:

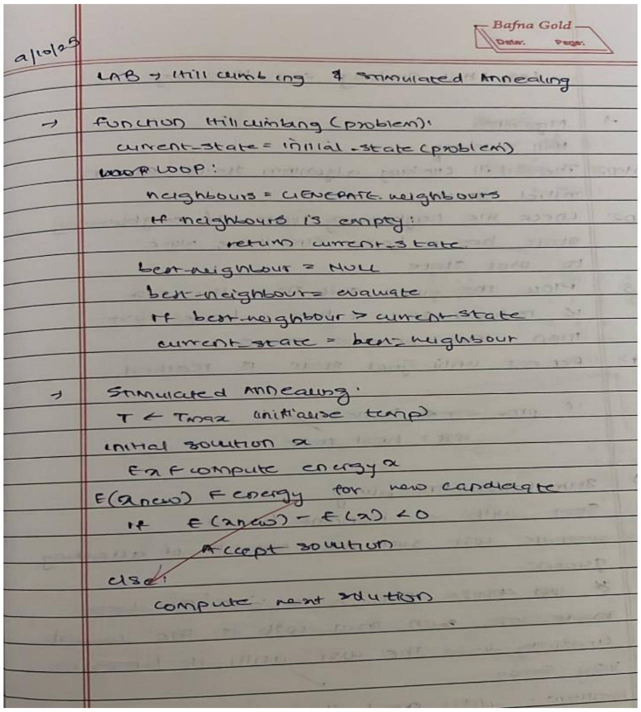
```
import random

def calculate_attacks(board):
    """Calculates the number of attacking pairs on the board."""
    n = len(board)
    attacks = 0
    for i in range(n):
        for j in range(i + 1, n):
            # Check row attacks
            if board[i] == board[j]:
                attacks += 1
            # Check diagonal attacks
            elif abs(board[i] - board[j]) == abs(i - j):
                attacks += 1
    return attacks

def hill_climbing_n_queens(n):
    """Solves the N-Queens problem using Hill Climbing."""
    # Initialize with a random board
    current_board = [random.randint(0, n - 1) for _ in range(n)]
```

```
    current_attacks = calculate_attacks(current_board)

    while current_attacks > 0:
        best_neighbor_board = list(current_board)
        best_neighbor_attacks = current_attacks

        found_better_neighbor = False
        for col_to_move in range(n):
            for row_new_pos in range(n):
                if current_board[col_to_move] == row_new_pos:
                    continue  # Don't move to the same position

                temp_board = list(current_board)
                temp_board[col_to_move] = row_new_pos
                temp_attacks = calculate_attacks(temp_board)

                if temp_attacks < best_neighbor_attacks:
                    best_neighbor_attacks = temp_attacks
                    best_neighbor_board = list(temp_board)
                    found_better_neighbor = True
                elif temp_attacks == best_neighbor_attacks and not found_better_neighbor:
                    # If multiple neighbors have the same best attack count,
                    # choose one randomly to avoid always picking the same one
                    if random.random() < 0.5: # Simple tie-breaking
                        best_neighbor_board = list(temp_board)

        if not found_better_neighbor:
            # Stuck in a local optimum or reached a solution
            break
        current_board = best_neighbor_board
        current_attacks = best_neighbor_attacks

    return current_board, current_attacks

# Example for 4-Queens
n = 4
solution, attacks = hill_climbing_n_queens(n)

print(f"Final board: {solution}")
print(f"Number of attacks: {attacks}")

if attacks == 0:
    print("Solution found!")
else:
    print("Stuck in a local optimum.")
```

Program 5

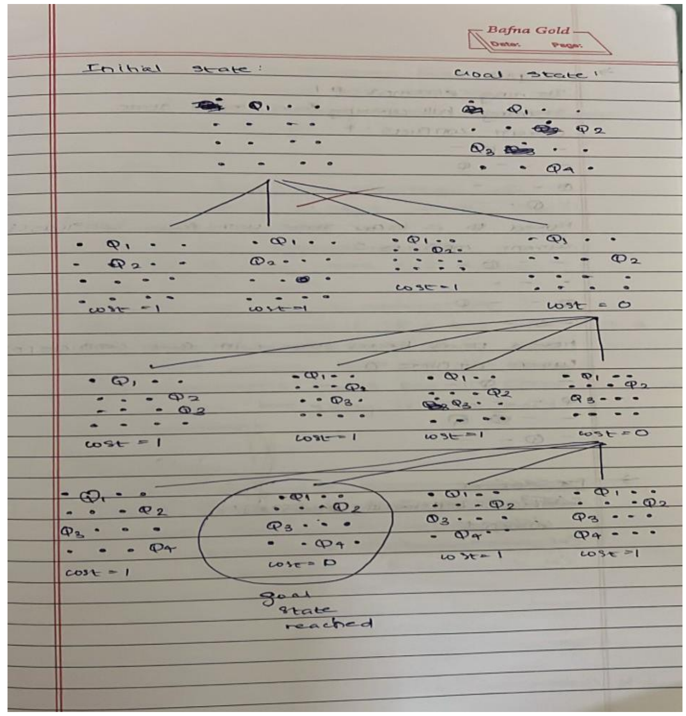
Simulated Annealing to Solve 8-Queens problem

Algorithm:


9/10/25
LAB → Hill climbing & Simulated Annealing

→ function Hill climbing (problem):
current-state = initial-state (problem)
LOOP:
neighbours = GENERATE neighbours
if neighbours is empty:
return current-state
best-neighbour = NULL
best-neighbour = evaluate
if best-neighbour > current-state
current-state = best-neighbour

→ Simulated Annealing:
T ← Tmax (initialise temp)
initial solution x
E x F compute energy x
E(xnew) F energy for new candidate
if E(xnew) − E(x) < 0
accept solution
else:
compute next solution



Code:

```
import random
import math

def calculate_attacks(board):
    """Calculates the number of attacking queen pairs on the board."""
    n = len(board)
    attacks = 0
    for i in range(n):
        for j in range(i + 1, n):
            # Check horizontal attacks
            if board[i] == board[j]:
                attacks += 1
            # Check diagonal attacks
            if abs(board[i] - board[j]) == abs(i - j):
                attacks += 1
    return attacks

def get_neighbor(board):
    """Generates a neighboring state by randomly moving one queen."""
    n = len(board)
```

```
    new_board = list(board)
    queen_to_move = random.randint(0, n - 1)
    new_position = random.randint(0, n - 1)
    new_board[queen_to_move] = new_position
    return tuple(new_board)

def simulated_annealing(n, initial_temperature, cooling_rate, iterations):
    """Solves the N-Queens problem using Simulated Annealing."""
    current_board = tuple(random.randint(0, n - 1) for _ in range(n))
    current_energy = calculate_attacks(current_board)
    best_board = current_board
    best_energy = current_energy
    temperature = initial_temperature

    for i in range(iterations):
        if temperature <= 0:
            break

        neighbor_board = get_neighbor(current_board)
        neighbor_energy = calculate_attacks(neighbor_board)

        # If neighbor is better, accept it
        if neighbor_energy < current_energy:
            current_board = neighbor_board
            current_energy = neighbor_energy
            if current_energy < best_energy:
                best_energy = current_energy
                best_board = current_board
        # If neighbor is worse, accept with a probability
        else:
            probability = math.exp((current_energy - neighbor_energy) / temperature)
            if random.random() < probability:
                current_board = neighbor_board
                current_energy = neighbor_energy

        temperature *= cooling_rate

        if current_energy == 0:  # Found a solution
            break

    return best_board, best_energy

def print_board(board):
    """Prints the N-Queens board."""
    n = len(board)
    for row in range(n):
        line = ["Q" if board[col] == row else "." for col in range(n)]
        print(" ".join(line))
```

```
if __name__ == "__main__":
    N = 4  # For the 4-Queens problem
    initial_temp = 100
    cooling_rate = 0.99
    num_iterations = 10000

    solution_board, solution_attacks = simulated_annealing(N, initial_temp, cooling_rate,
num_iterations)

    print(f"Final board configuration: {solution_board}")
    print(f"Number of attacks: {solution_attacks}")

    if solution_attacks == 0:
        print("\nSolution found:")
        print_board(solution_board)
    else:
        print("\nNo perfect solution found within iterations. Best found:")
        print_board(solution_board)
```

Program 6

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

Algorithm:

16/10/25

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

→ Algorithm:

Step 1 Input the query and knowledge base

Step 2 Call the function to check whether the entailment is true

Step 3 Check if any symbols are left. If it is empty, then call function else return true

Step 4 Generate all possible combinations

Step 5 For each model, check if KB is true and if it is true, check if query is also true

Step 6 In model where both KB and query is true, entailment exists, and in cases KB is true but query is false, there is no entailment

→ Pseudocode

```
symbol ← all unique prepositions
model ← all possible combinations.
for each model m in model:
        evaluate_KB ← Evaluate(KB, M)
        evaluate_Q ← Evaluate(Q, M)
        if evaluate_KB == true
                if evaluate_Q == true
                        return ("entailed")
        else
                return ("not entailed")
```

1. $Q \to P$
$P \to \sim Q$
$Q \lor R$

Truth Table

	P	Q	R	$Q \to P$	$P \to \sim Q$	$Q \lor R$	KB
1.	T	T	T	T	f	T	NO
2.	T	T	f	T	f	T	No
3.	T	f	T	T	T	T	yes
4.	T	f	f	T	T	F	NO
5	f	T	T	f	T	T	NO
6.	f	T	f	F	T	T	NO
7	f	f	T	T	T	T	Yes
8	f	f	f	T	T	f	NO

KB ~~entails~~ is true for row 3 and 7

(i) Does KB entail R

Yes KB entails R because when KB is true, R is also true in both row 3 and 7

Hence KB entails R

(ii) Does KB entail $R \to P$?

~~Yes, it entails $R \to R$~~

when KB = true

in row 3 premises – R = T and P = T

so, $R \to P$ is T

So it ~~entails~~

in row 7 R = T and P = f

$R \to P$ is false

So, it doesnot entail

(iii) Does KB entail $Q \to R$?

in row 3: Q = f R = T

$Q \to R$ is true.

in row 7: Q = f R = T

$Q \to R$ is true

Hence, KB entails $Q \to R$

16/10

→ Input:

$P \to Q$, $Q \to P$, $Q \lor R$

conclusion – "R"

→ Output

P	Q	R	$P \to \neg Q$	$Q \to P$	$Q \lor R$	R
False	False	f	T	T	f	f
False	False	T	T	T	T	T
False	True	f	T	f	T	f
False	True	T	T	f	T	T
True	False	f	T	T	f	f
True	False	T	T	T	T	T
True	True	f	f	T	T	f
True	True	T	f	T	T	T

Yes, the premises entail the conclusion

Code:

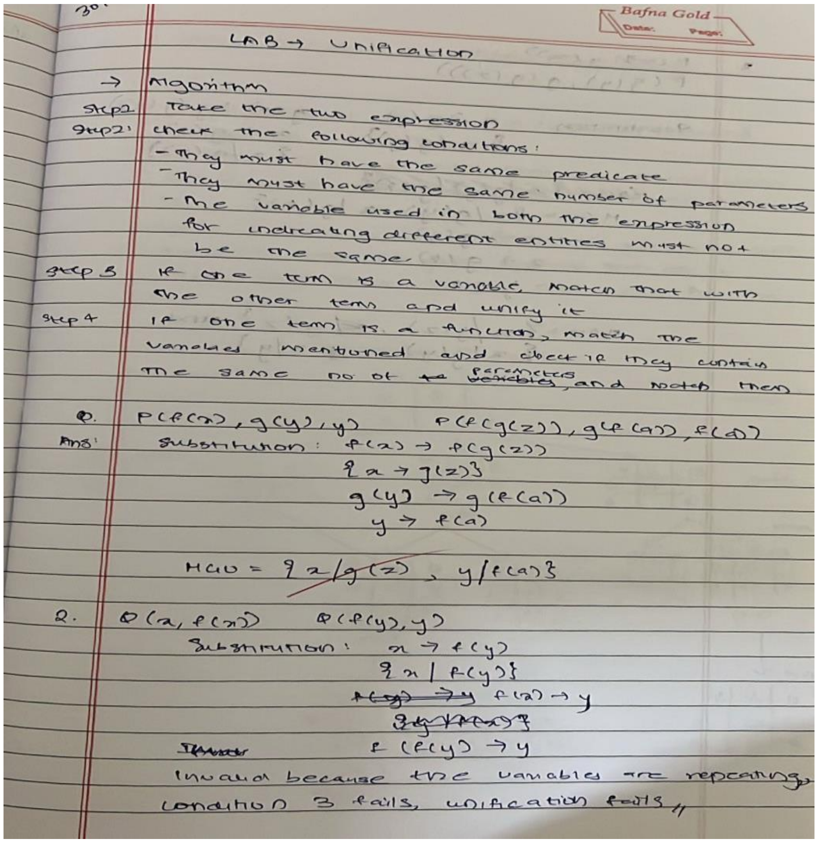
```
import pandas as pd
import itertools

# Define propositions
props = ['P', 'Q', 'R']

# Generate all truth assignments for P, Q, R
truth_values = list(itertools.product([False, True], repeat=3))

def implies(a, b):
    return (not a) or b

# Evaluate KB sentences and entailments
rows = []
for (P, Q, R) in truth_values:
    sentence1 = implies(Q, P)        # Q -> P
    sentence2 = implies(P, not Q)    # P -> ¬Q
    sentence3 = Q or R               # Q ∨ R

    kb_true = sentence1 and sentence2 and sentence3

    entail_R = R
    entail_R_implies_P = implies(R, P)
    entail_Q_implies_R = implies(Q, R)

    rows.append({
        'P': P, 'Q': Q, 'R': R,
        'Q->P': sentence1,
        'P->¬Q': sentence2,
        'Q∨R': sentence3,
        'KB True': kb_true,
        'Entail R': entail_R,
        'Entail R->P': entail_R_implies_P,
        'Entail Q->R': entail_Q_implies_R
    })

# Create DataFrame
df = pd.DataFrame(rows)

# Filter models where KB is true
models_where_KB_true = df[df['KB True']]

# Print full truth table
print("Full Truth Table:\n")
print(df.to_string(index=False))
```

```
# Checking entailments (whether KB entails each sentence)
# KB entails a sentence if the sentence is true in all models where KB is true
entail_R_result = models_where_KB_true['Entail R'].all()
entail_R_implies_P_result = models_where_KB_true['Entail R->P'].all()
entail_Q_implies_R_result = models_where_KB_true['Entail Q->R'].all()

print("\nModels where KB is True:")
print(models_where_KB_true.to_string(index=False))

print("\nEntailment Results:")
print(f"Does KB entail R? {'Yes' if entail_R_result else 'No'}")
print(f"Does KB entail R -> P? {'Yes' if entail_R_implies_P_result else 'No'}")
print(f"Does KB entail Q -> R? {'Yes' if entail_Q_implies_R_result else 'No'}")
```

Program 7

Implement unification in first order logic

Algorithm:



LAB → Unification

→ Algorithm

Step1: Take the two expression

Step2: check the following conditions:

- They must have the same predicate
- They must have the same number of parameters
- The variable used in both the expression for indicating different entities must not be the same

Step 3: If one term is a variable, match that with the other term and unify it

Step 4: If one term is a function, match the variables mentioned and check if they contain the same no of parameters, and match them

Q. P(f(x), g(y), y)   P(f(g(z)), g(f(a)), f(a))

Ans: Substitution: f(x) → f(g(z))

{x → g(z)}

g(y) → g(f(a))

y → f(a)

MGU = {~~x/g(z)~~, y/f(a)}

Q. Q(x, f(x))   Q(f(y), y)

Substitution: x → f(y)

{x / f(y)}

~~f(y) → y~~ f(x) → y

f(f(y)) → y

Invalid because the variables are repeating, condition 3 fails, unification fails//

Code:

```
import re

def is_variable(x):
    return isinstance(x, str) and x[0].islower() and x.isalpha()

def parse_term(term):
    # Parses a function or constant or variable into structured form
    term = term.strip()
    if '(' not in term:
        return term
    functor, args_str = term.split('(', 1)
    args = []
    depth = 0
    current = ''
    for ch in args_str[:-1]:  # skip last ')'
        if ch == ',' and depth == 0:
            args.append(parse_term(current.strip()))
            current = ''
```

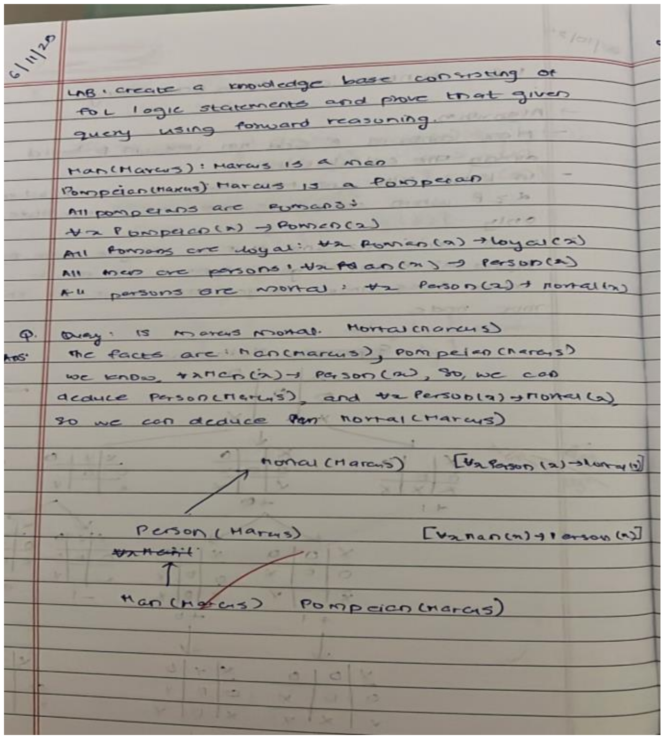
```
        else:
            if ch == '(':
                depth += 1
            elif ch == ')':
                depth -= 1
            current += ch
    if current:
        args.append(parse_term(current.strip()))
    return (functor.strip(), args)

def occurs_check(var, x, subst):
    if var == x:
        return True
    elif isinstance(x, str):
        if x in subst:
            return occurs_check(var, subst[x], subst)
        return False
    elif isinstance(x, tuple):
        return any(occurs_check(var, arg, subst) for arg in x[1])
    return False

def substitute(x, subst):
    if isinstance(x, str):
        # If x is a variable and has a substitution, apply it recursively.
        # This handles chained substitutions like x -> y, y -> f(z).
        if x in subst:
            return substitute(subst[x], subst)
        else:
            # If it's not in the substitution, it's either a constant string
            # or a variable that hasn't been substituted yet.
            return x
    elif isinstance(x, tuple):
        functor, args = x
        return (functor, [substitute(arg, subst) for arg in args])
    return x

def unify(x, y, subst=None):
    if subst is None:
        subst = {}
    x = substitute(x, subst)
    y = substitute(y, subst)
    if x == y:
        return subst
    elif is_variable(x):
        if occurs_check(x, y, subst):
            raise ValueError(f"Occurs check failed for {x} in {y}")
        subst[x] = y
        return subst
```

```
    elif is_variable(y):
        if occurs_check(y, x, subst):
            raise ValueError(f"Occurs check failed for {y} in {x}")
        subst[y] = x
        return subst
    elif isinstance(x, tuple) and isinstance(y, tuple):
        if x[0] != y[0] or len(x[1]) != len(y[1]):
            raise ValueError(f"Functor mismatch: {x[0]} vs {y[0]}")
        for a, b in zip(x[1], y[1]):
            subst = unify(a, b, subst)
        return subst
    else:
        raise ValueError(f"Cannot unify {x} with {y}")

# ----- Test -----
x = parse_term("P(f(x), g(y), y)")
y = parse_term("P(f(g(z)), g(f(a)), f(a))")

print("Parsed terms:")
print("x =", x)
print("y =", y)

try:
    result = unify(x, y)
    print("\nUnification successful!")
    print("Substitution set:")
    for var, val in result.items():
        print(f"  {var} = {val}")
except ValueError as e:
    print("\nUnification failed:", e)
```

Program 8

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

Algorithm:



6/11/20

LAB: create a knowledge base consisting of FOL logic statements and prove that given query using forward reasoning.

Man(Marcus): Marcus is a man
Pompeian(Marcus): Marcus is a Pompeian
All pompeians are Romans:
∀x Pompeian(x) → Roman(x)
All Romans are loyal: ∀x Roman(x) → loyal(x)
All men are persons: ∀x Man(x) → Person(x)
All persons are mortal: ∀x Person(x) → mortal(x)

Q. Query: Is Marcus mortal. Mortal(Marcus)
Ans: The facts are: Man(Marcus), Pompeian(Marcus)
we know, ∀x Man(x) → Person(x), so, we can deduce Person(Marcus), and ∀x Person(x) → Mortal(x), so we can deduce ~~Man~~ Mortal(Marcus)

Mortal(Marcus) [∀x Person(x) → Mortal(x)]
Person(Marcus) [∀x Man(x) → Person(x)]
Man(Marcus) Pompeian(Marcus)

Code:

```
import re

# -------------------------
# Helper functions
# -------------------------

def eliminate_implications(expr):
    """Eliminate implications (A -> B becomes ~A | B)."""
    expr = re.sub(r'\((.*?)\)->\((.*?)\)', r'(~(\1)|(\2))', expr)
    return expr

def move_not_inwards(expr):
    """Apply De Morgan's laws and double negation elimination."""
    expr = expr.replace("~~", "")
    expr = expr.replace("~(A&B)", "(~A|~B)")
    expr = expr.replace("~(A|B)", "(~A&~B)")
    return expr
```

```
def standardize_variables(expr):
    """Rename variables to avoid clashes."""
    # For demo, just ensure lowercase vars get unique suffixes
    var_map = {}
    count = 0
    new_expr = ""
    for ch in expr:
        if ch.islower() and ch.isalpha():
            if ch not in var_map:
                var_map[ch] = chr(ord('a') + count)
                count += 1
            new_expr += var_map[ch]
        else:
            new_expr += ch
    return new_expr

def skolemize(expr):
    """Replace existential quantifiers with Skolem constants/functions."""
    expr = re.sub(r'∃[a-z]₩.', '', expr)  # Remove existential quantifier
    return expr.replace("x", "c")  # Replace var with Skolem constant (simple demo)

def drop_universal(expr):
    """Remove universal quantifiers (implicit in CNF)."""
    expr = re.sub(r'∀[a-z]₩.', '', expr)
    return expr

def distribute_or_over_and(expr):
    """Simplified distribution (only handles basic patterns)."""
    # In a full implementation you'd need a tree structure, not regex.
    return expr.replace("|", "∨").replace("&", "∧")

# -------------------------
# Main CNF conversion function
# -------------------------

def fol_to_cnf(expr):
    print("Original:", expr)
    expr = eliminate_implications(expr)
    print("→ No implications:", expr)
    expr = move_not_inwards(expr)
    print("→ Negations inward:", expr)
    expr = standardize_variables(expr)
    print("→ Standardized vars:", expr)
    expr = skolemize(expr)
    print("→ Skolemized:", expr)
    expr = drop_universal(expr)
    print("→ Dropped universals:", expr)
```

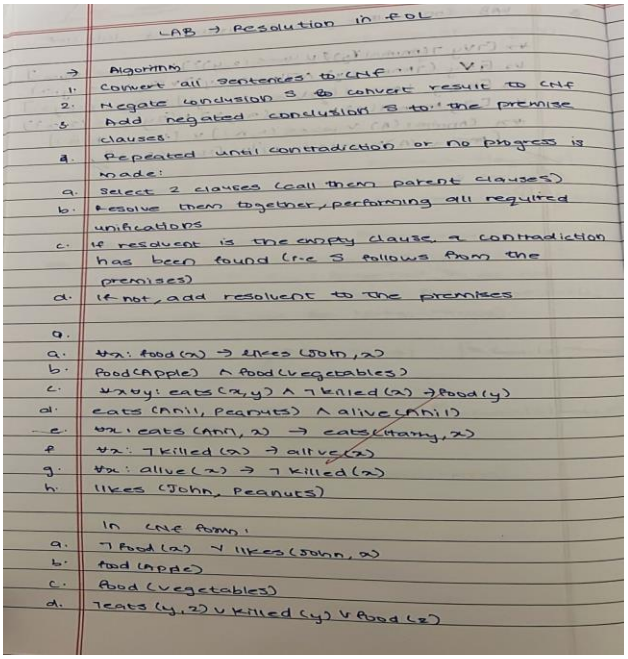
```
    expr = distribute_or_over_and(expr)
    print("→ CNF form:", expr)
    return expr

# ------------------------
# Example usage
# ------------------------

formula = "∀x.(P(x) -> ∃y.(Q(y) & R(x,y)))"
cnf = fol_to_cnf(formula)
print("\nFinal CNF:", cnf)

# Simple Forward Reasoning (Forward Chaining) in FOL

# Knowledge Base (Facts + Rules)
# Rules are written in the form: (premises, conclusion)
# Facts are just single statements

def forward_chaining(kb, query):
    facts = set()
    rules = []

    # Separate facts and rules
    for statement in kb:
        if "=>" in statement:
            premises, conclusion = statement.split("=>")
            premises = set(p.strip() for p in premises.split("&"))
            rules.append((premises, conclusion.strip()))
        else:
            facts.add(statement.strip())

    print("Initial Facts:", facts)
    print("Rules:", rules)
    print("Query:", query)

    inferred = True
    while inferred:
        inferred = False
        for premises, conclusion in rules:
            # Check if all premises are in facts
            if premises.issubset(facts) and conclusion not in facts:
                facts.add(conclusion)
                print(f"Inferred: {conclusion}")
                inferred = True
                if conclusion == query:
                    print("Query proven!")
                    return True
```

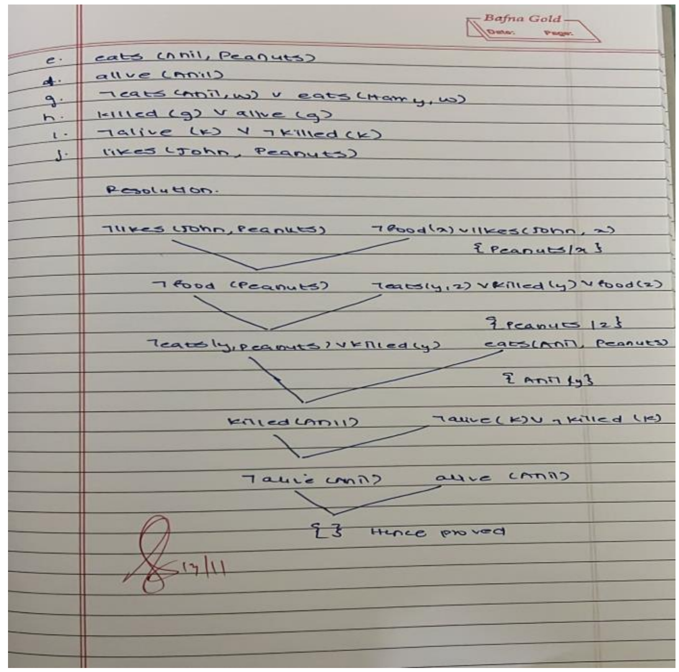
```
    print("Query cannot be proven.")
    return False


# Example Knowledge Base
kb = [
    "A",                    # Fact
    "A & B => C",           # Rule 1
    "C => D",               # Rule 2
    "D & E => F",           # Rule 3
    "B"                     # Fact
]

query = "D"

# Run forward chaining
forward_chaining(kb, query)
```

Program 9

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

Algorithm:





Code:

```
# Simple Forward Reasoning (Forward Chaining) in FOL
# Knowledge Base (Facts + Rules)
# Rules are written in the form: (premises, conclusion)
# Facts are just single statements

def forward_chaining(kb, query):
    facts = set()
    rules = []

    # Separate facts and rules
    for statement in kb:
        if "=>" in statement:
            premises, conclusion = statement.split("=>")
            premises = set(p.strip() for p in premises.split("&"))
            rules.append((premises, conclusion.strip()))
        else:
            facts.add(statement.strip())

    print("Initial Facts:", facts)
    print("Rules:", rules)
    print("Query:", query)
```

```
    inferred = True
    while inferred:
        inferred = False
        for premises, conclusion in rules:
            # Check if all premises are in facts
            if premises.issubset(facts) and conclusion not in facts:
                facts.add(conclusion)
                print(f"Inferred: {conclusion}")
                inferred = True
                if conclusion == query:
                    print("Query proven!")
                    return True

    print("Query cannot be proven.")
    return False


# Example Knowledge Base
kb = [
    "A",                    # Fact
    "A & B => C",           # Rule 1
    "C => D",               # Rule 2
    "D & E => F",           # Rule 3
    "B"                     # Fact
]

query = "D"

# Run forward chaining
forward_chaining(kb, query)
```

Resolution:

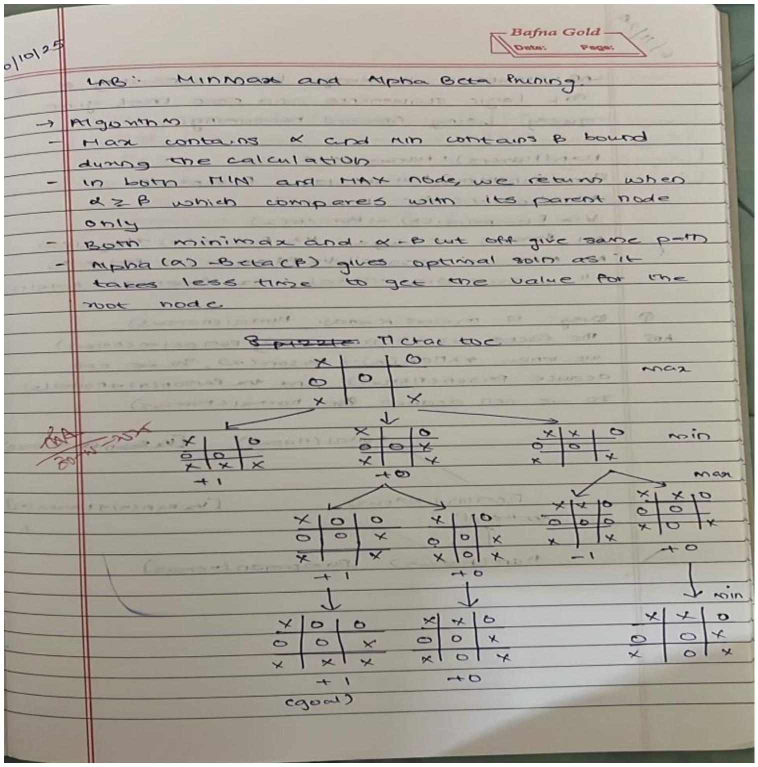
```
!pip install sympy

from sympy import symbols, Or, Not, And
from sympy.logic.inference import satisfiable

# Define propositional atoms (grounded)
food_Apple, food_Veg, food_Peanuts = symbols('food_Apple food_Veg food_Peanuts')
likes_John_Apple, likes_John_Veg, likes_John_Peanuts = symbols('likes_John_Apple
likes_John_Veg likes_John_Peanuts')
eats_Anil_Peanuts, killed_Anil, alive_Anil = symbols('eats_Anil_Peanuts killed_Anil alive_Anil')

# --- Knowledge Base (grounded CNF clauses) ---
KB = [
    Or(Not(food_Peanuts), likes_John_Peanuts),      # a. ¬food(Peanuts) ∨
likes(John, Peanuts)
    food_Apple,                              # b. food(Apple)
```

```
    food_Veg,                                    # c. food(vegetables)
    Or(Not(eats_Anil_Peanuts), killed_Anil, food_Peanuts), # d. ¬eats(Anil,
Peanuts) ∨ killed(Anil) ∨ food(Peanuts)
    eats_Anil_Peanuts,                           # e. eats(Anil, Peanuts)
    alive_Anil,                                  # f. alive(Anil)
    Or(killed_Anil, Not(alive_Anil)),            # h. killed(Anil) ∨ ¬alive(Anil)
    Or(Not(alive_Anil), Not(killed_Anil))        # i. ¬alive(Anil) ∨
¬killed(Anil)
]

# --- Negated conclusion ---
negated_conclusion = Not(likes_John_Peanuts)
KB.append(negated_conclusion)

# --- Check satisfiability ---
result = satisfiable(And(*KB))

if result is False:
    print("Conclusion PROVED by resolution: likes(John, Peanuts)")
else:
    print("Conclusion NOT proved.")
    print("Satisfying model (means no contradiction):")
    print(result)
```

Program 10

Implement Alpha-Beta Pruning.

Algorithm:



Bafna Gold
Date: Page:

0/10/25

LAB: MinMax and Alpha Beta Pruning.

→ Algorithm
- Max contains α and min contains β bound during the calculation
- in both MIN and MAX node, we return when $\alpha \geq \beta$ which compares with its parent node only
- Both minimax and α-β cut off give same path
- Alpha (α) -Beta (β) gives optimal soln as it takes less time to get the value for the root node.

~~8 puzzle~~ Tic tac toe

max

min

max

min

+1

+0

+1

+0

-1

+0

+1

(goal)

+0

Code:

```
import math

def alpha_beta_pruning(state, depth, alpha, beta, maximizing_player):
    # Base case: leaf node or maximum depth reached
    if depth == 0 or is_goal_state(state):
        return heuristic_value(state)

    if maximizing_player:
        max_eval = -math.inf
        for child_state in get_possible_moves(state):
            eval = alpha_beta_pruning(child_state, depth - 1, alpha, beta, False)
            max_eval = max(max_eval, eval)
            alpha = max(alpha, eval)
            if beta <= alpha:
                break  # Beta cutoff
        return max_eval
    else:  # Minimizing player
        min_eval = math.inf
```

```
        for child_state in get_possible_moves(state):
            eval = alpha_beta_pruning(child_state, depth - 1, alpha, beta, True)
            min_eval = min(min_eval, eval)
            beta = min(beta, eval)
            if beta <= alpha:
                break  # Alpha cutoff
        return min_eval

def is_goal_state(state):
    """Checks if the current state is the solved 8-puzzle."""
    # Assuming the goal state is a flattened list [1, 2, 3, 4, 5, 6, 7, 8, 0]
    return state == [1, 2, 3, 4, 5, 6, 7, 8, 0]

def heuristic_value(state):
    """Calculates the Manhattan distance heuristic for the 8-puzzle."""
    goal_state = {
        1: (0, 0), 2: (0, 1), 3: (0, 2),
        4: (1, 0), 5: (1, 1), 6: (1, 2),
        7: (2, 0), 8: (2, 1), 0: (2, 2)
    }
    manhattan_distance = 0
    for i in range(3):
        for j in range(3):
            tile = state[i * 3 + j]
            if tile != 0:
                goal_pos = goal_state[tile]
                manhattan_distance += abs(i - goal_pos[0]) + abs(j - goal_pos[1])
    return manhattan_distance

def get_possible_moves(state):
    """Returns a list of all possible next states from the current state."""
    possible_moves = []
    zero_index = state.index(0)
    zero_row, zero_col = divmod(zero_index, 3)

    # Define possible movements (up, down, left, right)
    movements = [(-1, 0), (1, 0), (0, -1), (0, 1)]

    for move_row, move_col in movements:
        new_row, new_col = zero_row + move_row, zero_col + move_col

        # Check if the new position is within the board boundaries
        if 0 <= new_row < 3 and 0 <= new_col < 3:
            new_state = list(state)  # Create a mutable copy of the state
            swap_index = new_row * 3 + new_col
            # Swap the blank tile with the tile at the new position
            new_state[zero_index], new_state[swap_index] = new_state[swap_index],
new_state[zero_index]
```

```
            possible_moves.append(new_state)

    return possible_moves
initial_state = [1, 2, 0, 3, 4, 5, 6, 7, 8]
initial_depth = 5

print(f"Initial State: {initial_state}")
print(f"Initial Depth: {initial_depth}")
best_value = alpha_beta_pruning(initial_state, initial_depth, -math.inf, math.inf, True)
print(f"Best value found: {best_value}")
print(f"The result of the alpha-beta pruning (best value from the initial state) is: {best_value}")
```

Minimax:

```
import math

# Represents the players
X = 'X'
O = 'O'
EMPTY = ' '

def check_winner(board):
    """
    Checks if there's a winner on the board.
    Returns X if X wins, O if O wins, None if no winner yet, or 'Tie' if full and no winner.
    """
    # Check rows
    for row in board:
        if row[0] == row[1] == row[2] and row[0] != EMPTY:
            return row[0]
    # Check columns
    for col in range(3):
        if board[0][col] == board[1][col] == board[2][col] and board[0][col] != EMPTY:
            return board[0][col]
    # Check diagonals
    if board[0][0] == board[1][1] == board[2][2] and board[0][0] != EMPTY:
        return board[0][0]
    if board[0][2] == board[1][1] == board[2][0] and board[0][2] != EMPTY:
        return board[0][2]

    # Check for tie (no winner and board is full)
    if all(cell != EMPTY for row in board for cell in row):
        return 'Tie'

    return None

def minimax(board, is_maximizing_player):
    """
```

```
    Implements the Minimax algorithm to find the optimal move.
    is_maximizing_player is True for 'X' (AI), False for 'O' (opponent).
    """
    winner = check_winner(board)
    if winner == X:
        return 1  # X wins, maximizing player gets a high score
    elif winner == O:
        return -1 # O wins, minimizing player gets a low score
    elif winner == 'Tie':
        return 0 # Tie game

    if is_maximizing_player:
        best_score = -math.inf
        for r in range(3):
            for c in range(3):
                if board[r][c] == EMPTY:
                    board[r][c] = X # Make the move
                    score = minimax(board, False)
                    board[r][c] = EMPTY # Undo the move
                    best_score = max(best_score, score)
        return best_score
    else: # Minimizing player
        best_score = math.inf
        for r in range(3):
            for c in range(3):
                if board[r][c] == EMPTY:
                    board[r][c] = O # Make the move
                    score = minimax(board, True)
                    board[r][c] = EMPTY # Undo the move
                    best_score = min(best_score, score)
        return best_score

def find_best_move(board):
    """
    Finds the best move for the AI (X) using the Minimax algorithm.
    """
    best_score = -math.inf
    best_move = None

    for r in range(3):
        for c in range(3):
            if board[r][c] == EMPTY:
                board[r][c] = X # Try the move
                score = minimax(board, False) # Evaluate the board state
                board[r][c] = EMPTY # Undo the move

                if score > best_score:
                    best_score = score
```

```
                best_move = (r, c)
    return best_move

def print_board(board):
    """Prints the Tic-Tac-Toe board."""
    for row in board:
        print("|".join(row))
        print("-----")

# Example usage:
if __name__ == "__main__":
    # Initial empty board
    board = [[EMPTY, EMPTY, EMPTY],
             [EMPTY, EMPTY, EMPTY],
             [EMPTY, EMPTY, EMPTY]]

    current_player = X

    while check_winner(board) is None:
        print_board(board)
        if current_player == X:
            print("AI's turn (X)")
            move = find_best_move(board)
            if move:
                board[move[0]][move[1]] = X
            else:
                print("No valid moves left for AI.")
                break
        else:
            print("Human's turn (O)")
            while True:
                try:
                    row = int(input("Enter row (0-2): "))
                    col = int(input("Enter column (0-2): "))
                    if 0 <= row <= 2 and 0 <= col <= 2 and board[row][col] == EMPTY:
                        board[row][col] = O
                        break
                    else:
                        print("Invalid move. Try again.")
                except ValueError:
                    print("Invalid input. Please enter numbers.")

        current_player = O if current_player == X else X

    print_board(board)
    final_result = check_winner(board)
    if final_result == 'Tie':
        print("It's a Tie!")
```

```
elif final_result:
    print(f"Player {final_result} wins!")
else:
    print("Game ended unexpectedly.")
```