Artificial Intelligence Lab Report

Submitted by

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Batch: 1

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Program 1 - Tic Tac toe

Algorithm

4/10/24

LAB-1

a) Implement a tic tac toe game using python

Pseudocode :

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

    if isMaximizingPlayer:
        bestValue = - infinity
        for each child in node:
            Value = minimax (child, depth + 1, false)
            bestValue = max( bestValue, Value)
        return bestValue

    else:
        bestValue = + infinity
        for each child in node:
            Value = minimax (child, depth + 1, true)
            bestValue = min (bestValue, Value)
        return bestValue
```

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Code

```
import random

import math



def print_board(board):

    for row in board:

        print(" | ".join(row))

        print("-" * 9)



def check_winner(board, mark):

    # Check rows, columns, and diagonals for a win

    for row in board:

        if all(cell == mark for cell in row):

            return True



    for col in range(3):

        if all(board[row][col] == mark for row in range(3)):

            return True
```

```
    if all(board[i][i] == mark for i in range(3)) or all(board[i][2 - i] == mark for i in range(3)):
        return True

    return False

def get_available_moves(board):
    return [(r, c) for r in range(3) for c in range(3) if board[r][c] == " "]

def minimax(board, depth, is_maximizing):
    if check_winner(board, "O"):
        return 10 - depth
    if check_winner(board, "X"):
        return depth - 10
    if not get_available_moves(board):
        return 0

    if is_maximizing:
        best_score = -math.inf
        for (row, col) in get_available_moves(board):
```

```
            board[row][col] = "O"
            score = minimax(board, depth + 1, False)
            board[row][col] = " "
            best_score = max(best_score, score)
        return best_score
    else:
        best_score = math.inf
        for (row, col) in get_available_moves(board):
            board[row][col] = "X"
            score = minimax(board, depth + 1, True)
            board[row][col] = " "
            best_score = min(best_score, score)
        return best_score


def computer_move(board):
    best_score = -math.inf
    best_move = None
    for (row, col) in get_available_moves(board):
        board[row][col] = "O"
```

```
        score = minimax(board, 0, False)

        board[row][col] = " "

        if score > best_score:

            best_score = score

            best_move = (row, col)

    return best_move



def main():

    print("Welcome to Tic Tac Toe!")

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



    print_board(board)



    for turn in range(9):

        if turn % 2 == 0:

            # Player's turn

            while True:

                try:
```

```
            row = int(input("Enter the row (0, 1, 2): "))
            col = int(input("Enter the column (0, 1, 2): "))

            if (row, col) not in get_available_moves(board):
                print("This spot is already taken or invalid. Try again.")
            else:
                board[row][col] = "X"
                break
        except ValueError:
            print("Invalid input. Please enter numbers 0, 1, or 2.")
else:
    # Computer's turn
    row, col = computer_move(board)
    board[row][col] = "O"
    print(f"Computer chose: ({row}, {col})")

print_board(board)

# Check for a winner
```

```
        if check_winner(board, "X"):
            print("Congratulations! You win!")
            return
        elif check_winner(board, "O"):
            print("Computer wins! Better luck next time.")
            return

    print("It's a tie!")

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

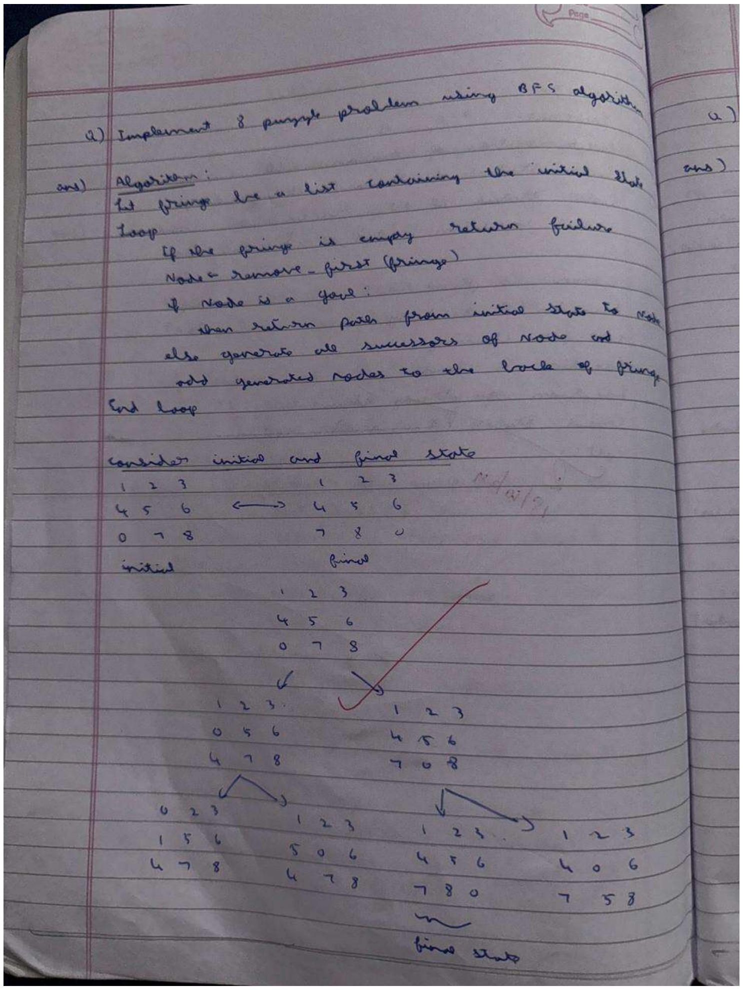
Output

```
Welcome to Tic Tac Toe!
  |   |
  |   |
  |   |
---------
Enter the row (0, 1, 2): 0
Enter the column (0, 1, 2): 0
X |   |
  |   |
  |   |
---------
Computer chose: (1, 1)
X |   |
  | O |
  |   |
---------
Enter the row (0, 1, 2): 1
Enter the column (0, 1, 2): 2
X |   |
  | O | X
  |   |
---------
Computer chose: (0, 1)
X | O |
  | O | X
  |   |
---------
Enter the row (0, 1, 2): 2
Enter the column (0, 1, 2): 1
X | O |
  | O | X
  | X |
```

```
Enter the row (0, 1, 2): 1
Enter the column (0, 1, 2): 1
This spot is already taken or invalid. Try again.
Enter the row (0, 1, 2): 2
Enter the column (0, 1, 2): 2
X | O |
  | O | X
O | X | X
---------
Computer chose: (0, 2)
X | O | O
  | O | X
O | X | X
---------
Computer wins! Better luck next time.


...Program finished with exit code 0
Press ENTER to exit console.
```

Program 2 - 8 Puzzle BFS and DFS

Algorithm



Q) Implement 8 puzzle problem using BFS algorithm

ans) Algorithm:

Let fringe be a list containing the initial state

Loop

If the fringe is empty return failure

Node ← remove_first (fringe)

If Node is a goal:

then return path from initial state to Node

else generate all successors of Node and

add generated nodes to the back of fringe

End loop

Consider initial and final state

```
1 2 3          1 2 3
4 5 6  <--->   4 5 6
0 7 8          7 8 0
initial        final
```

```
        1 2 3
        4 5 6
        0 7 8

   1 2 3        1 2 3
   0 5 6        4 5 6
   4 7 8        7 0 8

0 2 3   1 2 3   1 2 3   1 2 3
1 5 6   5 0 6   4 5 6   4 0 6
4 7 8   4 7 8   7 8 0   7 5 8
                final state
```

4) Implement 8 puzzle problem using DFS algorithm

ans) Algorithm:

Let fringe be a list containing the initial state

Loop

If fringe is empty return failure

Node ← remove-first (fringe)

if Node is a goal:

then return path from initial state to Node

else generate all successors of Node and

add generated nodes to front of fringe

End loop

Initial state -

1 2 3
4 5 6
0 7 8

1 2 3
0 5 6
4 7 8

0 2 3
1 5 6
4 7 8

2 0 3
1 5 6
4 7 8

⋮

1 2 3
4 5 6
7 8 0

} final state

Code (BFS)

```
from collections import deque


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


def print_state(state, label=None):
    if label:
        print(label)
    for row in state:
        print(" ".join(str(num) if num != 0 else " " for num in row))
    print()
```

```
def get_neighbors(state):
    rows, cols = len(state), len(state[0])
    for r in range(rows):
        for c in range(cols):
            if state[r][c] == 0:
                zero_pos = (r, c)
                break
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]
    neighbors = []
    for dr, dc in directions:
        nr, nc = zero_pos[0] + dr, zero_pos[1] + dc
        if 0 <= nr < rows and 0 <= nc < cols:
            new_state = [row[:] for row in state]
            new_state[zero_pos[0]][zero_pos[1]], new_state[nr][nc] = new_state[nr][nc],
new_state[zero_pos[0]][zero_pos[1]]
            neighbors.append(new_state)
    return neighbors


def bfs(initial, goal):
    queue = deque([(initial, [])])
```

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

    while queue:
        current, path = queue.popleft()
        if current == goal:
            return path + [current]

        for neighbor in get_neighbors(current):
            neighbor_tuple = tuple(tuple(row) for row in neighbor)
            if neighbor_tuple not in visited:
                visited.add(neighbor_tuple)
                queue.append((neighbor, path + [current]))
    return None

def main():
    print("8-Puzzle Solver Using BFS")
    initial_state = [[1, 2, 3], [4, 0, 5], [7, 8, 6]]  # Example initial state
```

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


print_state(initial_state, label="Initial State:")

print_state(goal_state, label="Goal State:")


if not is_solvable(initial_state):

    print("This puzzle is not solvable.")

    return


solution = bfs(initial_state, goal_state)

if solution:

    print("Solution found in {} steps:\n".format(len(solution) - 1))

    for i, step in enumerate(solution):

        if i == 0:

            print_state(step, label="Initial State:")

        elif i == len(solution) - 1:

            print_state(step, label="Final State:")

        else:

            print_state(step, label=f"Step {i}:")
```

```
    else:
        print("No solution exists.")


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

Code (DFS)

```
def is_solvable(state):

    inversions = 0

    flattened = [num for row in state for num in row if num != 0]

    for i in range(len(flattened)):

        for j in range(i + 1, len(flattened)):

            if flattened[i] > flattened[j]:

                inversions += 1

    return inversions % 2 == 0



def print_state(state, label=None):

    if label:

        print(label)

    for row in state:

        print(" ".join(str(num) if num != 0 else " " for num in row))

    print()



def get_neighbors(state):

    rows, cols = len(state), len(state[0])
```

```
    for r in range(rows):
        for c in range(cols):
            if state[r][c] == 0:
                zero_pos = (r, c)
                break
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]
    neighbors = []
    for dr, dc in directions:
        nr, nc = zero_pos[0] + dr, zero_pos[1] + dc
        if 0 <= nr < rows and 0 <= nc < cols:
            new_state = [row[:] for row in state]
            new_state[zero_pos[0]][zero_pos[1]], new_state[nr][nc] = new_state[nr][nc],
new_state[zero_pos[0]][zero_pos[1]]
            neighbors.append(new_state)
    return neighbors


def dfs(initial, goal):
    stack = [(initial, [])]
    visited = set()
    visited.add(tuple(tuple(row) for row in initial))
```

```
    while stack:
        current, path = stack.pop()
        if current == goal:
            return path + [current]

        for neighbor in get_neighbors(current):
            neighbor_tuple = tuple(tuple(row) for row in neighbor)
            if neighbor_tuple not in visited:
                visited.add(neighbor_tuple)
                stack.append((neighbor, path + [current]))
    return None

def main()
    print("8-Puzzle Solver Using DFS")
    initial_state = [[1, 2, 3], [4, 0, 5], [7, 8, 6]]  # Example initial state
    goal_state = [[1, 2, 3], [4, 5, 6], [7, 8, 0]]       # Goal state
```

```
print_state(initial_state, label="Initial State:")

print_state(goal_state, label="Goal State:")


if not is_solvable(initial_state):

    print("This puzzle is not solvable.")

    return


solution = dfs(initial_state, goal_state)

if solution:

    print("Solution found in {} steps:\n".format(len(solution) - 1))

    for i, step in enumerate(solution):

        if i == 0:

            print_state(step, label="Initial State:")

        elif i == len(solution) - 1:

            print_state(step, label="Final State:")

        else:

            print_state(step, label=f"Step {i}:")

else:

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

```
if _name____== "_main_":

    main()
```

Output (BFS)

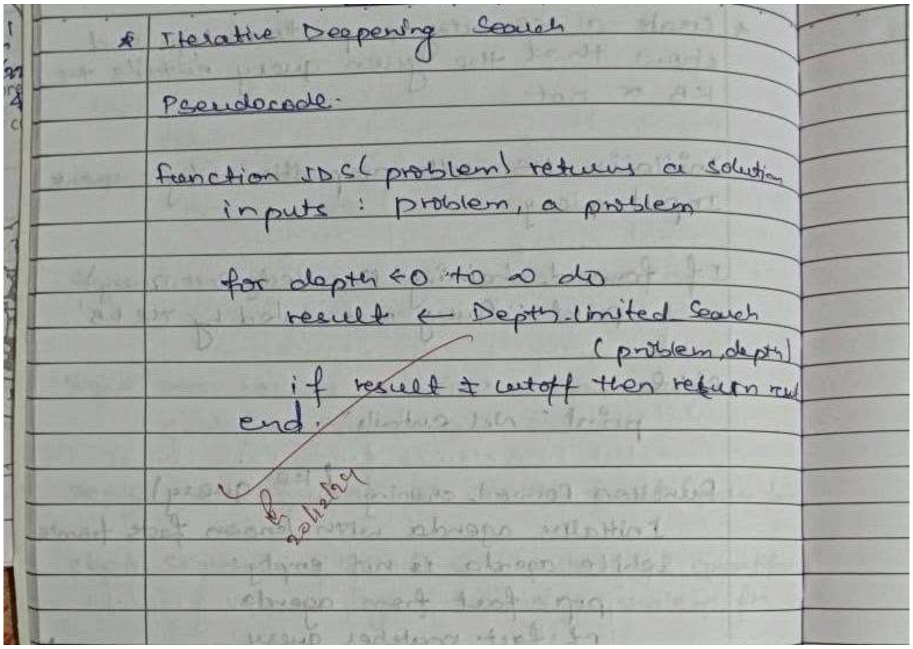
```
8-Puzzle Solver Using BFS
Initial State:
1 2 3
4   5
7 8 6

Goal State:
1 2 3
4 5 6
7 8

Solution found in 2 steps:

Initial State:
1 2 3
4   5
7 8 6

Step 1:
1 2 3
4 5
7 8 6

Final State:
1 2 3
4 5 6
7 8


...Program finished with exit code 0
Press ENTER to exit console.
```

Output (DFS)

```
8-Puzzle Solver Using DFS
Initial State:
1 2 3
4   5
7 8 6

Goal State:
1 2 3
4 5 6
7 8

Solution found in 2 steps:

Initial State:
1 2 3
4   5
7 8 6

Step 1:
1 2 3
4 5
7 8 6

Final State:
1 2 3
4 5 6
7 8



...Program finished with exit code 0
Press ENTER to exit console.
```

<u>Program 3 -</u> Iterative Deepening Search

<u>Algorithm</u>



* Iterative Deepening Search

Pseudocode.

```
function IDS(problem) returns a solution
    inputs : problem, a problem

    for depth ← 0 to ∞ do
        result ← Depth-Limited Search
                          (problem, depth)
        if result ≠ cutoff then return result
    end.
```

Code

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

def print_state(state, label=None):
    if label:
        print(label)
    for row in state:
        print(" ".join(str(num) if num != 0 else " " for num in row))
    print()

def get_neighbors(state):
    rows, cols = len(state), len(state[0])
    for r in range(rows):
        for c in range(cols):
            if state[r][c] == 0:
                zero_pos = (r, c)
                break
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]
    neighbors = []
    for dr, dc in directions:
        nr, nc = zero_pos[0] + dr, zero_pos[1] + dc
        if 0 <= nr < rows and 0 <= nc < cols:
            new_state = [row[:] for row in state]
            new_state[zero_pos[0]][zero_pos[1]], new_state[nr][nc] = new_state[nr][nc],
new_state[zero_pos[0]][zero_pos[1]]
            neighbors.append(new_state)
    return neighbors

def ids(initial, goal, depth_limit):
    def dls(state, path, depth):
        if state == goal:
```

```
            return path + [state]
        if depth == 0:
            return None
        for neighbor in get_neighbors(state):
            if tuple(tuple(row) for row in neighbor) not in visited:
                visited.add(tuple(tuple(row) for row in neighbor))
                result = dls(neighbor, path + [state], depth - 1)
                if result:
                    return result
        return None

    for depth in range(depth_limit):
        visited = set()
        visited.add(tuple(tuple(row) for row in initial))
        result = dls(initial, [], depth)
        if result:
            return result
    return None

def main():
    print("8-Puzzle Solver Using Iterative Deepening Search")
    initial_state = [[1, 2, 3], [4, 0, 5], [7, 8, 6]]  # Example initial state
    goal_state = [[1, 2, 3], [4, 5, 6], [7, 8, 0]]     # Goal state

    print_state(initial_state, label="Initial State:")
    print_state(goal_state, label="Goal State:")

    if not is_solvable(initial_state):
        print("This puzzle is not solvable.")
        return

    depth_limit = 20
    solution = ids(initial_state, goal_state, depth_limit)
    if solution:
        print("Solution found in {} steps:\n".format(len(solution) - 1))
        for i, step in enumerate(solution):
            if i == 0:
                print_state(step, label="Initial State:")
            elif i == len(solution) - 1:
                print_state(step, label="Final State:")
            else:
```

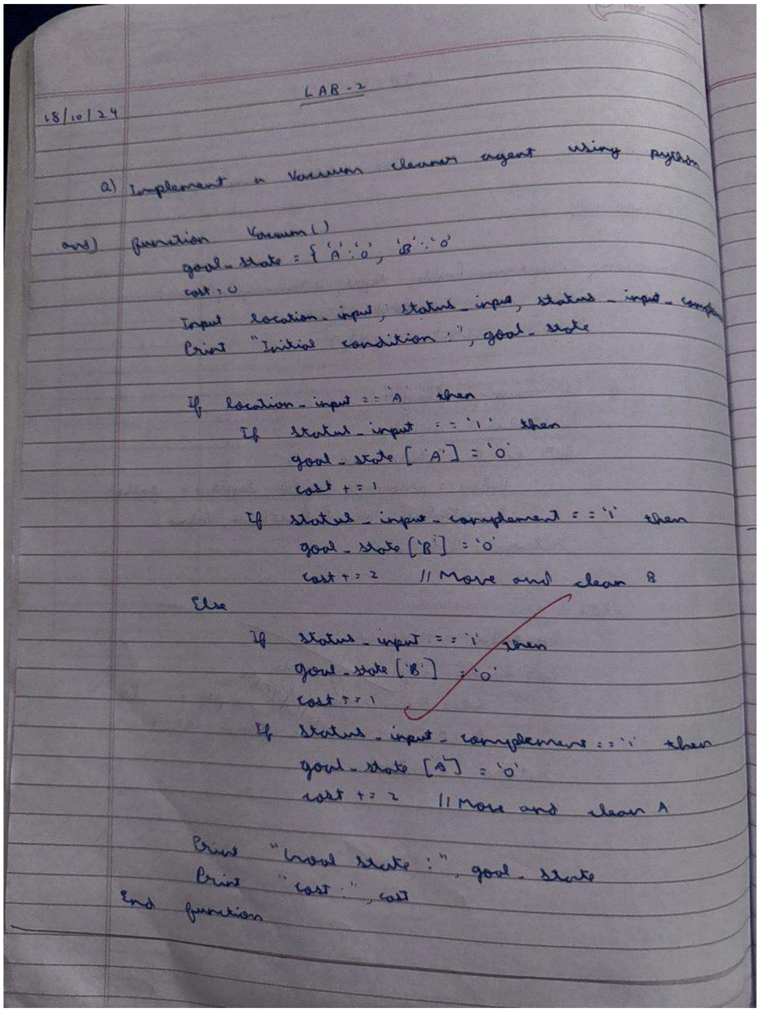
```
            print_state(step, label=f"Step {i}:")
    else:
        print("No solution exists within depth limit {}.".format(depth_limit))

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

Output

```
8-Puzzle Solver Using Iterative Deepening Search
Initial State:
1 2 3
  4 5
7 8 6

Goal State:
1 2 3
4 5 6
7 8

Solution found in 3 steps:

Initial State:
1 2 3
  4 5
7 8 6

Step 1:
1 2 3
4   5
7 8 6

Step 2:
1 2 3
4 5
7 8 6

Final State:
1 2 3
4 5 6
7 8
```

<u>Program 4 -</u> Vacuum Cleaner Agent

<u>Algorithm</u>



18/10/24

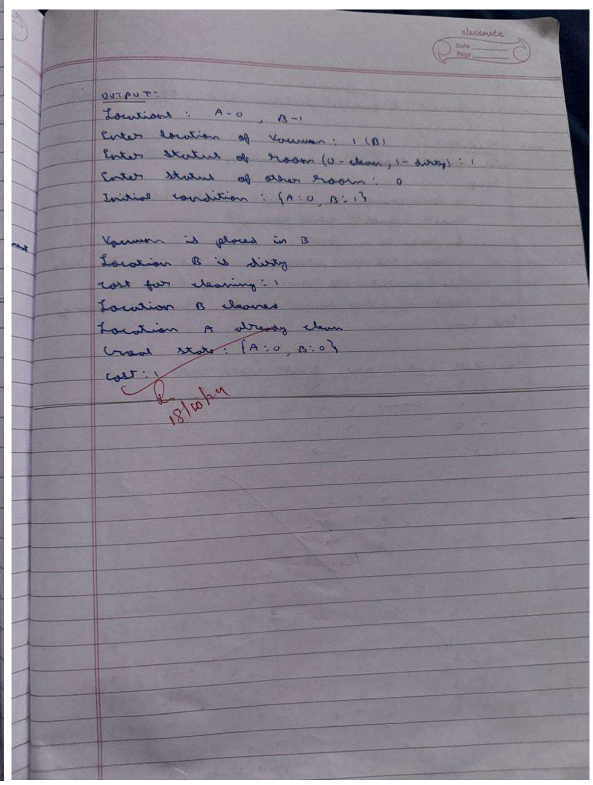
LAB - 2

a) Implement a Vacuum cleaner agent using python

ans) function Vacuum()
    goal_state = {'A':'0', 'B':'0'}
    cost = 0
    Input location_input, status_input, status_input_complement
    Print "Initial condition :", goal_state

    If location_input == 'A' then
        If status_input == '1' then
            goal_state['A'] = '0'
            cost += 1
        If status_input_complement == '1' then
            goal_state['B'] = '0'
            cost += 2   // Move and clean B
    Else
        If status_input == '1' then
            goal_state['B'] = '0'
            cost += 1
        If status_input_complement == '1' then
            goal_state['A'] = '0'
            cost += 2   // Move and clean A

    Print "Goal state :", goal_state
    Print "cost :", cost
End function



OUTPUT:
Locations : A - 0 , B - 1
Enter location of Vacuum : 1 (B)
Enter status of room (0 - clean, 1 - dirty) : 1
Enter status of other room : 0
Initial condition : {A : 0, B : 1}

Vacuum is placed in B
Location B is dirty
cost for cleaning : 1
Location B cleaned
Location A already clean
Goal state : {A : 0, B : 0}
cost : 1

18/10/24

Code

```
def vacuum_cleaner(initial_state):
    # Initial states of rooms A and B
    room_A, room_B = initial_state

    # Trace of actions
    actions = []

    # Start in Room A
    actions.append("Starting in Room A.")

    # Check room A
    if room_A == 1:
        actions.append("Room A is dirty. Cleaning Room A.")
        room_A = 0
    else:
        actions.append("Room A is already clean.")
```

```
# Move to Room B
actions.append("Moving to Room B.")

# Check room B
if room_B == 1:
    actions.append("Room B is dirty. Cleaning Room B.")
    room_B = 0
else:
    actions.append("Room B is already clean.")

# Move back to Room A
actions.append("Returning to Room A.")

# Final state
final_state = (room_A, room_B)
actions.append("Both rooms are now clean.")

return final_state, actions
```

```
def main():
    print("Vacuum Cleaner AI")

    # Input initial states of Room A and Room B
    room_A = int(input("Enter the state of Room A (0 for clean, 1 for dirty): "))
    room_B = int(input("Enter the state of Room B (0 for clean, 1 for dirty): "))

    # Validate input
    if room_A not in (0, 1) or room_B not in (0, 1):
        print("Invalid input. Please enter 0 or 1.")
        return

    # Solve using vacuum cleaner AI
    final_state, actions = vacuum_cleaner((room_A, room_B))

    # Output actions and final state
    print("\nActions:")
    for action in actions:
```

```
        print(action)

    print("\nFinal State:")
    print(f"Room A: {'Clean' if final_state[0] == 0 else 'Dirty'}")
    print(f"Room B: {'Clean' if final_state[1] == 0 else 'Dirty'}")

if _name___== "_main_":
    main()
```

Output

```
Vacuum Cleaner AI
Enter the state of Room A (0 for clean, 1 for dirty): 1
Enter the state of Room B (0 for clean, 1 for dirty): 1

Actions:
Starting in Room A.
Room A is dirty. Cleaning Room A.
Moving to Room B.
Room B is dirty. Cleaning Room B.
Returning to Room A.
Both rooms are now clean.

Final State:
Room A: Clean
Room B: Clean


...Program finished with exit code 0
Press ENTER to exit console.
```

Program 5 - A* Search Algorithm and Hill Climbing Algorithm

Algorithm

25/10/24

LAB-3

a) Implement A* algorithm using Python

function A* search (problem) returns a solution or failure

node ← a node n with n.state = problem.initial state, n.g = 0

frontier ← a priority queue ordered by ascending g+h, only element 'n'

loop do
    if empty?(frontier) then return failure
    n ← pop(frontier)
    if problem.goalTest(n.state) then return solution(n)
    for each action a in a problem.actions(n.states) do
        n' ← childNode(problem, n, a)
        insert(n', g(n') + h(n'), frontier)

OUTPUT:

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

Using Manhattan distance:

Initial State

1	2	3
4	5	6
0	7	8

Goal State

1	2	3
4	5	6
7	8	0

$f(0) = 0 + 2 = 2$

1	2	3
0	5	6
4	7	8

$f(1) = 1+3 = 4$

1	2	3
4	5	6
7	0	8

$f(1) = 1+1 = 2$

1	2	3
4	5	6
0	7	8

$f(3) = 2+2 = 4$

1	2	3
4	0	6
7	5	8

$f(2) = 2+2 = 4$

1	2	3
4	5	6
7	8	0

$f(3) = 2+0 = 2$ ✓

25/10/24

Code (A* algorithm using N – displaced Tiles)

```
import heapq

 # Goal state

goal_state = (

    (1, 2, 3),

    (4, 5, 6),

    (7, 8, 0)

)



# Function to compute the heuristic (misplaced tiles)

def misplaced_tiles(state):

    misplaced = 0

    for i in range(3):

        for j in range(3):

            if state[i][j] != goal_state[i][j] and state[i][j] != 0:

                misplaced += 1

    return misplaced



# Function to get possible moves (neighbors)
```

```
def get_neighbors(state):
    neighbors = []
    zero_pos = [(i, j) for i in range(3) for j in range(3) if state[i][j] == 0][0]
    i, j = zero_pos

    # Possible moves: up, down, left, right
    moves = [(-1, 0), (1, 0), (0, -1), (0, 1)]
    for move in moves:
        new_i, new_j = i + move[0], j + move[1]
        if 0 <= new_i < 3 and 0 <= new_j < 3:
            new_state = list(list(row) for row in state)  # Create a copy of the state
            new_state[i][j], new_state[new_i][new_j] = new_state[new_i][new_j], new_state[i][j]
            neighbors.append(tuple(tuple(row) for row in new_state))  # Convert back to tuple
    return neighbors

# Function to count the number of inversions in the puzzle
def count_inversions(state):
    one_d_state = [tile for row in state for tile in row if tile != 0]
    inversions = 0
```

```
    for i in range(len(one_d_state)):
        for j in range(i + 1, len(one_d_state)):
            if one_d_state[i] > one_d_state[j]:
                inversions += 1
    return inversions


# Check if the puzzle is solvable
def is_solvable(state):
    inversions = count_inversions(state)
    return inversions % 2 == 0


# A* Algorithm
def a_star(initial_state):
    if not is_solvable(initial_state):
        print("This puzzle is not solvable.")
        return None


    open_list = []
    heapq.heappush(open_list, (0 + misplaced_tiles(initial_state), 0, initial_state, []))  # (f(n), g(n),
state, path)
```

```python
closed_list = set()


while open_list:
    f, g, current_state, path = heapq.heappop(open_list)
    closed_list.add(current_state)


    # If goal state is reached
    if current_state == goal_state:
        return path + [current_state]


    # Generate neighbors
    for neighbor in get_neighbors(current_state):
        if neighbor not in closed_list:
            heapq.heappush(open_list, (
                g + 1 + misplaced_tiles(neighbor),  # f(n) = g(n) + h(n)
                g + 1,  # Increment g(n) by 1 for each move
                neighbor,
                path + [current_state]
            ))
```

```
    return None  # No solution found


# Function to display the puzzle state
def display_state(state, label):
    print(f"{label} state:")
    for row in state:
        print(" ".join(str(x) for x in row))
    print()


# Example initial state (this one is solvable)
initial_state = (
    (1, 2, 3),
    (5, 6, 4),
    (7, 8, 0)
)


# Solving the puzzle
solution = a_star(initial_state)
```

```python
# Displaying the result
if solution:
    # Print the initial state
    display_state(initial_state, "Initial")

    # Print the final state
    display_state(goal_state, "Goal")

    # Displaying the solution path
    print("Solution path:")
    for step in solution:
        display_state(step, "Step")
else:
    print("No solution found.")
```

Code (A* algorithm using Manhattan distance)

```
import heapq


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


# Function to compute the Manhattan distance heuristic
def manhattan_distance(state):
    distance = 0
    for i in range(3):
        for j in range(3):
            tile = state[i][j]
            if tile != 0:
                goal_i, goal_j = divmod(tile - 1, 3)
                distance += abs(goal_i - i) + abs(goal_j - j)
```

```
    return distance


# Function to get possible moves (neighbors)
def get_neighbors(state):
    neighbors = []
    zero_pos = [(i, j) for i in range(3) for j in range(3) if state[i][j] == 0][0]
    i, j = zero_pos

    # Possible moves: up, down, left, right
    moves = [(-1, 0), (1, 0), (0, -1), (0, 1)]
    for move in moves:
        new_i, new_j = i + move[0], j + move[1]
        if 0 <= new_i < 3 and 0 <= new_j < 3:
            new_state = list(list(row) for row in state)  # Create a copy of the state
            new_state[i][j], new_state[new_i][new_j] = new_state[new_i][new_j], new_state[i][j]
            neighbors.append(tuple(tuple(row) for row in new_state))  # Convert back to tuple
    return neighbors


# Function to count the number of inversions in the puzzle
```

```
def count_inversions(state):

    one_d_state = [tile for row in state for tile in row if tile != 0]

    inversions = 0

    for i in range(len(one_d_state)):

        for j in range(i + 1, len(one_d_state)):

            if one_d_state[i] > one_d_state[j]:

                inversions += 1

    return inversions



# Check if the puzzle is solvable

def is_solvable(state):

    inversions = count_inversions(state)

    return inversions % 2 == 0



# A* Algorithm

def a_star(initial_state):

    if not is_solvable(initial_state):

        print("This puzzle is not solvable.")

        return None
```

```
    open_list = []

    heapq.heappush(open_list, (0 + manhattan_distance(initial_state), 0, initial_state, []))  # (f(n),
g(n), state, path)

    closed_list = set()



    while open_list:

        f, g, current_state, path = heapq.heappop(open_list)

        closed_list.add(current_state)



        # Print the current state and its f(n) value

        print(f"State: {current_state}")

        print(f"f(n) = g(n) + h(n) = {g} + {manhattan_distance(current_state)} = {f}")

        print()



        # If goal state is reached

        if current_state == goal_state:

            return path + [current_state]



        # Generate neighbors
```

```
        for neighbor in get_neighbors(current_state):
            if neighbor not in closed_list:
                heapq.heappush(open_list, (
                    g + 1 + manhattan_distance(neighbor),  # f(n) = g(n) + h(n)
                    g + 1,  # Increment g(n) by 1 for each move
                    neighbor,
                    path + [current_state]
                ))

    return None  # No solution found


# Function to display the puzzle state
def display_state(state, label):
    print(f"{label} state:")
    for row in state:
        print(" ".join(str(x) for x in row))
    print()


# Example initial state (this one is solvable)
```

```
initial_state = (
    (1, 2, 3),
    (5, 6, 4),
    (7, 8, 0)
)


# Solving the puzzle
solution = a_star(initial_state)


# Displaying the result
if solution:
    # Print the initial state
    display_state(initial_state, "Initial")


    # Print the final state
    display_state(goal_state, "Goal")
```

```python
    # Displaying the solution path
    print("Solution path:")
    for step in solution:
        display_state(step, "Step")
else:
    print("No solution found.")
```

Output (N-displaced Tiles)

```
Initial state:
1 2 3
5 6 4
7 8 0

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

Solution path:
Step state:
1 2 3
5 6 4
7 8 0

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

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

Step state:
1 2 3
0 5 6
7 8 4
```

```
Step state:
1 2 3
7 4 5
0 8 6

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

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

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

Step state:
1 2 3
4 5 6
7 8 0
```


```
Step state:
1 2 3
7 4 5
0 8 6

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

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

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

Step state:
1 2 3
4 5 6
7 8 0
```

Output (Manhattan Distance)

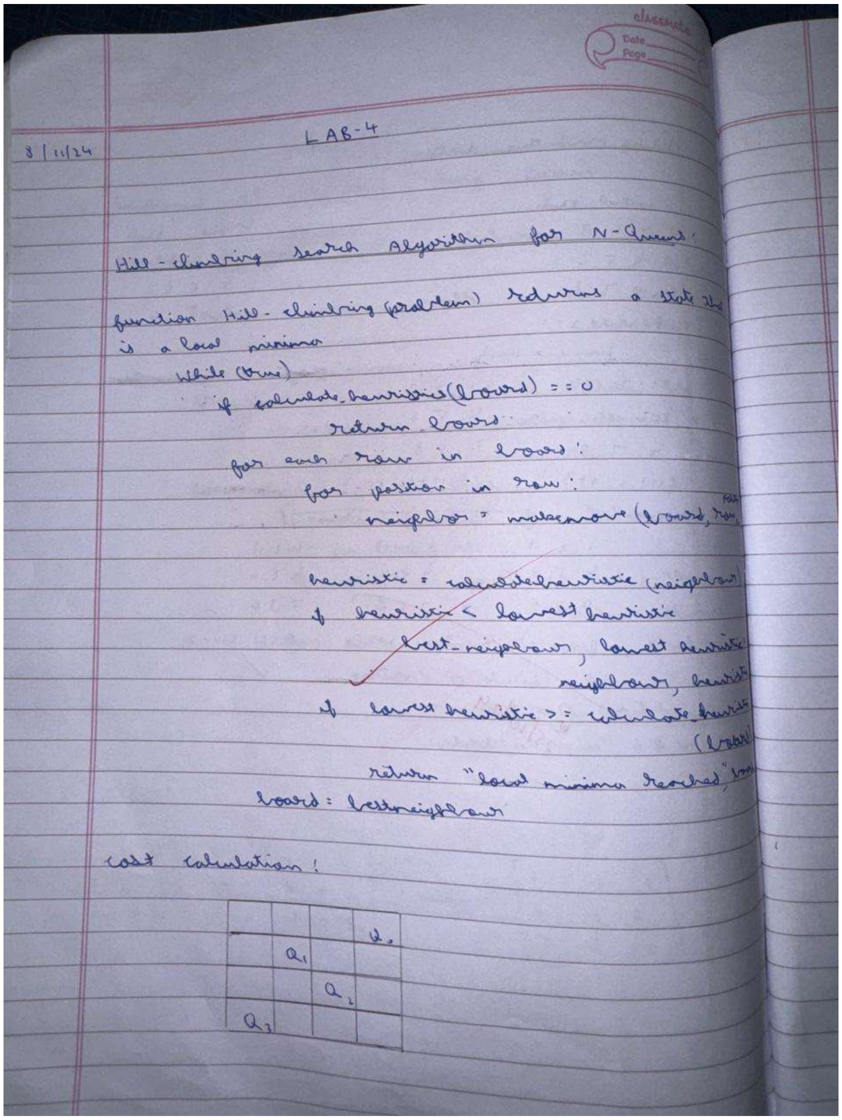
```
Initial state:
1 2 3
5 6 4
7 8 0

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

Solution path:
Step state:
1 2 3
5 6 4
7 8 0

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

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

Step state:
1 2 3
0 5 6
7 8 4
```

```
Step state:
1 2 3
7 5 6
0 8 4

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

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

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

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

Step state:
1 2 3
7 4 5
8 0 6
```

```
Step state:
1 2 3
7 4 5
0 8 6

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

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

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

Step state:
1 2 3
4 5 6
7 8 0
```

Program 6 - Hill Climbing Algorithm

Algorithm



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LAB-4

Hill-climbing search Algorithm for N-Queens:

function Hill-climbing (problem) returns a state that is a local minima

```
While (true)
    if calculate_heuristic(board) == 0
        return board
    for each row in board:
        for position in row:
            neighbour = makemove(board, row, pos)
            heuristic = calculateheuristic (neighbour)
            if heuristic < lowest heuristic
                best_neighbour, lowest heuristic = neighbour, heuristic
    if lowest heuristic >= calculate_heuristic (board)
        return "local minima reached", board
    board = bestneighbour
```

cost calculation:

			Q_0
	Q_1		
		Q_2	
Q_3			

Q_0	Q_1	Q_2	Q_3	
3	1	2	0	
1	3	2	0	Q_0 Q_1
2	1	3	0	Q_0 Q_2
0	1	2	3	Q_0 Q_3
3	0	2	1	Q_1 Q_3
3	2	1	0	Q_1 Q_2
3	1	0	2	Q_2 Q_3

	Q_0		
	-		Q_1
		Q_2	
Q_3			

Q_0 -
Q_1 Q_2
Q_2 Q_1
Q_3 -

cost = 1

		Q_0	
	Q_1		
			Q_2
Q_3			

Q_0 - Q_1
Q_1 - Q_0
Q_2 -
Q_3 -

cost = 1

Q_0			
	Q_1		
		Q_2	
			Q_3

Q_0 Q_1 Q_2 Q_3
Q_1 Q_0 Q_1 Q_3
Q_2 Q_0 Q_1 Q_3
Q_3 Q_0 Q_1 Q_2

cost = 3

			Q_0
Q_1			
		Q_2	
	Q_3		

Q_0 -
Q_1 -
Q_2 - Q_3
Q_3 - Q_2

cost = 1

		Q_2	
Q_0			
			Q_3
	Q_1		

cost = 0

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Q_0	Q_1	Q_2	Q_3
1	3	2	0
3	1	2	0
2	3	1	0
0	3	2	1
1	2	3	0
1	0	3	2
1	3	0	2

OUTPUT:

```
0 0 0 0 0 1 0 0
0 0 1 0 0 0 0 0
1 0 0 0 0 0 0 0
0 0 0 0 0 0 1 0
0 0 0 0 1 0 0 0
0 0 0 0 0 0 0 1
0 1 0 0 0 0 0 0
0 0 0 1 0 0 0 0
```

Code:

```
import random

# Function to calculate the number of attacking pairs of queens

def calculate_attacks(board):

    attacks = 0

    n = len(board)

    for i in range(n):

        for j in range(i + 1, n):

            if board[i] == board[j] or abs(board[i] - board[j]) == j - i:

                attacks += 1

    return attacks



# Function to generate a random initial state

def generate_initial_state(n):

    return [random.randint(0, n - 1) for _ in range(n)]



# Function to generate neighbors by moving one queen to a different row

def generate_neighbors(board):

    neighbors = []

    n = len(board)
```

```
    for col in range(n):
        for row in range(n):
            if row != board[col]:  # Make sure we are not moving the queen to its current row
                neighbor = board[:]
                neighbor[col] = row
                neighbors.append(neighbor)
    return neighbors
# Hill Climbing algorithm with random restarts
def hill_climbing(n, max_restarts=100):
    for restart in range(max_restarts):
        current_state = generate_initial_state(n)
        current_attacks = calculate_attacks(current_state)

        while True:
            # Generate all neighbors
            neighbors = generate_neighbors(current_state)

            # Find the neighbor with the minimum number of attacks
            next_state = None
            next_attacks = current_attacks
```

```
            for neighbor in neighbors:
                attacks = calculate_attacks(neighbor)
                if attacks < next_attacks:
                    next_state = neighbor
                    next_attacks = attacks

            # If no improvement, return the solution or terminate
            if next_attacks == current_attacks:
                break

            current_state = next_state
            current_attacks = next_attacks

        # If a solution is found, return the current state
        if current_attacks == 0:
            return current_state

    # If no solution found after max_restarts, return None
    return None
```

```
# Function to display the board
def display_board(board):
    n = len(board)
    for i in range(n):

        row = ['Q' if i == board[col] else '.' for col in range(n)]
        print(' '.join(row))
    print()

# Set the size of the board (N)
N = 8


# Solve the N-Queens problem with random restarts
solution = hill_climbing(N)


# Display the result
if solution:
    print(f"Solution for {N}-Queens:")
    display_board(solution)
else:
```

```
print(f"No solution found for {N}-Queens.")
```

Output (Hill Climbing)

```
Solution for 8-Queens:
. . . Q . . . .
. Q . . . . . .
. . . . . . Q .
. . . . Q . . .
Q . . . . . . .
. . . . . . . Q
. . . . . Q . .
. . Q . . . . .


...Program finished with exit code 0
Press ENTER to exit console.
```

Program 7 - Simulated Annealing

Algorithm

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LAB-5

Simulated Annealing for N-Queens problem:

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

OUTPUT:

Queen positions in each row: [2, 5, 7, 0, 3, 6, 4, 7]

```
0 0 1 0 0 0 0 0
0 0 0 0 0 1 0 0
0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0
0 0 0 1 0 0 0 0
0 0 0 0 0 0 1 0
0 0 0 0 1 0 0 0
0 0 0 0 0 0 0 1
```

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Code

```
import random

import math

# Objective function: count the number of attacking pairs of queens

def calculate_attacks(board):

attacks = 0

    n = len(board)

    for i in range(n):

        for j in range(i + 1, n):

            # Check if two queens are in the same row, column, or diagonal

            if board[i] == board[j] or abs(board[i] - board[j]) == j - i:

                attacks += 1

    return attacks



# Function to generate a random initial state (random queen positions in each column)

def generate_initial_state(n):

    return [random.randint(0, n - 1) for _ in range(n)]



# Function to generate a neighboring solution by moving one queen in a column
```

```
def generate_neighbor(board):

    neighbor = board[:]

    column = random.randint(0, len(board) - 1)

    # Randomly select a new row for the queen in the chosen column

    neighbor[column] = random.randint(0, len(board) - 1)

    return neighbor



# Simulated Annealing algorithm to solve the N-Queens problem

def simulated_annealing(n, max_iterations, initial_temperature, cooling_rate):

    current_state = generate_initial_state(n)

    current_attacks = calculate_attacks(current_state)

    temperature = initial_temperature



    best_state = current_state

    best_attacks = current_attacks



    for iteration in range(max_iterations):

        # Generate a neighbor solution

        neighbor = generate_neighbor(current_state)

        neighbor_attacks = calculate_attacks(neighbor)
```

```
# Calculate the energy difference (how much worse the new state is)

delta_attacks = neighbor_attacks - current_attacks

# Accept the neighbor if it has fewer attacks or with a probability if it's worse

if delta_attacks < 0 or random.random() < math.exp(-delta_attacks / temperature):

    current_state = neighbor

    current_attacks = neighbor_attacks



# Update the best solution if necessary

if current_attacks < best_attacks:

    best_state = current_state

    best_attacks = current_attacks



# Cool down the temperature

temperature *= cooling_rate



# If no attacks, we found the solution

if best_attacks == 0:

    break
```

```python
    return best_state, best_attacks

# Function to display the board (where 'Q' is a queen and '.' is an empty space)
def display_board(board):
    n = len(board)
    for i in range(n):
        row = ['Q' if i == board[col] else '.' for col in range(n)]
        print(' '.join(row))
    print()


# Parameters for Simulated Annealing
N = 8  # Set the size of the board (N x N)
max_iterations = 10000  # Higher number of iterations for better convergence
initial_temperature = 1000  # High initial temperature
cooling_rate = 0.995  # Cooling rate (temperature decreases by 0.5% every iteration)


# Solve the N-Queens problem using Simulated Annealing
solution, attacks = simulated_annealing(N, max_iterations, initial_temperature, cooling_rate)


# Output the result
print(f"Solution for {N}-Queens found:")
```

```
display_board(solution)

print(f"Total number of attacks: {attacks}")
```

Output

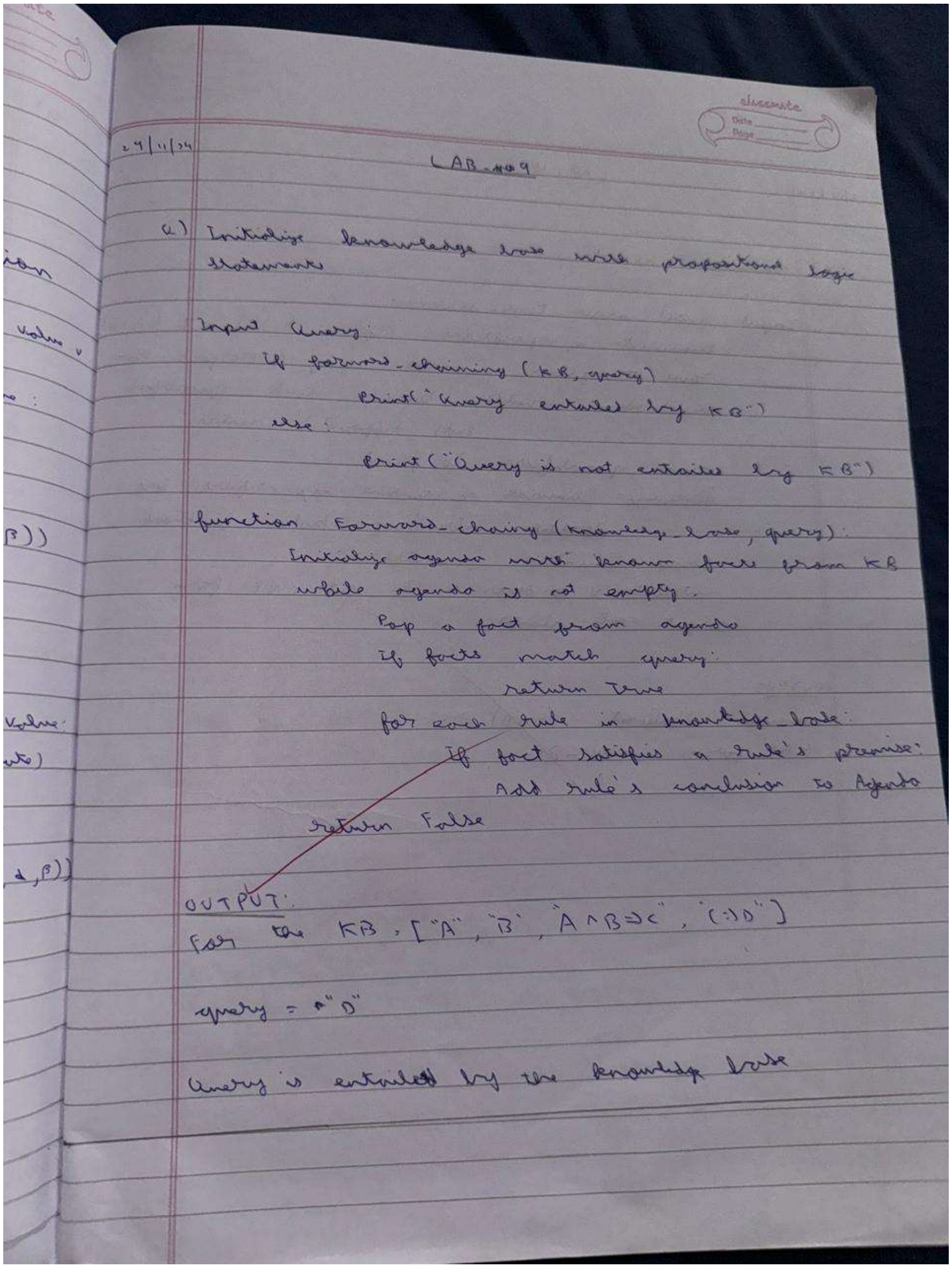
```
Solution for 8-Queens found:
Q . . . . . . .
. . . . Q . . .
. . . . . . . Q
. . . . . Q . .
. . Q . . . . .
. . . . . . Q .
. Q . . . . . .
. . . Q . . . .

Total number of attacks: 0


...Program finished with exit code 0
Press ENTER to exit console.
```

Program 8 - Knowledge base using prepositional logic and show that the given query entails the knowledge base or not.

Algorithm



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LAB-#09

a) Initialize knowledge base with propositional logic statements

Input Query:
    If forward_chaining (KB, query)
        Print("Query entailed by KB")
    else:
        Print ("Query is not entailed by KB")

function Forward_chaining (knowledge_base, query):
    Initialize agenda with known facts from KB
    while agenda is not empty:
        Pop a fact from agenda
        If facts match query:
            return True
        for each rule in knowledge_base:
            If fact satisfies a rule's premise:
                Add rule's conclusion to Agenda
    return False

OUTPUT:
For the KB, ["A", "B", "A ^ B => C", "C => D"]

query = "D"

Query is entailed by the knowledge base

Code

```
from sympy.logic.boolalg import Or, And, Not
from sympy.abc import A, B, C, D, E, F
from sympy import simplify_logic


def is_entailment(kb, query):
    # Negate the query
    negated_query = Not(query)


    # Combine the knowledge base with the negated query
    kb_with_negated_query = And(*kb, negated_query)  # Combine all KB clauses and the negated
query


    # Simplify the combined KB to CNF (Conjunctive Normal Form)
    simplified_kb = simplify_logic(kb_with_negated_query, form="cnf")


    # If the simplified KB evaluates to False, the query is entailed
    return simplified_kb == False


# Define a larger Knowledge Base (kb)
kb = [
    Or(A, B),        # A ∨ B
    Or(Not(A), C),   # ¬A ∨ C
    Or(Not(B), D),   # ¬B ∨ D
    Or(Not(D), E),   # ¬D ∨ E
    Or(Not(E), F),   # ¬E ∨ F
]


# Query to check (C ∨ F)
query = Or(C, F)


# Check entailment
```

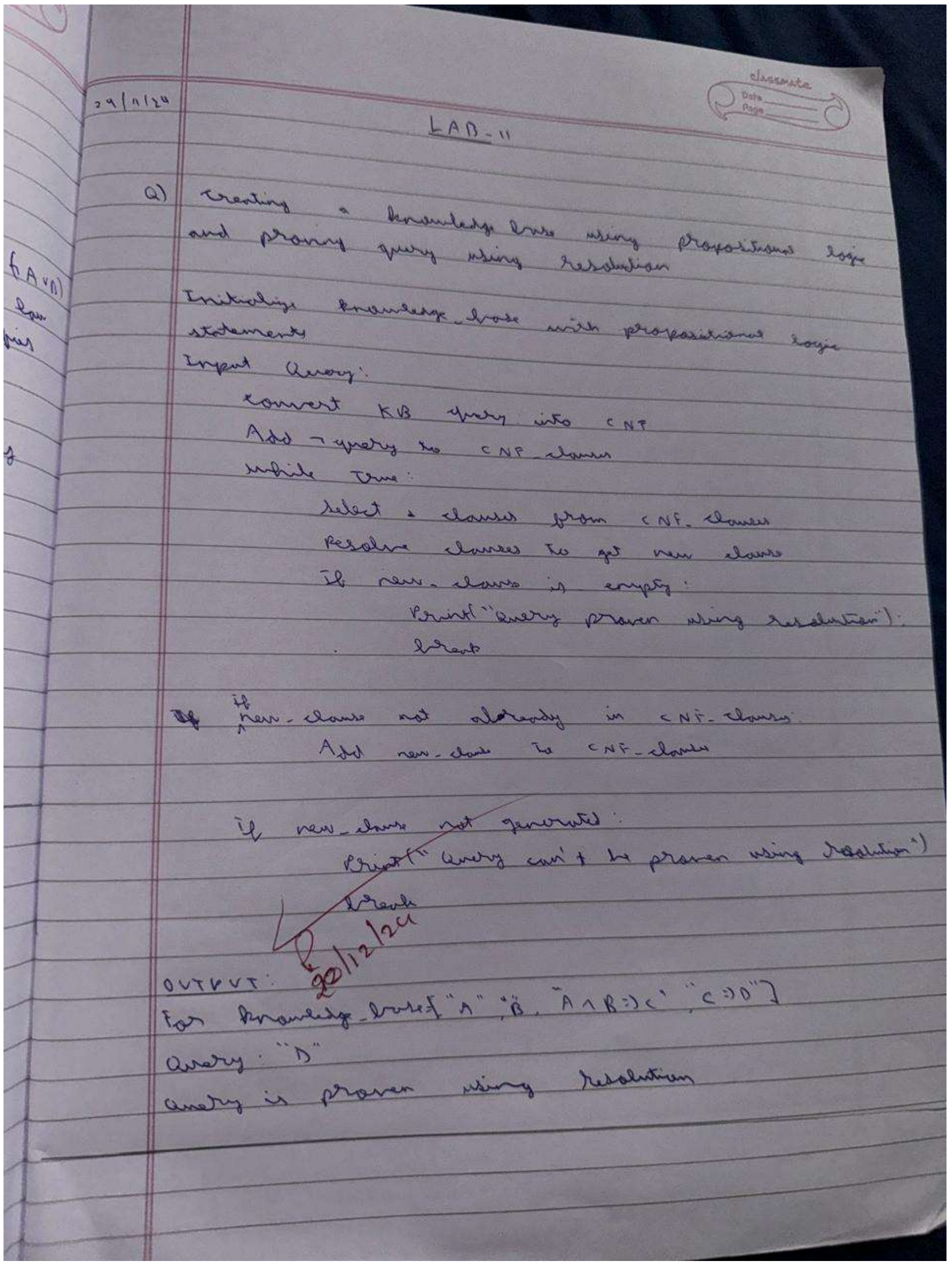
```
result = is_entailment(kb, query)

# Output the result
print(f"Is the query '{query}' entailed by the knowledge base? {'Yes' if result else 'No'}")
```

OUTPUT:

```
Is the query 'C | F' entailed by the knowledge base? Yes
```

Program 9 - **Knowledge base using prepositional logic and prove the given query using resolution.**

Algorithm



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LAB - 11

Q) Creating a knowledge base using propositional logic and proving query using resolution

Initialize knowledge_base with propositional logic statements

Input Query:

convert KB query into CNF

Add ¬query to CNF_clauses

while True:

select 2 clauses from CNF_clauses

Resolve clauses to get new clause

If new_clause is empty:

Print("Query proven using resolution");

break

If new_clause not already in CNF_clauses:

Add new_clause to CNF_clauses

If new_clause not generated:

Print("Query can't be proven using resolution")

break

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OUTPUT:

For knowledge_base = ["A", "B", "A∧B⟹C", "C⟹D"]

Query: "D"

Query is proven using resolution

Code

```
def negation(p):
    """Negate a literal."""
    if p.startswith("~"):
        return p[1:]  # remove the '~' from negated literals
    return f"~{p}"


def resolution(kb, query):
    """Perform resolution on the knowledge base to prove the query."""


    # Add the negation of the query to the knowledge base (for proof by contradiction)
    kb.append(negation(query))


    # Apply the resolution rule until we reach an empty clause (which means contradiction)
    new_clauses = set(kb)  # Keep track of all unique clauses in the knowledge base
    print(f"Initial Knowledge Base + negation of query: {kb}")


    while True:
        added_new_clause = False
```

```
# Try to resolve every pair of clauses
clauses = list(new_clauses)
for i in range(len(clauses)):
    for j in range(i + 1, len(clauses)):
        clause1 = clauses[i]
        clause2 = clauses[j]

        # Try to resolve these two clauses
        resolvent = resolve(clause1, clause2)

        if resolvent is not None:
            print(f"Resolving clauses: {clause1} and {clause2}")
            print(f"Resolved to: {resolvent}")

            # If resolvent is empty, we found a contradiction
            if not resolvent:
                return True  # Found a contradiction, so the query is provable

            # Add the new clause if it's not already in the set
```

```
                    if resolvent not in new_clauses:
                        new_clauses.add(resolvent)
                        added_new_clause = True

        # If no new clause was added, resolution has terminated without a contradiction
        if not added_new_clause:
            break

    return False  # No contradiction found, so the query is not provable



def resolve(clause1, clause2):
    """Resolve two clauses if possible and return the resolvent."""
    # Split clauses into literals
    literals1 = set(clause1.split(" v "))
    literals2 = set(clause2.split(" v "))

    # Try to find complementary literals
    for literal in literals1:
```

```
        neg_literal = negation(literal)
        if neg_literal in literals2:
            # Resolve the two clauses by removing complementary literals
            new_clause = literals1.union(literals2) - {literal, neg_literal}
            return " v ".join(sorted(new_clause))  # Return the resolved clause as a string
    return None  # No resolvent found


# Example knowledge base and query (where T is provable)
kb = [
    "P v Q",          # P or Q
    "~P v R",         # Not P or R
    "Q v ~R",         # Q or Not R
    "R v T"           # R or T
]

query = "T"  # Query to prove (e.g., prove T)

# Perform resolution to prove the query
```

```
result = resolution(kb, query)

if result:
    print(f"\nQuery '{query}' is provable from the knowledge base.")
else:
    print(f"\nQuery '{query}' is not provable from the knowledge base.")
```

Output

```
Initial Knowledge Base + negation of query: ['P v Q', '~P v R', 'Q v ~R', 'R v T', '~T']
Resolving clauses: P v Q and ~P v R
Resolved to: Q v R
Resolving clauses: Q v ~R and ~P v R
Resolved to: Q v ~P
Resolving clauses: Q v ~R and R v T
Resolved to: Q v T
Resolving clauses: ~T and R v T
Resolved to: R
Resolving clauses: Q v R and Q v ~R
Resolved to: Q
Resolving clauses: P v Q and Q v ~P
Resolved to: Q
Resolving clauses: P v Q and ~P v R
Resolved to: Q v R
Resolving clauses: Q v T and ~T
Resolved to: Q
Resolving clauses: Q v ~R and ~P v R
Resolved to: Q v ~P
Resolving clauses: Q v ~R and R v T
Resolved to: Q v T
Resolving clauses: Q v ~R and R
Resolved to: Q
Resolving clauses: ~T and R v T
Resolved to: R
Resolving clauses: Q v R and Q v ~R
Resolved to: Q
Resolving clauses: P v Q and Q v ~P
Resolved to: Q
Resolving clauses: P v Q and ~P v R
Resolved to: Q v R
```

```
Resolving clauses: Q v T and ~T
Resolved to: Q
Resolving clauses: Q v ~R and ~P v R
Resolved to: Q v ~P
Resolving clauses: Q v ~R and R v T
Resolved to: Q v T
Resolving clauses: Q v ~R and R
Resolved to: Q
Resolving clauses: ~T and R v T
Resolved to: R

Query 'T' is not provable from the knowledge base.


...Program finished with exit code 0
Press ENTER to exit console.
```

Program 10 – Unification in First Order Logic.

Algorithm

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LAB-6

Unification Algorithm:

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

Step 2: If the initial Predicate symbol in Ψ_1 and Ψ_2 are not the same then return FAILURE

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

Step 4: Set Substitution set (SUBST) to NIL

Step 5: For i=1 to the number of elements in Ψ_1
a) Call Unify function with the ith element of Ψ_1 and ith element of Ψ_2 and put result into S
b) If S = FAILURE then return FAILURE
c) If S ≠ NIL then do,
i) Apply S to the remainder

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both L1 and L2

(i) SUBST = APPEND (S, SUBST)

Step 6: Return SUBST

OUTPUT:

Enter two terms to unify
Enter first term : f(x, y)
Enter second term : f(a, b)
Unifying terms: ('f', 'x', 'y') and ('f', 'a', 'b')
Unification Successful
Substitution : {'a': 'x', 'b': 'y'}
Unified expression:
Term 1 after substitution: ('f', 'x', 'y')
Term 2 after substitution : ('f', 'x', 'y')

Code

```
def occurs_check(var, term):

    """Check if a variable occurs in a term."""

    if var == term:

        return True

    elif isinstance(term, tuple):  # If the term is a function or a tuple

        return any(occurs_check(var, t) for t in term[1:])

    return False



def unify(term1, term2, substitution=None):

    """Attempt to unify two terms (or predicates)."""

    if substitution is None:

        substitution = {}



    # If both terms are the same, no unification needed

    if term1 == term2:

        return substitution
```

```
    # If term1 is a variable, try to unify it with term2
    if isinstance(term1, str) and term1.isupper():
        if term1 in substitution:
            return unify(substitution[term1], term2, substitution)
        if occurs_check(term1, term2):
            return None  # Avoid circular unification (occurs check)
        substitution[term1] = term2
        return substitution

    # If term2 is a variable, try to unify it with term1
    if isinstance(term2, str) and term2.isupper():
        return unify(term2, term1, substitution)

    # If both terms are functions or predicates (tuples), unify their components
    if isinstance(term1, tuple) and isinstance(term2, tuple):
        if len(term1) != len(term2):
            return None  # Different number of arguments
        for t1, t2 in zip(term1[1:], term2[1:]):
```

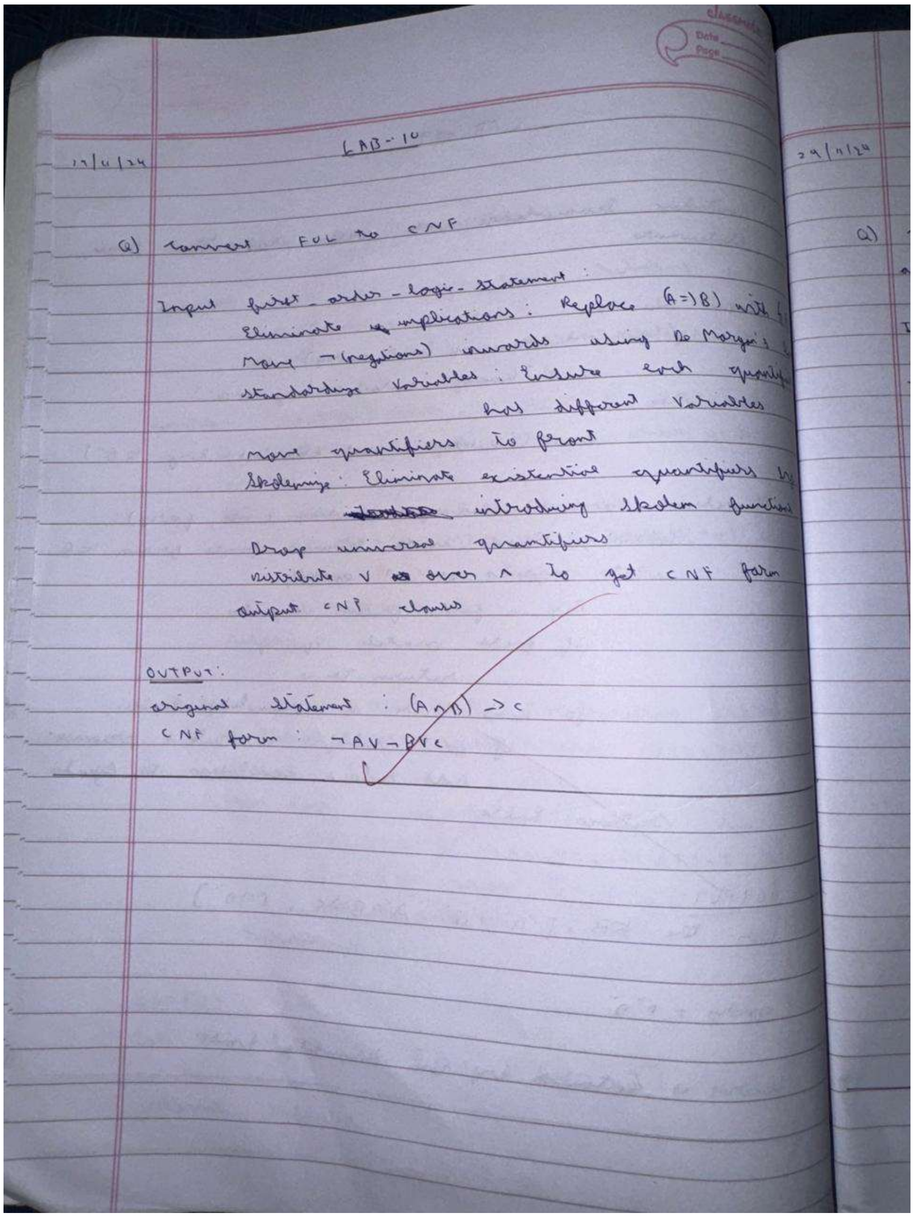
```
            substitution = unify(t1, t2, substitution)

            if substitution is None:

                return None  # If any unification fails, return None

        return substitution



    return None  # If no other cases match, return None (failure)



# Example usage

term1 = ('P', 'X', 'a')  # Predicate P(X, a)

term2 = ('P', 'b', 'a')  # Predicate P(b, a)



# Attempt to unify

substitution = unify(term1, term2)

if substitution is not None:

    print("Unification succeeded with substitution:", substitution)

else:

    print("Unification failed")
```

Output

```
Unification succeeded with substitution: {'X': 'b'}
```

Program 11 - **Convert a given first order logic statement into Conjunctive Normal Form (CNF).**

Algorithm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LAB - 10

Q) Convert FOL to CNF

Input first_order_logic_statement :
Eliminate ~~~~ implications : Replace (A => B) with
Move ¬ (negations) inwards using De Morgan's
standardize Variables : Ensure each quantifier has different Variables
move quantifiers to front
Skolemize : Eliminate existential quantifiers by ~~~~ introducing Skolem functions
Drop universal quantifiers
Distribute ∨ ~~~~ over ∧ to get CNF form
Output CNF clauses

OUTPUT :
original statement : (A ∧ B) -> C
CNF form : ¬A ∨ ¬B ∨ C

Code:

```
from sympy import symbols, Not, Or, And, Implies, Equivalent
from sympy.logic.boolalg import to_cnf

def fol_to_cnf(fol_expr):
    fol_expr = fol_expr.replace(Equivalent, lambda a, b: And(Implies(a, b), Implies(b, a)))
    fol_expr = fol_expr.replace(Implies, lambda a, b: Or(Not(a), b))
    cnf_form = to_cnf(fol_expr, simplify=True)
    return cnf_form

def main():
    P = symbols("P")
    Q = symbols("Q")
    R = symbols("R")

    fol_expr1 = Implies(P, Q)
    print("Example 1: P → Q")
    print("Original FOL Expression:")
    print(fol_expr1)
    cnf1 = fol_to_cnf(fol_expr1)
    print("\nCNF Form:")
    print(cnf1)

    fol_expr2 = Implies(Or(P, Not(Q)), Or(Q, R))
    print("\nExample 2: (P ∨ ¬Q) → (Q ∨ R)")
    print("Original FOL Expression:")
    print(fol_expr2)
    cnf2 = fol_to_cnf(fol_expr2)
    print("\nCNF Form:")
    print(cnf2)
```

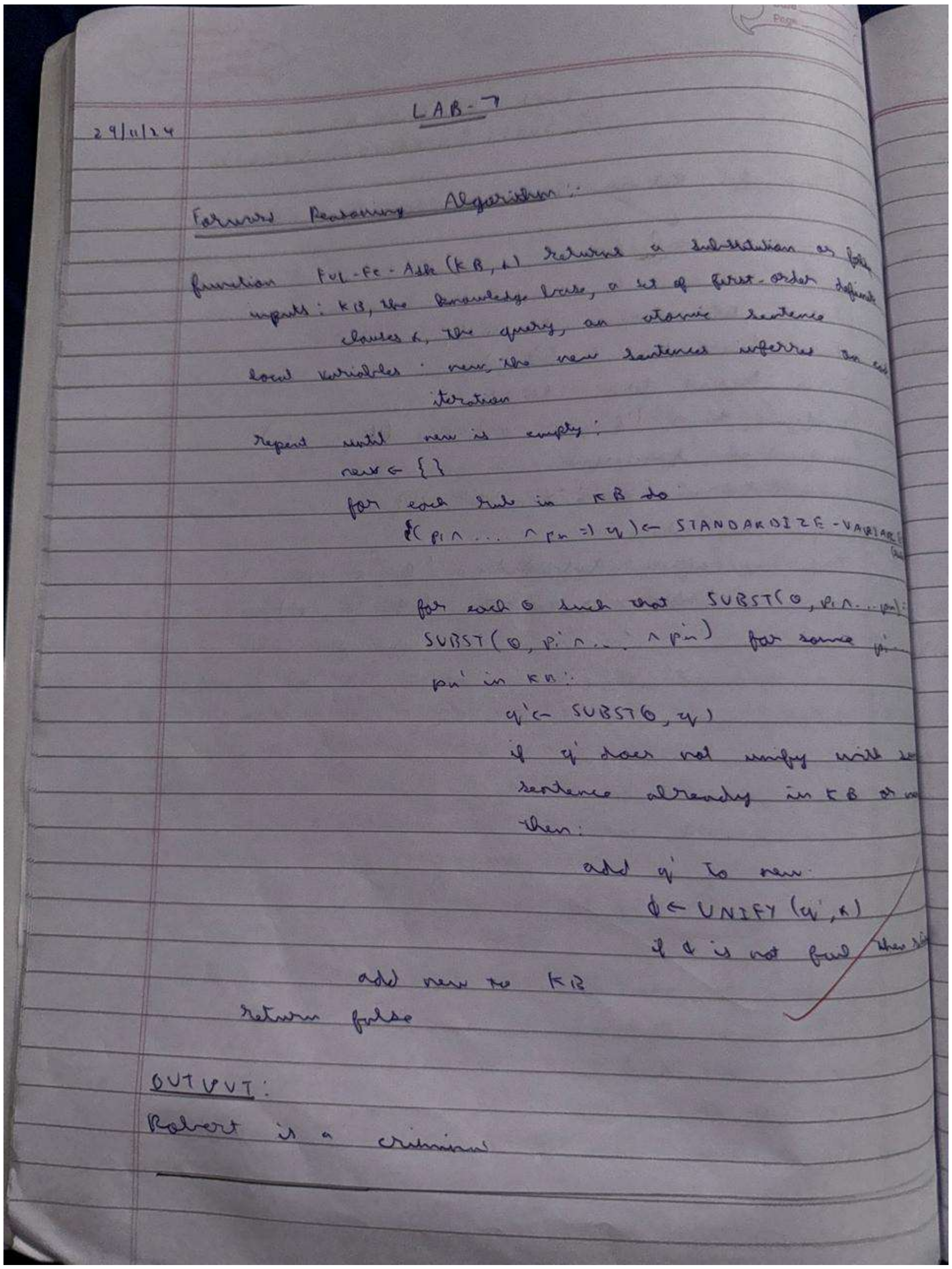
```
if __name__ == "__main__":
    main()
```

OUTPUT:

```
Example 1: P → Q
Original FOL Expression:
Implies(P, Q)

CNF Form:
Q | ~P

Example 2: (P V ¬Q) → (Q V R)
Original FOL Expression:
Implies(P | ~Q, Q | R)

CNF Form:
Q | R
```

Program 12 - **Knowledge base consisting of first order logic statements and prove the given query using forward reasoning..**

Algorithm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Forward Reasoning Algorithm:

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

inputs: KB, the knowledge base, a set of first-order definite clauses α, the query, an atomic sentence

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

repeat until new is empty:

new ← {}

for each rule in KB do

(p1 ∧ ... ∧ pn ⇒ q) ← STANDARDIZE-VARIABLES(rule)

for each θ such that SUBST(θ, p1 ∧ ... pn) = SUBST(θ, p1' ∧ ... ∧ pn') for some p1' ... pn' in KB:

q' ← SUBST(θ, q)

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

add q' to new

φ ← UNIFY(q', α)

if φ is not fail then return φ

add new to KB

return false

OUTPUT:

Robert is a criminal

Knowledge base (KB) :

KB : [

"~~Ame~~ American (Robert)",

"Enemy (A, America)",

"Missile (T1)",

"owns (A, T1)",

"missile (x) => Weapon (x)",

"Weapon (x) ^ sells (Robert, x, A) ^ Hostile (A) => Criminal (Robert)",

"Enemy (x, America) => Hostile (x)",

"sells (Robert, T1, A)",

]

query = "Criminal (Robert)"

This query can be proved

- missile (x) => weapon (x)

  Substitute x = T1, Inference : Weapon (T1)

- Enemy (x, America) => Hostile (x)

  Fact in KB : Enemy (A, America)

  Substitute x = A, Inference : Hostile (A)

- Weapon (x) ^ sells (p, x, r) ^ Hostile (r) => Criminal (p)

  Substitute x = T1, p = Robert, r = A

  Weapon (T1), Sells (Robert, T1, A), Hostile (A)

  Inference : Criminal (Robert)

Consider a vocabulary with the following symbols

Occupation (p, o) : Predicate person p has occupation o
Customer (p1, p2) : Predicate person p1 ~~was~~ is customer of p2
Boss (p1, p2) : Predicate person p1 is boss of p2

Doctor, Surgeon, lawyer, Actor : constants denoting occupations
Emily, Joe : constants denoting ppl

using these symbols to write assertions in FOL:

a) Emily is surgeon or lawyer
occupation (Emily, Surgeon) ∨ occupation (Emily, lawyer)

b) Joe is an actor, but has other job
occupation (Joe, Actor) ∧ ∃ c (c ≠ actor ∧ occupation (Joe, c))

c) All surgeons are doctors
∀ p occupation (p, Surgeon) ⇒ occupation (p, doctor)

d) Joe doesn't ~~know~~ have a lawyer
¬∃ (p, lawyer) ∧ customer (Joe, p)

e) Emily has boss who is lawyer
∃ p Boss (p, Emily) ∧ occupation (p, lawyer)

f) There exists a lawyer all of whose customers are doctors
∃ p (occupation (p, lawyer) ∧ ∀ c (customer (c, p) ⇒ occupation (c, doctor)))

g) Every surgeon has a lawyer
∀ p (occupation (p, surgeon) ⇒ ∃ l (occupation (l, lawyer) ∧ customer (p, l)))

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Code

```
knowledge_base = {
    "facts": {
        "American(Robert)",
        "Enemy(A, America)",
        "Owns(A, T1)",
        "Missile(T1)",
    },
    "rules": [
        {"if": ["Missile(x)"], "then": ["Weapon(x)"]},
        {"if": ["Enemy(x, America)"], "then": ["Hostile(x)"]},
        {"if": ["Missile(x)", "Owns(A, x)"], "then": ["Sells(Robert, x, A)"]},
        {
            "if": ["American(p)", "Weapon(q)", "Sells(p, q, r)", "Hostile(r)"],
            "then": ["Criminal(p)"],
        },
    ],
}

def forward_chaining(kb):
    facts = kb["facts"].copy()
    rules = kb["rules"]
    inferred = set()

    while True:
        new_inferences = set()

        for rule in rules:
            if_conditions = rule["if"]
            then_conditions = rule["then"]
            substitutions = {}
            all_conditions_met = True
```

```
for condition in if_conditions:
    predicate, args = condition.split("(")
    args = args[:-1].split(",")
    matched = False

    for fact in facts:
        fact_predicate, fact_args = fact.split("(")
        fact_args = fact_args[:-1].split(",")

        if predicate == fact_predicate and len(args) == len(fact_args):
            temp_subs = {}
            for var, val in zip(args, fact_args):
                if var.islower():
                    if var in temp_subs and temp_subs[var] != val:
                        break
                    temp_subs[var] = val
                elif var != val:
                    break
            else:
                matched = True
                substitutions.update(temp_subs)
                break

    if not matched:
        all_conditions_met = False
        break

if all_conditions_met:
    for condition in then_conditions:
        predicate, args = condition.split("(")
        args = args[:-1].split(",")
        new_fact = predicate + "(" + ",".join(substitutions.get(arg, arg) for arg in args) + ")"
        new_inferences.add(new_fact)
```

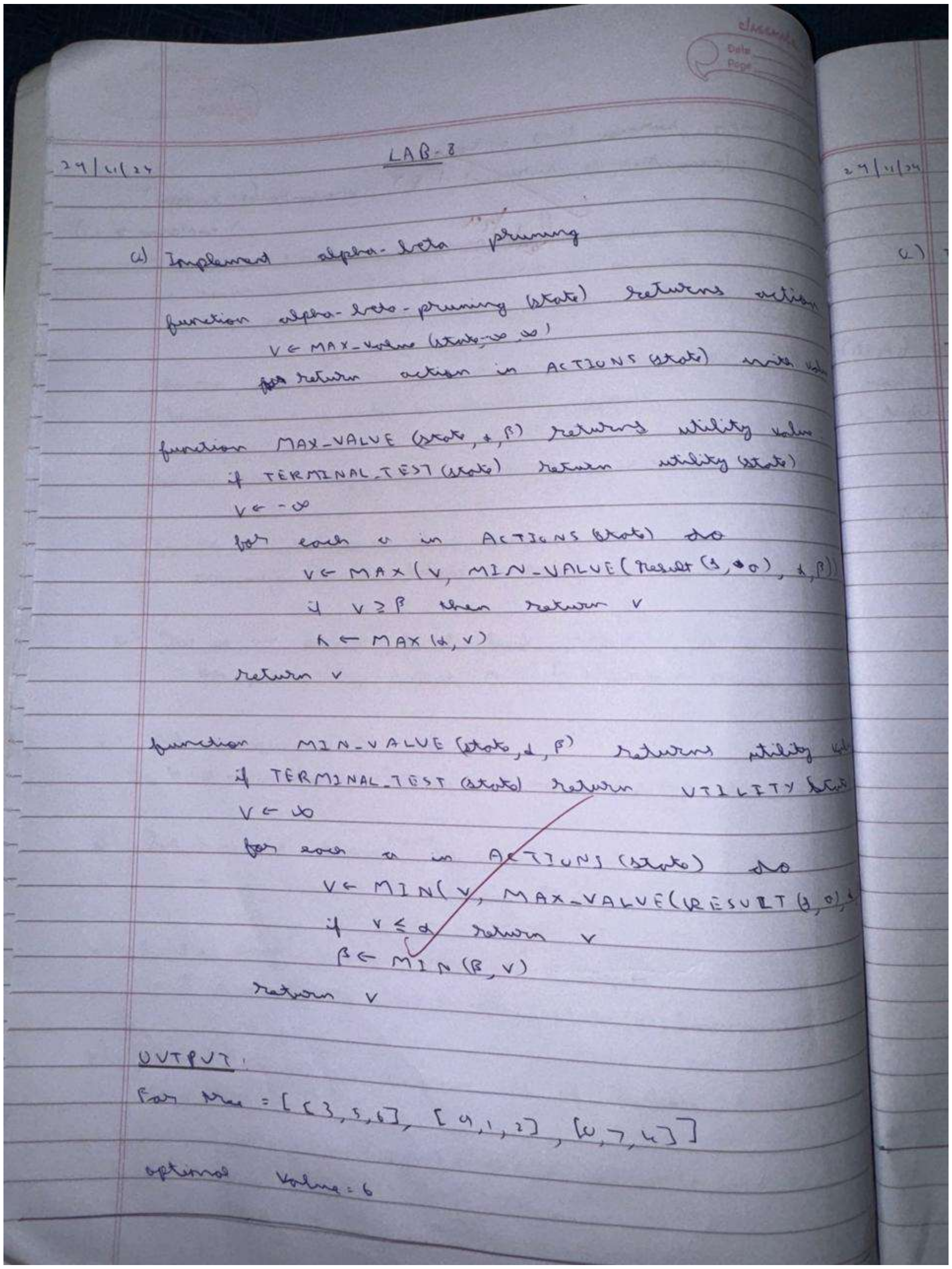
```
        if new_inferences - inferred:
            inferred.update(new_inferences)
            facts.update(new_inferences)
        else:
            break

    return inferred

result = forward_chaining(knowledge_base)

if "Criminal(Robert)" in result:
    print("Proved: Robert is a criminal.")
else:
    print("Could not prove that Robert is a criminal.")
```

OUTPUT:

```
Proved: Robert is a criminal.
```

<u>Program 13</u> - Implement Alpha-Beta Pruning.

<u>Algorithm</u>



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LAB-8

a) Implement alpha-beta pruning

```
function alpha-beta-pruning(state) returns action
    v ← MAX-VALUE(state, -∞, ∞)
    return action in ACTIONS(state) with value v

function MAX-VALUE(state, α, β) returns utility value
    if TERMINAL-TEST(state) 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 utility value
    if TERMINAL-TEST(state) return UTILITY(state)
    v ← ∞
    for each a in ACTIONS(state) do
        v ← MIN(v, MAX-VALUE(RESULT(s, a), α, β))
        if v ≤ α return v
        β ← MIN(β, v)
    return v
```

OUTPUT:

For tree = [[3,5,6], [9,1,2], [0,7,4]]

optimal value: 6

Code

```
import math

def alpha_beta_pruning(depth, node_index, is_maximizing_player, values, alpha, beta, max_depth):
    if depth == max_depth:
        return values[node_index]

    if is_maximizing_player:
        best = -math.inf
        for i in range(2):
            val = alpha_beta_pruning(depth + 1, node_index * 2 + i, False, values, alpha, beta,
max_depth)
            best = max(best, val)
            alpha = max(alpha, best)
            if beta <= alpha:
                break
        return best
    else:
        best = math.inf
        for i in range(2):
            val = alpha_beta_pruning(depth + 1, node_index * 2 + i, True, values, alpha, beta,
max_depth)
            best = min(best, val)
            beta = min(beta, best)
            if beta <= alpha:
                break
        return best

if __name__ == "__main__":
    values = [3, 5, 6, 9, 1, 2, 0, -1]  # Example tree represented as a list of leaf node values
```

```
max_depth = 3  # Height of the tree
result = alpha_beta_pruning(0, 0, True, values, -math.inf, math.inf, max_depth)
print("The optimal value is:", result)
```

OUTPUT

```
The optimal value is: 5


...Program finished with exit code 0
Press ENTER to exit console.
```