VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

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

B.M.S. COLLEGE OF ENGINEERING
(Autonomous Institution under VTU)
BENGALURU-560019
Sep-2024 to Jan-2025

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CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Ashwini L (1BM24CS402),** who is bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

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Github Link:

https://github.com/Ashvinigowda/AI

Program 1

Implement Tic –Tac –Toe Game

Implement vacuum cleaner agent

Algorithm:

Week- 01

Tik Tac Toe Implementation

1> Initialize 3×3 matrix

2> Pre define the values in the matrix with '–'

3> Define the winning conditions like $\boxed{\begin{matrix}x\\x\\x\end{matrix}}$ in same row $\boxed{x\ x\ x}$ same column & diagonally $\boxed{x\ x\ x}$

4> Ask the user to enter the row no & column no.

5> Check if the ~~the~~ that row is already occupied or not.

if occupied :

The place you specified is marked already

else :

Mark the place with user symbol O/X.

6> Check for the Step 3 with the current Status of the matrix if there is a match in winning condition.

if yes :

Out put: play x wins.

else :

Continue with Step 5 until the matrix is filled.

If there is no matching condition declare as draw.

Tic Tac Toe code:

```
import math

def print_board(board):
    for row in board:
        print(" | ".join(row))
        print("-" * 5)

def check_winner(board, player):
    # Rows, columns, diagonals
    for row in board:
        if all(cell == player for cell in row):
            return True
    for col in range(3):
        if all(board[row][col] == player for row in range(3)):
            return True
    if all(board[i][i] == player for i in range(3)) or \
       all(board[i][2-i] == player for i in range(3)):
        return True
    return False

def is_full(board):
    return all(cell != " " for row in board for cell in row)

def minimax(board, depth, is_maximizing):
    if check_winner(board, "O"):  # Computer wins
        return 1
    if check_winner(board, "X"):  # Player wins
```

```
        return -1
    if is_full(board):
        return 0
    if is_maximizing:  # Computer's move
        best_score = -math.inf
        for i in range(3):
            for j in range(3):
                if board[i][j] == " ":
                    board[i][j] = "O"
                    score = minimax(board, depth + 1, False)
                    board[i][j] = " "
                    best_score = max(score, best_score)
        return best_score
    else:  # Player's move
        best_score = math.inf
        for i in range(3):
            for j in range(3):
                if board[i][j] == " ":
                    board[i][j] = "X"
                    score = minimax(board, depth + 1, True)
                    board[i][j] = " "
                    best_score = min(score, best_score)
        return best_score
def best_move(board):
```

```
    best_score = -math.inf
    move = None
    for i in range(3):
        for j in range(3):
            if board[i][j] == " ":
                board[i][j] = "O"
                score = minimax(board, 0, False)
                board[i][j] = " "
                if score > best_score:
                    best_score = score
                    move = (i, j)
    return move
def tic_tac_toe():
    board = [[" " for _ in range(3)] for _ in range(3)]
    print("Welcome to Tic-Tac-Toe! You are 'X' and computer is 'O'.")
    print_board(board)
    while True:
        # Player move
        while True:
            try:
                row = int(input("Enter row (0-2): "))
                col = int(input("Enter col (0-2): "))
                if board[row][col] == " ":
                    board[row][col] = "X"
```

```
            break
        else:
            print("Cell already taken, try again.")
    except (ValueError, IndexError):
        print("Invalid input! Enter numbers 0-2.")
print_board(board)
if check_winner(board, "X"):
    print("🎉 You win!")
    break
if is_full(board):
    print("It's a draw!")
    break
# Computer move
print("Computer's turn...")
move = best_move(board)
if move:
    board[move[0]][move[1]] = "O"
print_board(board)
if check_winner(board, "O"):
    print("💻 Computer wins!")
    break
if is_full(board):
    print("It's a draw!")
    break
```

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

Vaccum cleaner code:

```
import random
rooms=[1,1,1,1]
botpos =(int(input("Enter Initial Position: "))-1)
cleanedpos=[]
cost=0
def movebot(pos):
    while True:
        n= random.randint(0,3)
        if n != pos and n not in cleanedpos:
            pos = n
            break
    return pos
while True:
    print(str(rooms))
    print(botpos+1)
    if rooms[botpos]==1:
        rooms[botpos]=0
        cleanedpos.append(botpos)
        cost+=1
        if len(cleanedpos) == 4:
```

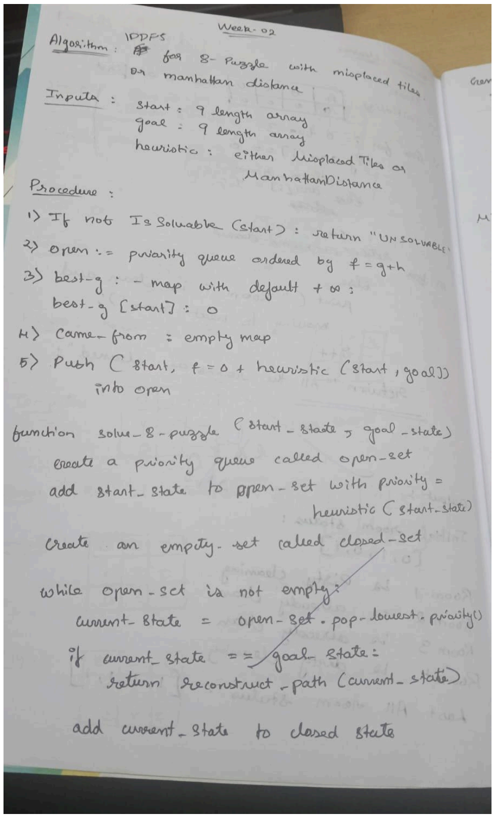
```
            break
        botpos=movebot(botpos)
    elif rooms[botpos]==0:
        cleanedpos.append(botpos)
        if len(cleanedpos) == 4:
            break
        botpos = movebot(botpos)
print("cost="+str(cost))
```

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)

Implement Iterative deepening search algorithm

Algorithm:



Week-02

Algorithm: IDDFS for 8-Puzzle with misplaced tiles or manhattan distance.

Inputs: Start: 9 length array
goal: 9 length array
heuristic: either MisplacedTiles or ManhattanDistance

Procedure:

1> If not IsSolvable (start): return "UNSOLVABLE"
2> open := priority queue ordered by f = g+h
3> best_g : - map with default +∞ ;
best_g [start] : 0
4> Came_from = empty map
5> Push (start, f = 0 + heuristic (start, goal)) into open

function solve_8-puzzle (start_state, goal_state)
create a priority queue called open_set
add start_state to open_set with priority = heuristic (start_state)
Create an empty_set called closed_set
while open_set is not empty:
current_state = open_set.pop_lowest_priority()
if current_state == goal_state:
return reconstruct_path (current_state)
add current_state to closed state

DFS code:

```
import time

def find_possible_moves(state):

    index = state.index('_')

    moves = {

        0: [1, 3],

        1: [0, 2, 4],

        2: [1, 5],
```

```
        3: [0, 4, 6],
        4: [1, 3, 5, 7],
        5: [2, 4, 8],
        6: [3, 7],
        7: [6, 8, 4],
        8: [5, 7],
    }
    return moves.get(index, [])
def dfs(initial_state, goal_state, max_depth=50):
    stack = [(initial_state, [], 0)]
    visited = {tuple(initial_state)}
    states_explored = 0
    printed_depths = set()
    while stack:
        current_state, path, depth = stack.pop()
        if depth > max_depth:
            continue
        if depth not in printed_depths:
            print(f"\n--- Depth {depth} ---")
            printed_depths.add(depth)
        states_explored += 1
        print(f"State #{states_explored}: {current_state}")
        if current_state == goal_state:
            print(f"\n Goal reached at depth {depth} after exploring {states_explored} states.\n")
```

```
            return path, states_explored

        possible_moves_indices = find_possible_moves(current_state)

        for move_index in reversed(possible_moves_indices):  # Reverse for DFS order

            next_state = list(current_state)

            blank_index = next_state.index('_')

            next_state[blank_index], next_state[move_index] = next_state[move_index],
next_state[blank_index]

            if tuple(next_state) not in visited:

                visited.add(tuple(next_state))

                stack.append((next_state, path + [next_state], depth + 1))

    print(f"\n Goal state not reachable within depth {max_depth}. Explored {states_explored} states.\n")

    return None, states_explored

# ----------------- TEST -----------------

initial_state = [1, 2, 3,

                 4, 8, '_',

                 7, 6, 5]

goal_state    = [1, 2, 3,

                 4, 5, 6,

                 7, 8, '_']

# Measure execution time

start_time = time.time()

solution_path, explored = dfs(initial_state, goal_state, max_depth=50)

end_time = time.time()

if solution_path is None:

    print("No solution found.")
```

```
else:
    print("Solution path:")
    for step, state in enumerate(solution_path, start=1):
        print(f"Step {step}: {state}")
print("\nExecution time: {:.6f} seconds".format(end_time - start_time))
print("Total states explored:", explored)
```

IDDFS code:

```
import time
# ----------------- MOVE GENERATOR -----------------
def find_possible_moves(state):
    index = state.index('_')
    if index == 0:
        return [1, 3]
    elif index == 1:
        return [0, 2, 4]
    elif index == 2:
        return [1, 5]
    elif index == 3:
        return [0, 4, 6]
    elif index == 4:
        return [1, 3, 5, 7]
    elif index == 5:
        return [2, 4, 8]
```

```
    elif index == 6:
        return [3, 7]
    elif index == 7:
        return [4, 6, 8]
    elif index == 8:
        return [5, 7]
    return []
# ----------------- DEPTH LIMITED SEARCH -----------------
def depth_limited_dfs(state, goal_state, limit, path, visited):
    if state == goal_state:
        return path
    if limit <= 0:
        return None
    visited.add(tuple(state))
    for move_index in find_possible_moves(state):
        next_state = list(state)
        blank_index = next_state.index('_')
        next_state[blank_index], next_state[move_index] = next_state[move_index], next_state[blank_index]
        if tuple(next_state) not in visited:
            result = depth_limited_dfs(next_state, goal_state, limit - 1, path + [next_state], visited)
            if result is not None:
                return result
    return None
# ----------------- ITERATIVE DEEPENING DFS -----------------
```

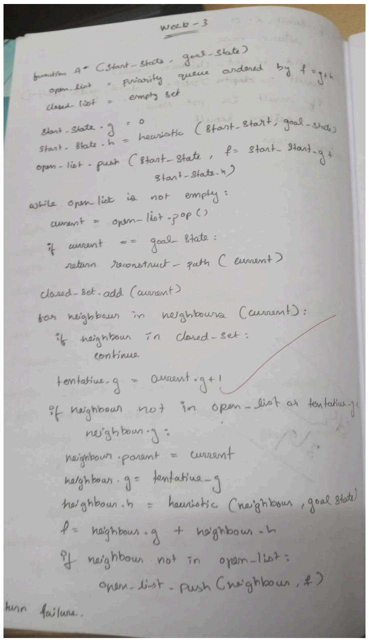
```
def iddfs(initial_state, goal_state, max_depth=30):
    for depth in range(max_depth):
        print(f"Searching at depth limit = {depth}")
        visited = set()
        result = depth_limited_dfs(initial_state, goal_state, depth, [initial_state], visited)
        if result is not None:
            return result, depth
    return None, max_depth
# ----------------- TEST -----------------
initial_state = [1, 2, 3,
                 4, 8, '_',
                 7, 6, 5]
goal_state    = [1, 2, 3,
                 4, 5, 6,
                 7, 8, '_']
# Measure execution time
start_time = time.time()
solution_path, depth_reached = iddfs(initial_state, goal_state, max_depth=30)
end_time = time.time()
if solution_path is None:
    print("Goal state is not reachable within given depth limit.")
else:
    print("\n\nSolution path found:")
    for step, state in enumerate(solution_path, start=0):
```

```
    print(f"Step {step}: {state}")
print("\nExecution time: {:.6f} seconds".format(end_time - start_time))
print("Depth reached:", depth_reached)
```

Program 3

Implement A* search algorithm

Algorithm:



```
Week - 3
function A* (start_state, goal_state)
  open_list = priority queue ordered by f = g+h
  closed list = empty set

start_state.g = 0
start_state.h = heuristic (start_start, goal_state)
open_list.push (start_state, f = start_start.g +
                start_state.h)
while open_list is not empty:
  current = open_list.pop()
  if current == goal_state:
    return reconstruct_path (current)
  closed_set.add (current)
  for neighbour in neighbours (current):
    if neighbour in closed_set:
        continue
    tentative_g = current.g+1
    if neighbour not in open_list or tentative_g
        neighbour.g :
      neighbour.parent = current
      neighbour.g = tentative_g
      neighbour.h = heuristic (neighbour, goal_state)
      f = neighbour.g + neighbour.h
      if neighbour not in open_list:
        open_list.push (neighbour, f)
return failure.
```

A* code:

```
import heapq

def state_key(state):
    return ",".join(map(str, state))

def is_solvable(state):
    inversions = 0
    arr = [x for x in state if x != 0]
    for i in range(len(arr)):
        for j in range(i+1, len(arr)):
            if arr[i] > arr[j]:
                inversions += 1
    return inversions % 2 == 0
```

```
def manhattan(state):
    total = 0
    for index, val in enumerate(state):
        if val == 0:
            continue
        goal_idx = val - 1
        curr_row, curr_col = divmod(index, 3)
        goal_row, goal_col = divmod(goal_idx, 3)
        total += abs(curr_row - goal_row) + abs(curr_col - goal_col)
    return total
def get_neighbours(state):
    neighbours = []
    blank_idx = state.index(0)
    row, col = divmod(blank_idx, 3)
    moves = []
    if row > 0: moves.append(blank_idx - 3)
    if row < 2: moves.append(blank_idx + 3)
    if col > 0: moves.append(blank_idx - 1)
    if col < 2: moves.append(blank_idx + 1)
    for m in moves:
        new_state = list(state)
        new_state[blank_idx], new_state[m] = new_state[m], new_state[blank_idx]
        neighbours.append(tuple(new_state))
    return neighbours
```

```
def reconstruct_path(came_from, current_key):
    path = []
    while current_key in came_from:
        path.append(tuple(map(int, current_key.split(","))))
        current_key = came_from[current_key]
    path.append(tuple(map(int, current_key.split(","))))
    path.reverse()
    return path
def a_star(start_state, goal_state):
    if not is_solvable(start_state):
        return "UNSOLVABLE"
    start_key = state_key(start_state)
    goal_key = state_key(goal_state)
    if start_key == goal_key:
        return [start_state]
    open_heap = []
    g_score = {start_key: 0}
    f_score = {start_key: manhattan(start_state)}
    came_from = {}
    heapq.heappush(open_heap, (f_score[start_key], manhattan(start_state), start_state))
    closed = set()
    while open_heap:
        f_current, h_current, current_state = heapq.heappop(open_heap)
        current_key = state_key(current_state)
```

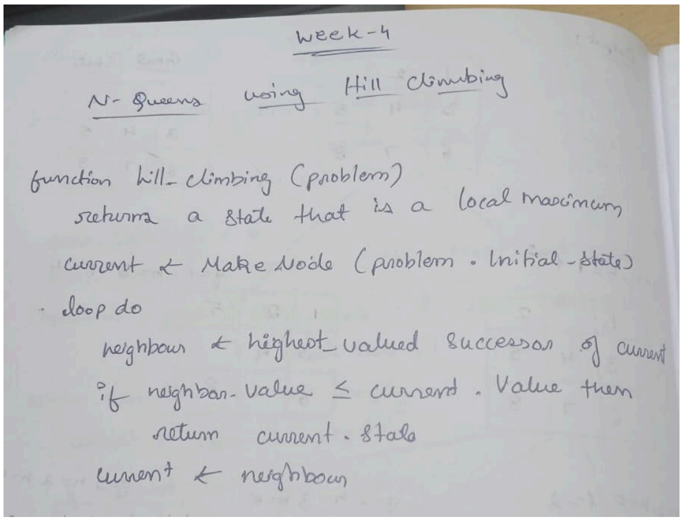
```
            if f_current > f_score.get(current_key, float("inf")):
                continue
            if current_key == goal_key:
                return reconstruct_path(came_from, current_key)
            closed.add(current_key)
            for neighbour in get_neighbours(current_state):
                neighbour_key = state_key(neighbour)
                tentative_g = g_score[current_key] + 1
                if neighbour_key in closed and tentative_g >= g_score.get(neighbour_key, float("inf")):
                    continue
                if tentative_g < g_score.get(neighbour_key, float("inf")):
                    came_from[neighbour_key] = current_key
                    g_score[neighbour_key] = tentative_g
                    h = manhattan(neighbour)
                    f = tentative_g + h
                    f_score[neighbour_key] = f
                    heapq.heappush(open_heap, (f, h, neighbour))
        return "FAILURE"
    if __name__ == "__main__":
        print("Enter start state of the puzzle (9 numbers, 0 for blank space):")
        user_input = input().strip().split()
        if len(user_input) != 9:
            print("Invalid input! Please enter exactly 9 numbers")
            exit()
```

```
try:
    start = tuple(map(int, user_input))
except ValueError:
    print("Invalid input! Please enter integers only")
    exit()
goal = (1, 2, 3,
        4, 5, 6,
        7, 8, 0)
solution = a_star(start, goal)
if solution == "UNSOLVABLE":
    print("Puzzle cannot be solved!")
elif solution == "FAILURE":
    print("No solution found")
else:
    print("Solution found in", len(solution) - 1, "moves:")
    for state in solution:
        for i in range(0, 9, 3):
            print(state[i:i+3])
        print("-----")
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:



week-4

N-Queens using Hill Climbing

function hill-climbing (problem)
returns a state that is a local maximum

current ← Make Node (problem . Initial-state)

loop do

neighbour ← highest_valued successor of current

if neighbor. value ≤ current . Value then

return current . state

current ← neighbour

Hill Climbing code:

```
def print_board(state):

    """Prints the 4x4 board representation with 'Q' and '.'."""

    n = len(state)

    for row in range(n):

        for col in range(n):

            if state[col] == row:

                print("Q", end=" ")

            else:

                print(".", end=" ")

        print()

    print()

def calculate_cost(state):
```

```
    """Returns number of attacking pairs of queens."""
    cost = 0
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            # same row
            if state[i] == state[j]:
                cost += 1
            # same diagonal
            elif abs(state[i] - state[j]) == abs(i - j):
                cost += 1
    return cost
def get_neighbors(state):
    """Generates all neighbors by swapping two queen positions."""
    neighbors = []
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            neighbor = state.copy()
            neighbor[i], neighbor[j] = neighbor[j], neighbor[i]
            neighbors.append((neighbor, (i, j)))
    return neighbors
def hill_climbing(state):
    print("\nInitial State:", state)
```

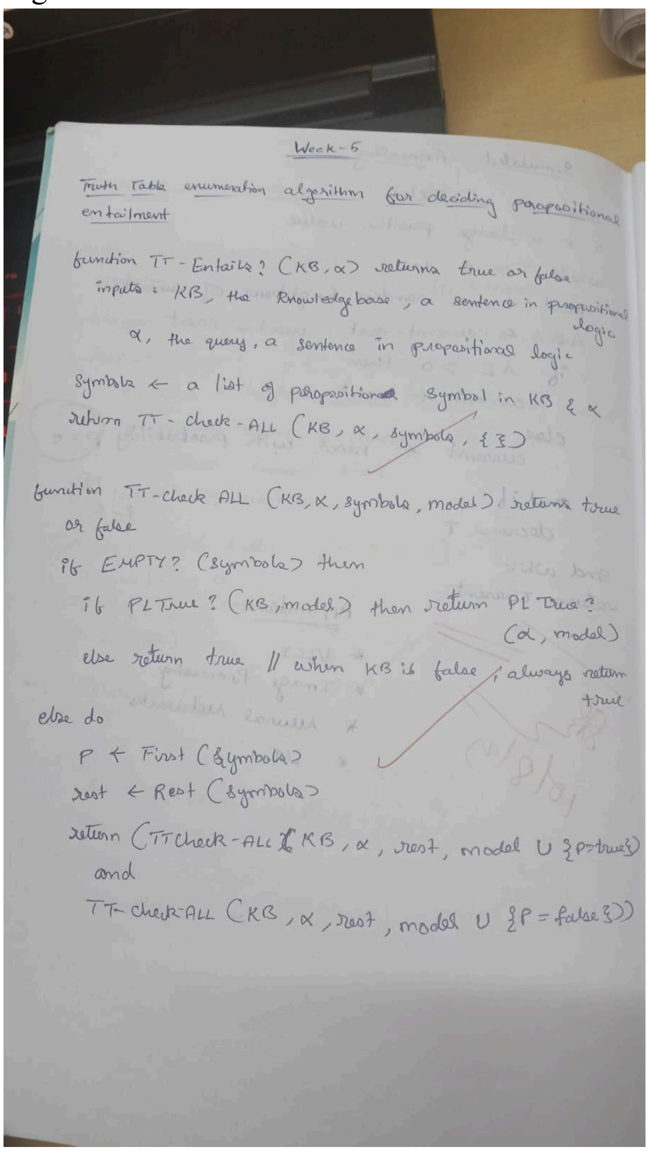
```
print_board(state)
current_cost = calculate_cost(state)
step = 1
while True:
    print(f"Step {step}: Current cost = {current_cost}")
    neighbors = get_neighbors(state)
    neighbor_costs = []
    # Calculate cost for all neighbors
    for neighbor, swapped in neighbors:
        cost = calculate_cost(neighbor)
        neighbor_costs.append((cost, neighbor, swapped))
    # Sort by cost and then by smallest column pair as per rules
    neighbor_costs.sort(key=lambda x: (x[0], x[2][0], x[2][1]))
    # Display neighbor costs
    print("Neighbor states and their costs:")
    for cost, neighbor, swapped in neighbor_costs:
        print(f"Swap x{swapped[0]} & x{swapped[1]} => {neighbor}, Cost = {cost}")
    best_cost, best_state, swap = neighbor_costs[0]
    print("\nBest Neighbor after swap", swap, "is", best_state, "with cost =", best_cost)
    print_board(best_state)
    if best_cost >= current_cost:  # No improvement (local minimum)
        print("No better neighbor found. Hill Climbing terminated.")
        print("Final state:", state)
        print_board(state)
```

```
            break
        else:
            state = best_state
            current_cost = best_cost
        if current_cost == 0:
            print("Goal state reached!")
            print_board(state)
            break
        step += 1
# ---------------- MAIN ----------------
if __name__ == "__main__":
    print("Hill Climbing for 4-Queens Problem")
    print("Enter the row positions of 4 queens (each between 0 and 3):")
    state = list(map(int, input("Example (1 2 0 3): ").split()))
    hill_climbing(state)
```

Program 5

Simulated Annealing to Solve 8-Queens problem

Algorithm:



Week-5

Truth Table enumeration algorithm for deciding propositional entailment

function TT-Entails? (KB, α) returns true or false
inputs: KB, the knowledge base, a sentence in propositional logic
α, the query, a sentence in propositional logic
symbols ← a list of propositional symbol in KB & α
return TT-Check-ALL (KB, α, symbols, { })

function TT-Check ALL (KB, α, symbols, model) returns true or false
if EMPTY? (symbols) then
if PL True? (KB, model) then return PL True? (α, model)
else return true // when KB is false, always return true
else do
P ← First (symbols)
rest ← Rest (symbols)
return (TT-Check-ALL (KB, α, rest, model ∪ {P=true})
and
TT-Check-ALL (KB, α, rest, model ∪ {P = false}))

Simulated annealing code:

import random

import math

----- Helper functions -----

def random_state(n):

```
    """Generate a random state: one queen per column."""
    return [random.randint(0, n - 1) for _ in range(n)]
def cost(state):
    """Compute the number of attacking pairs of queens (lower is better)."""
    n = len(state)
    conflicts = 0
    for i in range(n):
        for j in range(i + 1, n):
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                conflicts += 1
    return conflicts
def random_neighbour(state):
    """Generate a neighbour by moving one queen to another row."""
    n = len(state)
    neighbour = state.copy()
    col = random.randint(0, n - 1)      # random column
    new_row = random.randint(0, n - 1)  # new random row
    neighbour[col] = new_row
    return neighbour
# ----- Simulated Annealing -----
def simulated_annealing(n, initial_temp=1000, cooling_rate=0.95, stop_temp=1e-3, max_iterations=10000):
    current = random_state(n)
    current_cost = cost(current)
    T = initial_temp
```

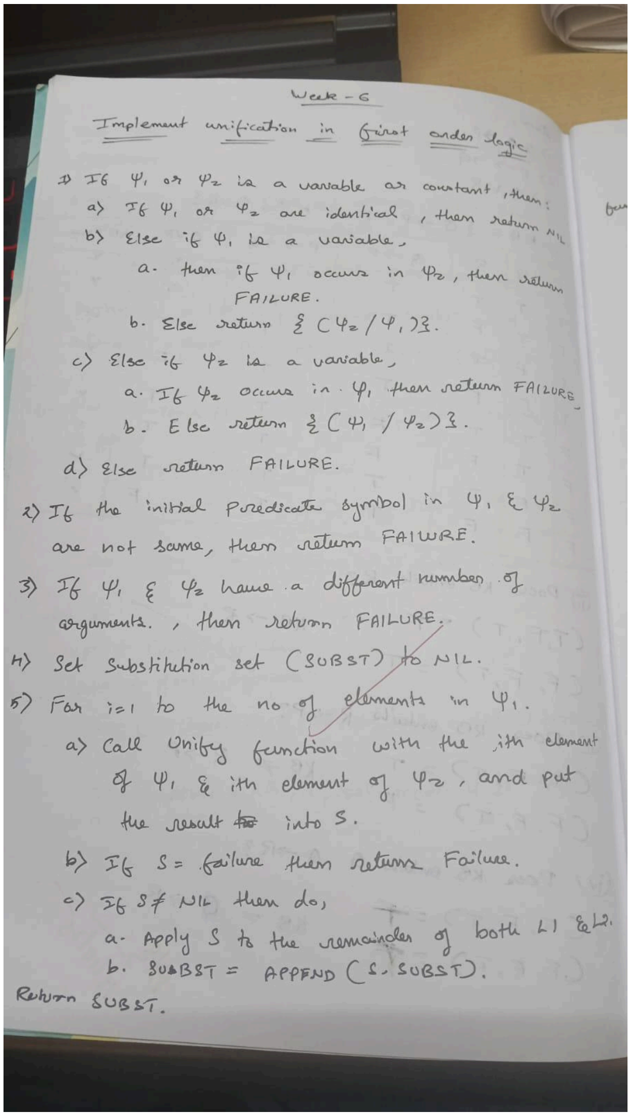
```
iteration = 0
print("\nInitial state:", current, "Cost:", current_cost)
while T > stop_temp and iteration < max_iterations:
    next_state = random_neighbour(current)
    next_cost = cost(next_state)
    deltaE = current_cost - next_cost
    # Acceptance condition
    if deltaE > 0:
        accepted = True
    else:
        p = math.exp(deltaE / T)
        accepted = random.random() < p
    # Print current step info
    print(f"\nStep {iteration+1}:")
    print(f"  Current: {current} (Cost={current_cost})")
    print(f"  Next:    {next_state} (Cost={next_cost})")
    print(f"  ΔE = {deltaE:.3f}, T = {T:.3f}")
    print(f"  Accepted: {accepted}")
    # Accept or reject
    if accepted:
        current = next_state
        current_cost = next_cost
    # Cooling
    T *= cooling_rate
```

```
        iteration += 1

        # Stop if solved

        if current_cost == 0:

            break

    return current, current_cost, iteration

# ----- Main -----

if __name__ == "__main__":

    n = int(input("Enter the number of queens (N): "))

    solution, cost_val, iterations = simulated_annealing(n)

    print("\nFinal state:", solution)

    print("Conflicts:", cost_val)

    print("Iterations:", iterations)

    if cost_val == 0:

        print("\nSolution found:\n")

        for row in range(n):

            print(" ".join("Q" if solution[col] == row else "." for col in range(n)))

    else:

        print("\nNo perfect solution found (try rerunning; SA is stochastic).")
```

Program 6

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

Algorithm:



Propositional logic code:

from itertools import product

Function to safely evaluate logical expressions from user input

def eval_expr(expr, model):

    # Replace logical symbols for Python syntax

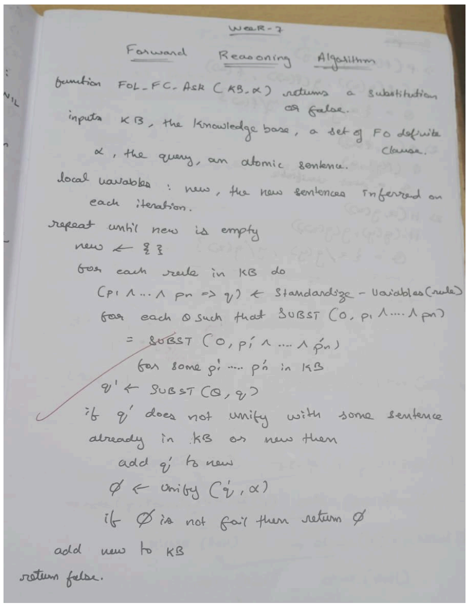
```
    expr = expr.replace('∨', 'or').replace('∧', 'and').replace('¬', 'not ')
    return eval(expr, {}, model)
# Generate all possible truth assignments (models)
def all_models(symbols):
    for values in product([False, True], repeat=len(symbols)):
        yield dict(zip(symbols, values))
# Check entailment: KB ⊨ α
def entails(KB_expr, alpha_expr, symbols):
    for model in all_models(symbols):
        kb_val = eval_expr(KB_expr, model)
        alpha_val = eval_expr(alpha_expr, model)
        if kb_val and not alpha_val:
            print(" Counterexample found:", model)
            return False
    return True
# Display truth table
def truth_table(KB_expr, alpha_expr, symbols):
    headers = "  ".join(f"{s:^6}" for s in symbols)
    print(f"{headers}    {'KB':^8}    {'α':^8}")
    print("-" * (10 * len(symbols) + 20))
    for model in all_models(symbols):
        values = "  ".join(f"{str(model[s]):^6}" for s in symbols)
        kb_val = eval_expr(KB_expr, model)
        alpha_val = eval_expr(alpha_expr, model)
```

```
        print(f"{values}    {str(kb_val):^8}    {str(alpha_val):^8}")

# === Main Program ===

print("=== Propositional Entailment using Truth Table Enumeration ===")

# Input propositional variables

symbols = input("Enter propositional symbols (comma separated, e.g., A,B,C): ").replace(" ", "").split(",")

# Input Knowledge Base (KB) and Query (α)

KB_expr = input("Enter Knowledge Base (use and/or/not or ∧/∨/¬): ")

alpha_expr = input("Enter Query α (use and/or/not or ∧/∨/¬): ")

# Display truth table

print("\n--- Truth Table ---")

truth_table(KB_expr, alpha_expr, symbols)

# Check entailment

result = entails(KB_expr, alpha_expr, symbols)

print("\nResult:")

print(" KB entails α" if result else " KB does NOT entail α")
```

Program 7

Implement unification in first order logic

Algorithm:



Week-7

Forward Reasoning Algorithm

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

inputs KB, the knowledge base, a set of FO definite clause.

α, the query, an atomic sentence.

local variables : new, the new sentences inferred on each iteration.

repeat until new is empty

new $\leftarrow$ { }

for each rule in KB do

($p_1 \wedge \ldots \wedge p_n \Rightarrow q$) $\leftarrow$ Standardize - Variables(rule)

for each θ such that SUBST (θ, $p_1 \wedge \ldots \wedge p_n$)

= SUBST (θ, $p_1' \wedge \ldots \wedge p_n'$)

for some $p_1' \ldots p_n'$ in KB

q' $\leftarrow$ SUBST (θ, q)

if q' does not unify with some sentence already in KB or new then

add q' to new

ϕ $\leftarrow$ Unify (q', α)

if ϕ is not fail then return ϕ

add new to KB

return false.

Unification code:

```
import re

# Utility: parse the expression into function/operator and arguments

def parse(expr):

    expr = expr.strip()

    if '(' not in expr:

        return expr, []

    func = expr[:expr.index('(')].strip()

    args = expr[expr.index('(')+1:-1]

    args = [a.strip() for a in split_args(args)]

    return func, args

# Split arguments correctly (handles nested brackets)
```

```
def split_args(args_str):
    args, level, start = [], 0, 0
    for i, ch in enumerate(args_str):
        if ch == ',' and level == 0:
            args.append(args_str[start:i].strip())
            start = i + 1
        elif ch == '(':
            level += 1
        elif ch == ')':
            level -= 1
    args.append(args_str[start:].strip())
    return args
# Apply substitution to an expression
def substitute(expr, subs):
    for var, val in subs.items():
        expr = re.sub(rf'\b{var}\b', val, expr)
    return expr
# Check if variable occurs inside term (Occurs check)
def occurs_check(var, term):
    if var == term:
        return True
    if '(' not in term:
        return False
    _, args = parse(term)
```

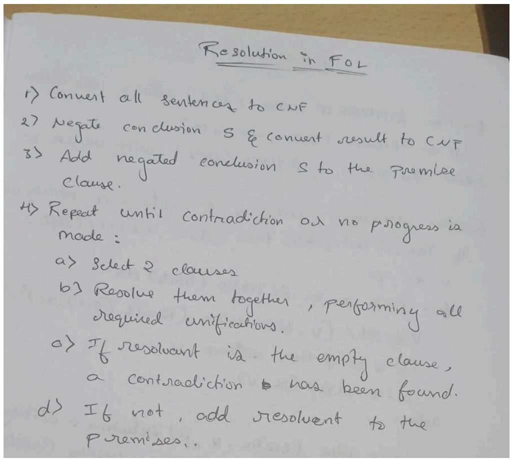
```
    return any(occurs_check(var, arg) for arg in args)
# Unification algorithm
def unify(e1, e2, subs=None):
    if subs is None:
        subs = {}
    e1 = substitute(e1, subs)
    e2 = substitute(e2, subs)
    if e1 == e2:
        return subs
    f1, args1 = parse(e1)
    f2, args2 = parse(e2)
    # Case 1: Both are compound terms
    if args1 and args2:
        if f1 != f2 or len(args1) != len(args2):
            print(f"❌ Function symbols or arity mismatch: {f1} vs {f2}")
            return None
        for a1, a2 in zip(args1, args2):
            subs = unify(a1, a2, subs)
            if subs is None:
                return None
        return subs
    # Case 2: Variable binding
    elif e1.islower() and e1.isalpha(): # e1 is variable
        if occurs_check(e1, e2):
```

```
            print(f"❌ Occurs check failed: {e1} occurs in {e2}")
            return None
        subs[e1] = e2
        return subs
    elif e2.islower() and e2.isalpha(): # e2 is variable
        if occurs_check(e2, e1):
            print(f"❌ Occurs check failed: {e2} occurs in {e1}")
            return None
        subs[e2] = e1
        return subs
    # Otherwise mismatch
    else:
        print(f"❌ Cannot unify {e1} with {e2}")
        return None
# --- MAIN PROGRAM ---
print("=== Unification Algorithm ===")
expr1 = input("Enter first expression: ").strip()
expr2 = input("Enter second expression: ").strip()
result = unify(expr1, expr2)
if result:
    print("\n✅ Unification Successful!")
    print("Substitutions:")
    for k, v in result.items():
        print(f" {k} / {v}")
```

```
else:
    print("\n❌ Unification Failed.")
```

Program 8
Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning.

Algorithm:



Resolution in FOL

1> Convert all sentences to CNF
2> Negate conclusion S & convert result to CNF
3> Add negated conclusion S to the premise clause.
4> Repeat until contradiction or no progress is made :
a> Select 2 clauses
b> Resolve them together, performing all required unifications.
c> If resolvent is the empty clause, a contradiction has been found.
d> If not, add resolvent to the premises.

Forward reasoning code:

```
import re

def isVariable(x):

    return len(x) == 1 and x.islower() and x.isalpha()

def getAttributes(string):

    expr = r'\([^)]+\)'

    matches = re.findall(expr, string)

    return matches

def getPredicates(string):

    expr = r'([a-z~]+)\([^&|]+\)'

    return re.findall(expr, string)

class Fact:

    def __init__(self, expression):

        self.expression = expression

        predicate, params = self.splitExpression(expression)
```

```
        self.predicate = predicate

        self.params = params

        self.result = any(self.getConstants())

    def splitExpression(self, expression):

        predicate = getPredicates(expression)[0]

        params = getAttributes(expression)[0].strip('()').split(',')

        return [predicate, params]

    def getResult(self):

        return self.result

    def getConstants(self):

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

    def getVariables(self):

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

    def substitute(self, constants):

        constants_copy = constants.copy()

        expr = f"{self.predicate}({','.join([constants_copy.pop(0) if isVariable(p) else p for p in
self.params])})"

        return Fact(expr)

class Implication:

    def __init__(self, expression):

        self.expression = expression

        l = expression.split('=>')

        self.lhs = [Fact(f) for f in l[0].split('&')]

        self.rhs = Fact(l[1])

    def evaluate(self, facts):
```

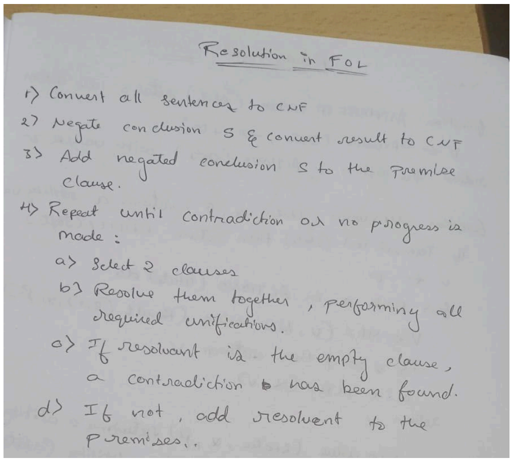
```
        constants = {}
        new_lhs = []
        for fact in facts:
            for val in self.lhs:
                if val.predicate == fact.predicate:
                    for i, v in enumerate(val.getVariables()):
                        if v:
                            constants[v] = fact.getConstants()[i]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

```
            self.facts.add(Fact(e))
        for i in self.implications:
            res = i.evaluate(self.facts)
            if res:
                self.facts.add(res)
    def ask(self, e):
        facts = set([f.expression for f in self.facts])
        print(f'\nQuerying {e}:')
        i = 1
        found = False
        for f in facts:
            if Fact(f).predicate == Fact(e).predicate:
                print(f'\t{i}. {f}')
                i += 1
                found = True
        if not found:
            print("\tNo matching facts found.")
    def display(self):
        print("\nAll facts:")
        for i, f in enumerate(set([f.expression for f in self.facts])):
            print(f'\t{i+1}. {f}')
def main():
    kb = KB()
    print("Enter the number of FOL expressions present in KB:")
```

```
    n = int(input())
    print("Enter the expressions:")
    for i in range(n):
        fact = input().strip()
        kb.tell(fact)
    print("Enter the query:")
    query = input().strip()
    kb.ask(query)
    kb.display()
if __name__ == "__main__":
    main()
```

Program 9

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



Resolution in FOL

1> Convert all sentences to CNF
2> Negate conclusion S & convert result to CNF
3> Add negated conclusion S to the premise clause.
4> Repeat until contradiction or no progress is made :
a> Select 2 clauses
b> Resolve them together, performing all required unifications.
c> If resolvant is the empty clause, a contradiction has been found.
d> If not, add resolvent to the premises..

Algorithm:
Resolution code:

```
def parse_clause(clause_str):

    return set(clause_str.split('v'))

def get_complement(literal):

    return literal[1:] if literal.startswith('~') else '~' + literal

def resolve(ci, cj):

    resolvents = set()

    for literal in ci:

        complement = get_complement(literal)

        if complement in cj:

            new_clause = (ci - {literal}) | (cj - {complement})

            resolvents.add(frozenset(new_clause))

    return resolvents

def resolution(kb_clauses, query):

    negated_query = get_complement(query)

    kb = [parse_clause(clause) for clause in kb_clauses] + [parse_clause(negated_query)]
```

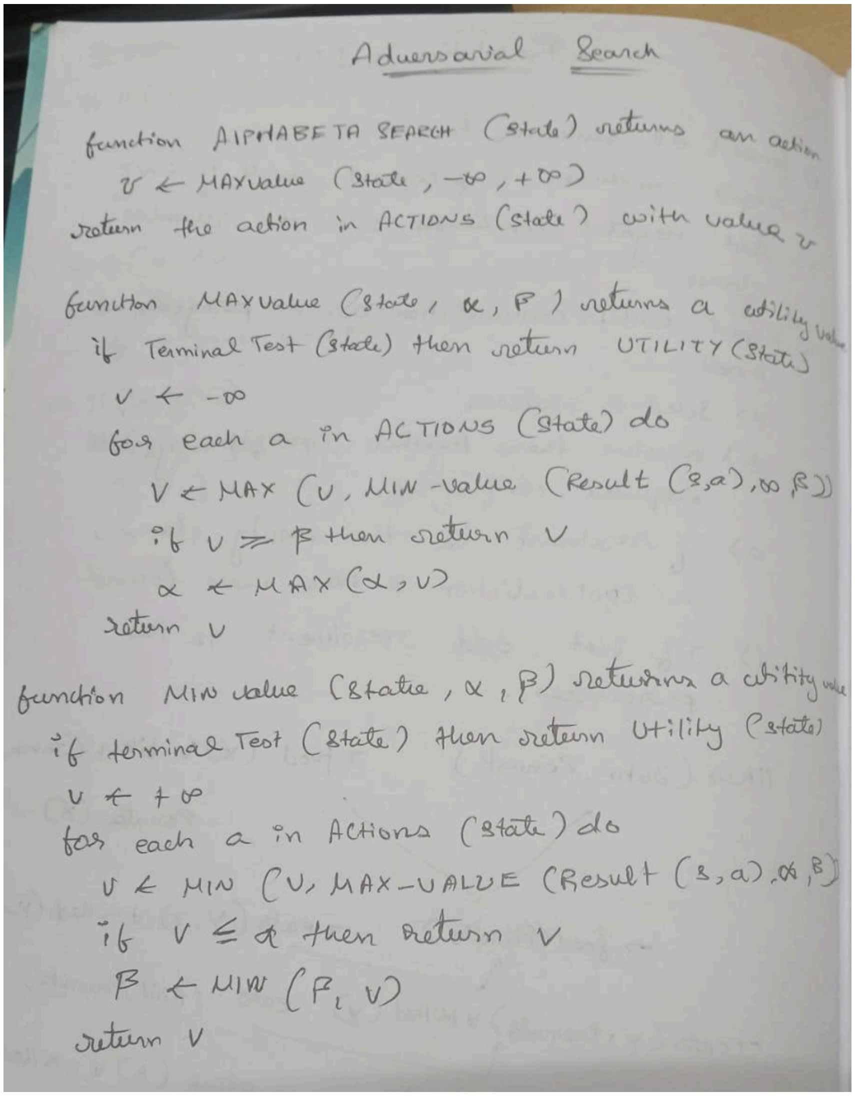
```
print("\n----------------------------")
print("KnowledgeBase - Resolution")
print("----------------------------")
print(f"\nKnowledge Base Clauses: {kb_clauses}")
print(f"Query: {query}")
print(f"Negated Query Added: {negated_query}")
print("\nResolution Steps:\n")
new = set()
while True:
    pairs = [(kb[i], kb[j]) for i in range(len(kb)) for j in range(i + 1, len(kb))]
    for (ci, cj) in pairs:
        resolvents = resolve(ci, cj)
        for resolvent in resolvents:
            print(f"Resolving {set(ci)} and {set(cj)} => {set(resolvent)}")
            if not resolvent:
                print("\n Knowledge Base entails the query (empty clause derived).")
                return True
            new.add(resolvent)
    if new.issubset(set(map(frozenset, kb))):
        print("\n Knowledge Base does NOT entail the query (no empty clause derived).")
        return False
    for clause in new:
        if clause not in kb:
            kb.append(clause)
```

```
print("KnowledgeBase - Resolution")

print("------------------------------")

print("Enter clauses for the Knowledge Base.")

print("Use 'v' for OR between literals (e.g., '~qv~pvr'), and separate each clause with a space.\n")

kb_input = input("Enter clauses: ").split()

query_input = input("Enter the query: ")

resolution(kb_input, query_input)
```

Program 10

Implement Alpha-Beta Pruning.

Algorithm:



Adversarial Search

function ALPHABETA SEARCH (state) returns an action
  v ← MAXvalue (state, −∞, +∞)
return the action in ACTIONS (state) with value v

function MAXValue (state, α, β) returns a utility value
  if Terminal Test (state) then return UTILITY (state)
  v ← −∞
  for each a in ACTIONS (State) do
    V ← MAX (v, MIN-value (Result (s,a), α, β))
    if v ≥ β then return v
    α ← MAX (α, v)
  return v

function MIN value (state, α, β) returns a utility value
  if terminal Test (state) then return Utility (state)
  v ← +∞
  for each a in Actions (state) do
    v ← MIN (v, MAX-VALUE (Result (s,a), α, β))
    if v ≤ α then return v
    β ← MIN (β, v)
  return v

Alpha Beta Pruning code:

```
import math

import random

# Use an external "real" board only for the main game loop; recursive functions use state parameters.

board = [" " for _ in range(9)]  # 3x3 board

def print_board(state):

    print("\n")
```

```
    for i in range(3):
        print(" " + " | ".join(state[i*3:(i+1)*3]))
        if i < 2:
            print("---+---+---")
    print("\n")
def is_winner(state, player):
    win_combinations = [
        [0, 1, 2], [3, 4, 5], [6, 7, 8],
        [0, 3, 6], [1, 4, 7], [2, 5, 8],
        [0, 4, 8], [2, 4, 6]
    ]
    return any(all(state[i] == player for i in combo) for combo in win_combinations)
def is_full(state):
    return " " not in state
def actions(state):
    return [i for i in range(9) if state[i] == " "]
def result(state, action, player):
    new_state = state.copy()
    new_state[action] = player
    return new_state
def utility(state):
    if is_winner(state, "O"):
        return +1
    elif is_winner(state, "X"):
```

```
        return -1
    else:
        return 0
def terminal_test(state):
    return is_winner(state, "X") or is_winner(state, "O") or is_full(state)
# --- Alpha-Beta Functions ---
def max_value(state, alpha, beta):
    if terminal_test(state):
        return utility(state)
    v = -math.inf
    for a in actions(state):
        v = max(v, min_value(result(state, a, "O"), alpha, beta))
        if v >= beta:
            return v
        alpha = max(alpha, v)
    return v
def min_value(state, alpha, beta):
    if terminal_test(state):
        return utility(state)
    v = math.inf
    for a in actions(state):
        v = min(v, max_value(result(state, a, "X"), alpha, beta))
        if v <= alpha:
            return v
```

```
        beta = min(beta, v)
    return v
def alpha_beta_search(state):
    best_score = -math.inf
    best_action = None
    if not actions(state):
        return None
    for a in actions(state):
        value = min_value(result(state, a, "O"), -math.inf, math.inf)
        if value > best_score:
            best_score = value
            best_action = a
    # Fallback: if something goes wrong, return a random legal move
    if best_action is None:
        legal = actions(state)
        return random.choice(legal) if legal else None
    return best_action
# --- Game Loop ---
def human_move():
    while True:
        try:
            move = int(input("Enter your move (1-9): ")) - 1
        except ValueError:
            print("Please enter a number 1-9.")
```

```
            continue
        if move < 0 or move > 8:
            print("Move out of range. Choose 1-9.")
            continue
        if board[move] != " ":
            print("Cell already taken. Try another.")
            continue
        return move
def choose_first():
    while True:
        ans = input("Who goes first? (me/ai) [me]: ").strip().lower()
        if ans == "" or ans.startswith("m"):
            return "me"
        if ans.startswith("a"):
            return "ai"
        print("Type 'me' or 'ai' (or press Enter for me).")
def main():
    global board
    board = [" " for _ in range(9)]
    print("Welcome to Tic-Tac-Toe! You are X, AI is O.")
    first = choose_first()
    print_board(board)
    while True:
        if first == "me":
```

```
# Human turn
move = human_move()
board[move] = "X"
print_board(board)
if is_winner(board, "X"):
    print("You win!")
    break
if is_full(board):
    print("It's a draw!")
    break
# AI turn
print("AI is thinking...")
ai_move = alpha_beta_search(board)
if ai_move is None:
    print("AI could not find a move — it's a draw.")
    break
board[ai_move] = "O"
print_board(board)
if is_winner(board, "O"):
    print("AI wins!")
    break
if is_full(board):
    print("It's a draw!")
    break
```

```
else:  # AI first
    print("AI is thinking...")
    ai_move = alpha_beta_search(board)
    if ai_move is None:
        print("AI could not find a move — it's a draw.")
        break
    board[ai_move] = "O"
    print_board(board)
    if is_winner(board, "O"):
        print("AI wins!")
        break
    if is_full(board):
        print("It's a draw!")
        break
    # Human turn
    move = human_move()
    board[move] = "X"
    print_board(board)
    if is_winner(board, "X"):
        print("You win!")
        break
    if is_full(board):
        print("It's a draw!")
        break
```

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

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