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
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(Affiliated To Visvesvaraya Technological University, Belgaum)

Department of Computer Science and Engineering

<u>CERTIFICATE</u>

This is to certify that the Lab work entitled “Artificial Intelligence (23CS5PCAIN)” carried out by **Prerana Meda Krishna(1BM22CS209),** who is Bonafide student of **B.M.S. College of Engineering.** It is in partial fulfilment 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.

Radhika A D Assistant Professor Department of CSE, BMSCE	Dr. Kavitha Sooda Professor & HOD Department of CSE, BMSCE

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

Program 1

Implement Tic –Tac –Toe Game

Algorithm:

lab 1 Tic Tac Toe Game

Step1: Start

Step2: Creation of board

Step3: Allocate AI with O and player with X

Step4: take alternate input from AI and player

Step5: to win()
for i in range(3) row column
if b[i][0] == b[i][1] == b[i][2] != ' '
return b[i][0]
if b[0][i] == b[1][i] == b[2][i] != ' '
return b[0][i]
if b[0][0] == b[1][1] == b[2][2] != ' '
return b[0][0]
if b[0][2] == b[1][1] == b[2][0] != ' '
return b[0][2]
return -1

Step6: Draw()
if (is_b_full()) && either of player not w
Draw has occured
else
continue playing

Step 7: if any of the two cells are filled and are same then return the middle portion which is empty.
return position
else call to_win

Step 8: take input from AI and players alternatively
if (pos == -1)
print(AI/player win)

Step 9: stop

Code:

```
# Set up the game board as a 2D list
board = [["-", "-", "-"],
         ["-", "-", "-"],
         ["-", "-", "-"]]

# Define a function to print the game board
def print_board():
    for row in board:
        print(" | ".join(row))

# Define a function to handle a player's turn
def take_turn(player):
```

```
    print(player + "'s turn.")
    position = input("Choose a position from 1-9: ")
    while position not in ["1", "2", "3", "4", "5", "6", "7", "8", "9"]:
        position = input("Invalid input. Choose a position from 1-9: ")
    position = int(position) - 1
    row, col = divmod(position, 3)
    while board[row][col] != "-":
        position = int(input("Position already taken. Choose a different position: ")) - 1
        row, col = divmod(position, 3)
    board[row][col] = player
    print_board()

# Define a function to check if the game is over
def check_game_over():
    # Check for a win
    for i in range(3):
        if board[i][0] == board[i][1] == board[i][2] != "-":
            return "win"
        if board[0][i] == board[1][i] == board[2][i] != "-":
            return "win"
    if board[0][0] == board[1][1] == board[2][2] != "-":
        return "win"
    if board[0][2] == board[1][1] == board[2][0] != "-":
        return "win"
    # Check for a tie
    elif all(cell != "-" for row in board for cell in row):
        return "tie"
    # Game is not over
    else:
        return "play"

# Define the main game loop
def play_game():
    print_board()
    current_player = "X"
    game_over = False
    while not game_over:
        take_turn(current_player)
        game_result = check_game_over()
        if game_result == "win":
            print(current_player + " wins!")
            game_over = True
        elif game_result == "tie":
            print("It's a tie!")
            game_over = True
        else:
            # Switch to the other player
            current_player = "O" if current_player == "X" else "X"
```

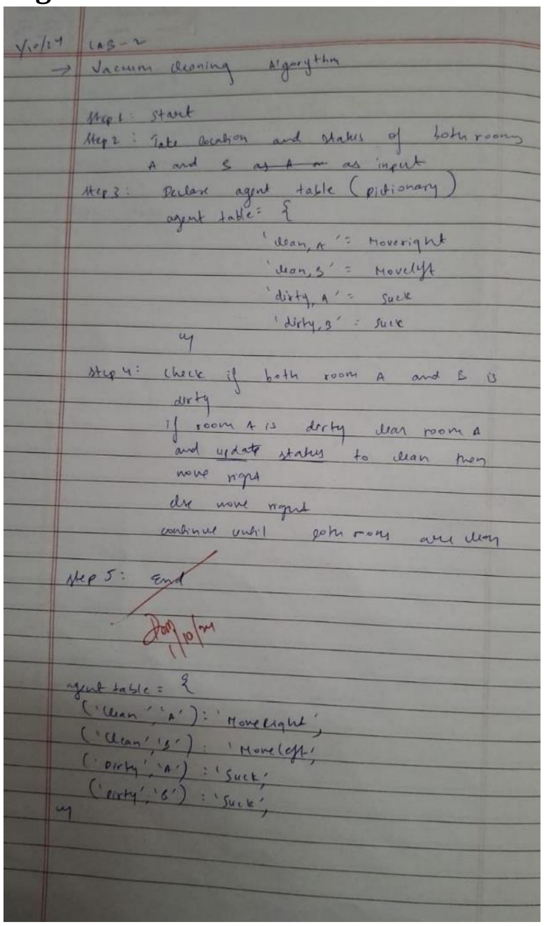
# Start the game
play_game()

Output:
- | - | -
- | - | -
- | - | -
X's turn.
Choose a position from 1-9: 1
X | - | -
- | - | -
- | - | -
O's turn.
Choose a position from 1-9: 2
X | O | -
- | - | -
- | - | -
X's turn.
Choose a position from 1-9: 3
X | O | X
- | - | -
- | - | -
O's turn.
Choose a position from 1-9: 5
X | O | X
- | O | -
- | - | -
X's turn.
Choose a position from 1-9: 4
X | O | X
X | O | -
- | - | -
O's turn.
Choose a position from 1-9: 6
X | O | X
X | O | O
- | - | -
X's turn.
Choose a position from 1-9: 8
X | O | X
X | O | O
- | X | -
O's turn.
Choose a position from 1-9: 7
X | O | X
X | O | O
O | X | -

X's turn.
Choose a position from 1-9: 9
X | O | X
X | O | O
O | X | X
It's a tie!

Implement vacuum cleaner agent

Algorithm:



9/10/24 LAB-2

→ Vacuum cleaning Algorythm

Step 1: Start

Step 2: Take location and status of both rooms A and B ~~as A~~ as input

Step 3: Declare agent table (Dictionary)

agent table = {
'clean, A': Moveright
'clean, B' = Moveleft
'dirty, A': Suck
'dirty, B': Suck
}

Step 4: Check if both room A and B is dirty
if room A is dirty clean room A and update status to clean then move right
else move right
continue until both rooms are clean

Step 5: End

agent table = {
('clean','A'): 'MoveRight',
('clean','B'): 'MoveLeft',
('dirty','A'): 'Suck',
('dirty','B'): 'Suck',
}

Code:

```
#For two quadrants
def vacuum_cleaner_simulation():

    current_room = input("Enter current room either A or B: ").upper()
    room_A = int(input("Is Room A dirty? (yes:1/no:0): "))
    room_B = int(input("Is Room B dirty? (yes:1/no:0): "))

    cost = 0

    def display_rooms():
        print(f"Room A: {'Clean' if room_A == 0 else 'Dirty'}")
        print(f"Room B: {'Clean' if room_B == 0 else 'Dirty'}")

    print("\nInitial status of rooms:")
    display_rooms()
    print()

    while room_A == 1 or room_B == 1:
```

```
        if current_room == 'A' and room_A == 1:
            print("Cleaning Room A...")
            room_A = 0
            cost += 1
        elif current_room == 'B' and room_B == 1:
            print("Cleaning Room B...")
            room_B = 0
            cost += 1
        else:
            current_room = 'B' if current_room == 'A' else 'A'
            print(f"Moving to Room {current_room}...")
        print("Current status:")
        display_rooms()

    print(f"\nBoth rooms are now clean! Total cost: {cost}")

vacuum_cleaner_simulation()

#For four quadrants
def vacuum_cleaner_simulation():
    current_room = input("Enter current room (A, B, C, or D): ").upper()
    room_A = int(input("Is Room A dirty? (yes:1/no:0): "))
    room_B = int(input("Is Room B dirty? (yes:1/no:0): "))
    room_C = int(input("Is Room C dirty? (yes:1/no:0): "))
    room_D = int(input("Is Room D dirty? (yes:1/no:0): "))

    cost = 0
    count=2
    def display_rooms():
        print(f"Room A: {'Clean' if room_A == 0 else 'Dirty'}")
        print(f"Room B: {'Clean' if room_B == 0 else 'Dirty'}")
        print(f"Room C: {'Clean' if room_C == 0 else 'Dirty'}")
        print(f"Room D: {'Clean' if room_D == 0 else 'Dirty'}")

    print("\nInitial status of rooms:")
    display_rooms()
    print()


    while room_A == 1 or room_B == 1 or room_C == 1 or room_D == 1:
        if count==0:
          print("Vacuum is recharging")
          count=2
        else:
          if current_room == 'A' and room_A == 1:
              print("Cleaning Room A...")
              room_A = 0
              cost += 1
```

```
            count-=1
        elif current_room == 'B' and room_B == 1:
            print("Cleaning Room B...")
            room_B = 0
            cost += 1
            count-=1
        elif current_room == 'C' and room_C == 1:
            print("Cleaning Room C...")
            room_C = 0
            cost += 1
            count-=1
        elif current_room == 'D' and room_D == 1:
            print("Cleaning Room D...")
            room_D = 0
            cost += 1
            count-=1
        else:
            if current_room == 'A':
                current_room = 'B'
            elif current_room == 'B':
                current_room = 'C'
            elif current_room == 'C':
                current_room = 'D'
            else:
                current_room = 'A'
            print(f"Moving to Room {current_room}...")

    print("\nCurrent status:")
    display_rooms()
    print(f"\nAll rooms are now clean! Total cost: {cost}")

vacuum_cleaner_simulation()
```

Output:

Enter current room either A or B: A
Is Room A dirty? (yes:1/no:0): 0
Is Room B dirty? (yes:1/no:0): 1

Initial status of rooms:
Room A: Clean
Room B: Dirty

Moving to Room B...
Current status:
Room A: Clean
Room B: Dirty
Cleaning Room B...
Current status:

Room A: Clean
Room B: Clean

Both rooms are now clean! Total cost: 1
Enter current room (A, B, C, or D): A
Is Room A dirty? (yes:1/no:0): 0
Is Room B dirty? (yes:1/no:0): 0
Is Room C dirty? (yes:1/no:0): 1
Is Room D dirty? (yes:1/no:0): 0

Initial status of rooms:
Room A: Clean
Room B: Clean
Room C: Dirty
Room D: Clean

Moving to Room B...
Moving to Room C...
Cleaning Room C...

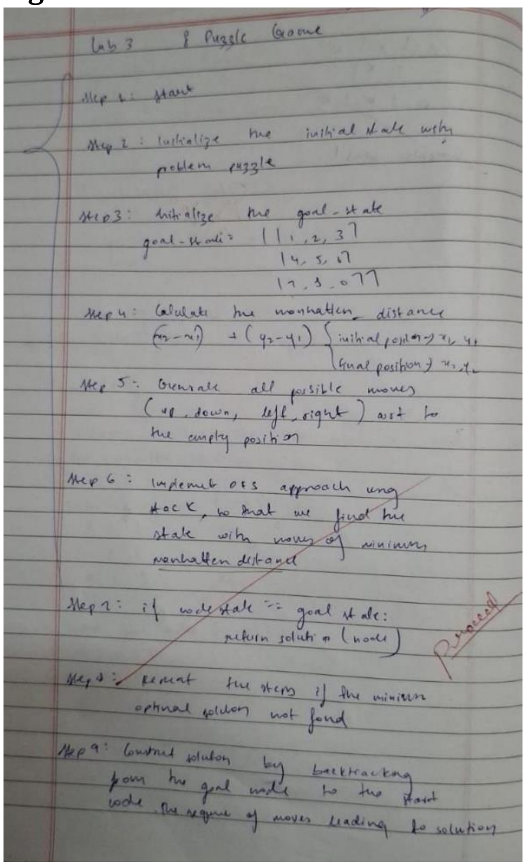
Current status:
Room A: Clean
Room B: Clean
Room C: Clean
Room D: Clean

All rooms are now clean! Total cost: 1

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)

Algorithm:


Lab 3 8 Puzzle Game

Step 1: start

Step 2: Initialize the initial state with problem puzzle

Step 3: Initialize the goal-state
goal-state = [[1, 2, 3]
[4, 5, 6]
[7, 8, 0]]

Step 4: Calculate the manhattan distance
$(x_2 - x_1) + (y_2 - y_1)$ { initial position → x_1, y_1
final position → x_2, y_2

Step 5: Generate all possible moves (up, down, left, right) w.r.t to the empty position

Step 6: Implement DFS approach using stack, so that we find the state with moves of minimum manhattan distance

Step 7: if node state == goal state:
return solution (node)

Step 8: Repeat the steps if the minimum optimal solution not found

Step 9: Construct solution by backtracking from the goal node to the start node. The sequence of moves leading to solution

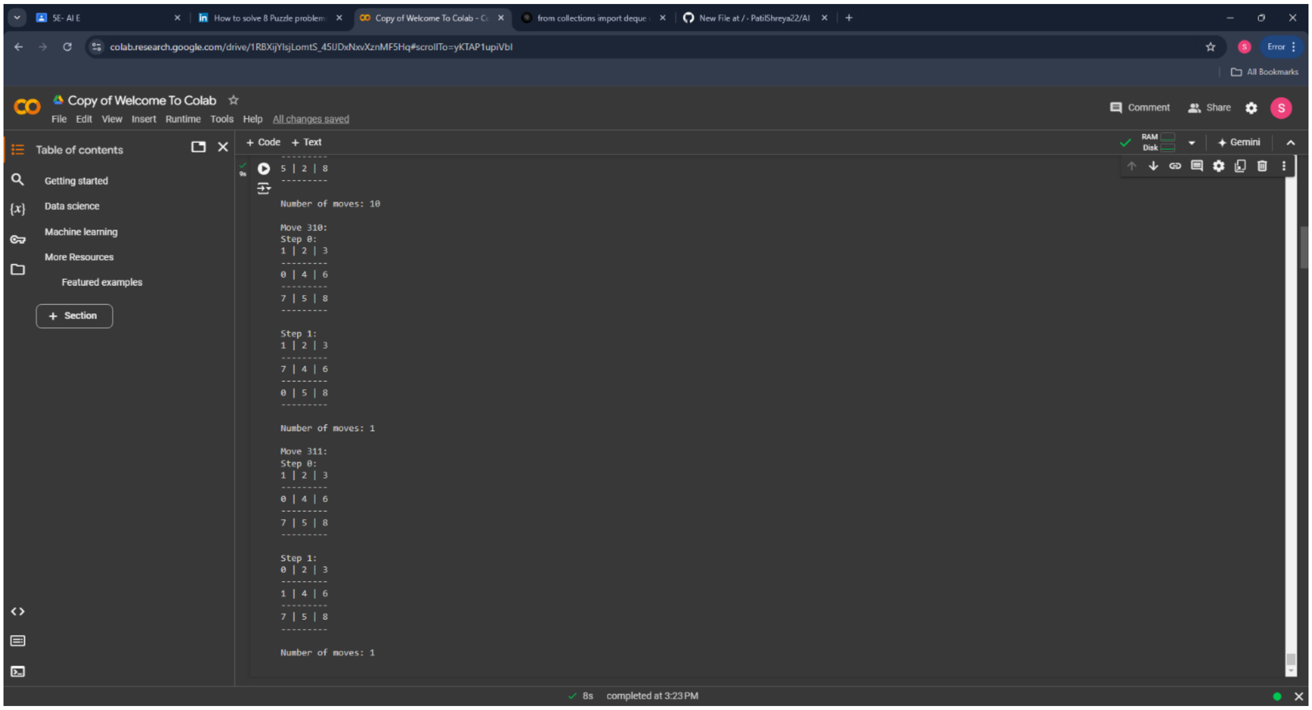
Proceed

Code:

```
from collections import deque

def dfs(start, max_depth):
    stack = deque([(start, [start], 0)])  # (node, path, level)
    visited = set([start])
    all_moves = []
    while stack:
        node, path, level = stack.pop()
        all_moves.append((path, level))
        if level < max_depth:
            for next_node in get_neighbors(node):
                if next_node not in visited:
                    visited.add(next_node)
                    stack.append((next_node, path + [next_node], level + 1))
    return all_moves

def get_neighbors(node):
    neighbors = []
```

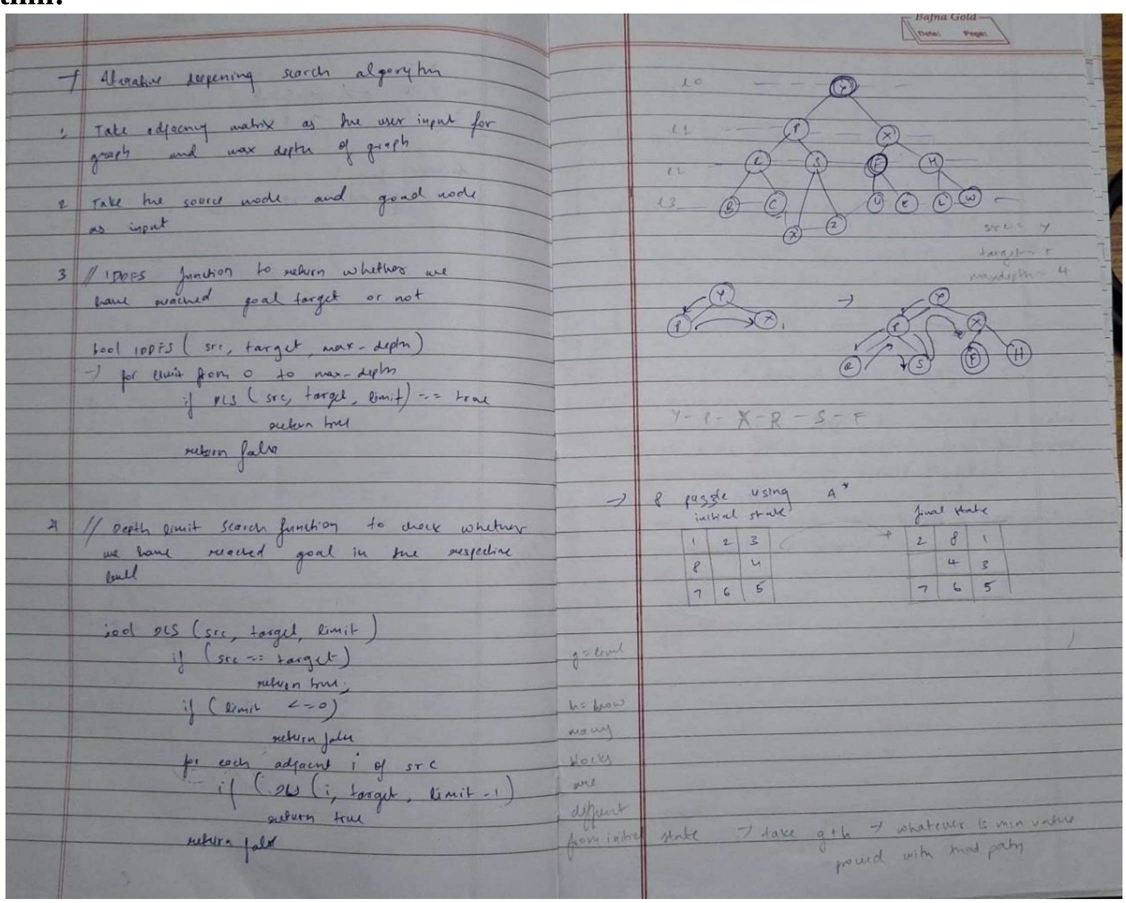
```
    for i in range(9):
        if node[i] == 0:
            x, y = i // 3, i % 3
            for dx, dy in [(-1, 0), (1, 0), (0, -1), (0, 1)]:
                nx, ny = x + dx, y + dy
                if 0 <= nx < 3 and 0 <= ny < 3:
                    n = list(node)
                    n[i], n[nx * 3 + ny] = n[nx * 3 + ny], n[i]
                    neighbors.append(tuple(n))
            break
    return neighbors

def print_board(board):
    board = [board[i:i+3] for i in range(0, 9, 3)]
    for row in board:
        print(" | ".join(str(x) for x in row))
        print("---------")

def main():
    start = tuple(int(x) for x in input("Enter the initial state (space-separated): ").split())
    max_depth = 10  # maximum depth to search
    all_moves = dfs(start, max_depth)
    if all_moves:
        print("All possible moves:")
        for i, (path, level) in enumerate(all_moves):
            print(f"Move {i+1}:")
            for j, node in enumerate(path):
                print(f"Step {j}:")
                print_board(node)
                print()
            print(f"Number of moves: {level}")
            print()
    else:
        print("No solution found.")

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

Output:



Implement Iterative deepening search algorithm

Algorithm:

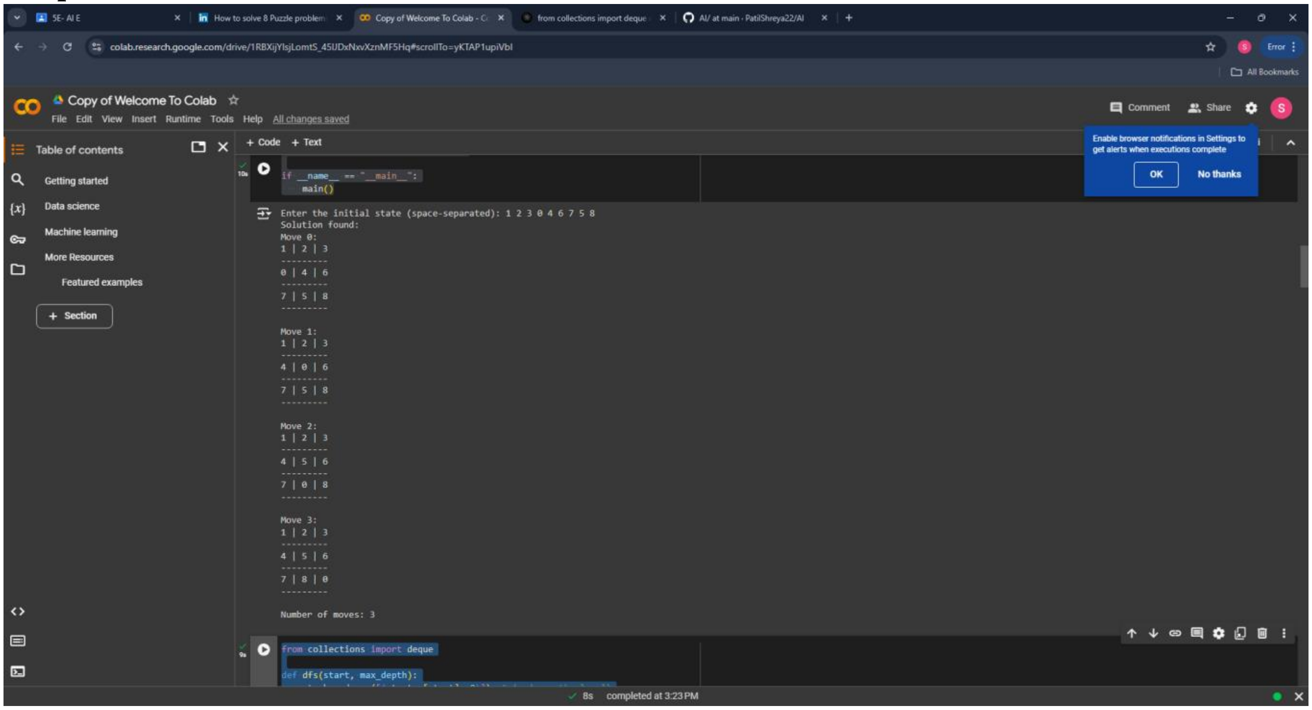


Code:

```
from collections import deque

def bfs(start, goal):
    queue = deque([(start, [start], 0)])  # (node, path, level)
    visited = set([start])
    while queue:
        node, path, level = queue.popleft()
        if node == goal:
            return path, level
        for next_node in get_neighbors(node):
            if next_node not in visited:
                visited.add(next_node)
                queue.append((next_node, path + [next_node], level + 1))
    return None, None

def get_neighbors(node):
    neighbors = []
    for i in range(9):
        if node[i] == 0:
            x, y = i // 3, i % 3
            for dx, dy in [(-1, 0), (1, 0), (0, -1), (0, 1)]:
                nx, ny = x + dx, y + dy
                if 0 <= nx < 3 and 0 <= ny < 3:
                    n = list(node)
                    n[i], n[nx * 3 + ny] = n[nx * 3 + ny], n[i]
                    neighbors.append(tuple(n))
            break
    return neighbors

def print_board(board):
    board = [board[i:i+3] for i in range(0, 9, 3)]
    for row in board:
        print(" | ".join(str(x) for x in row))
        print("---------")

def main():
    start = tuple(int(x) for x in input("Enter the initial state (space-separated): ").split())
    goal = (1, 2, 3, 4, 5, 6, 7, 8, 0)
    path, level = bfs(start, goal)
    if path:
        print("Solution found:")
        for i, node in enumerate(path):
            print(f"Move {i}:")
            print_board(node)
            print()
        print(f"Number of moves: {level}")
```

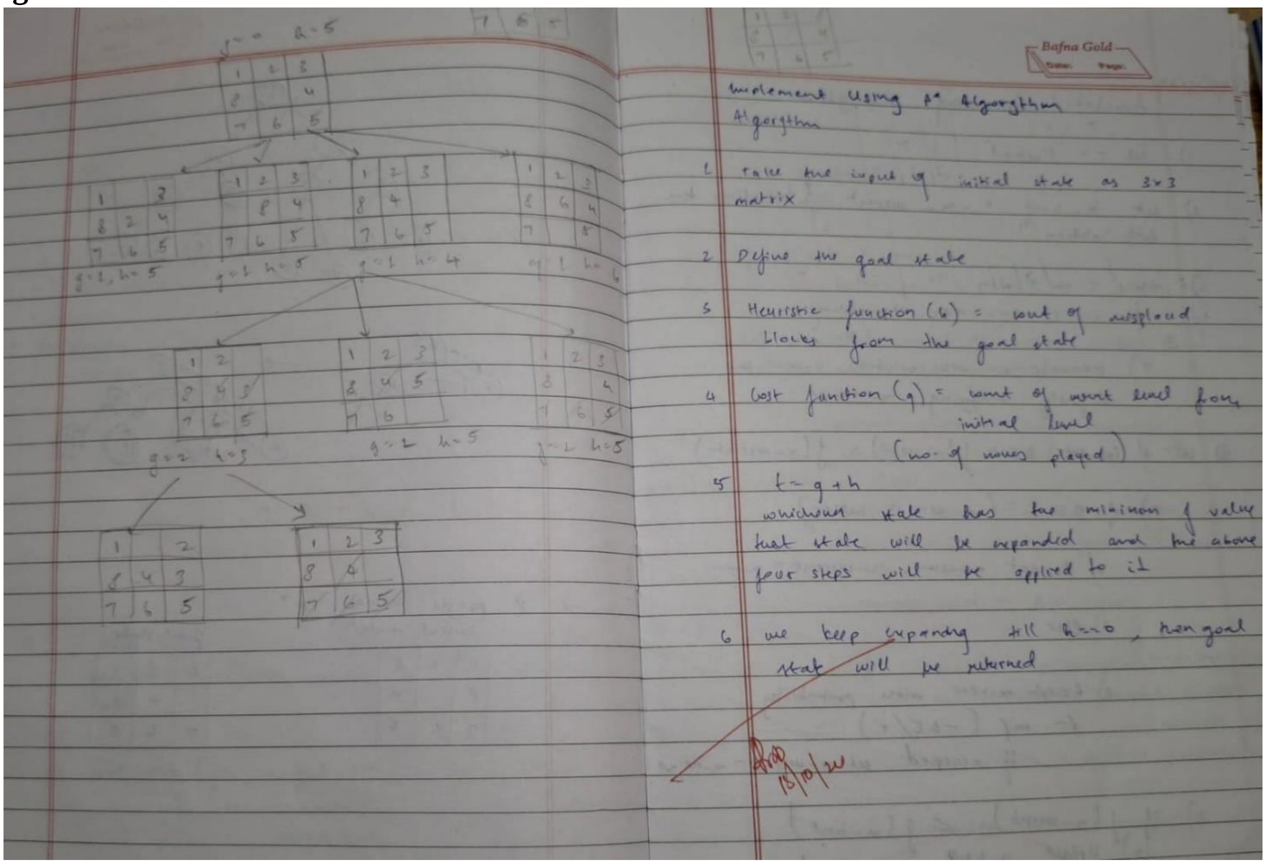
```
    else:
        print("No solution found.")

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

Output:



<u>Program 3</u>
Implement A* search algorithm

Algorithm:



Code:

```
import heapq

def misplaced_tile(state, goal_state):
    misplaced = 0
    for i in range(3):
        for j in range(3):
            if state[i][j] != 0 and state[i][j] != goal_state[i][j]:
                misplaced += 1
    return misplaced

def find_blank(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
```

```
def generate_neighbors(state):
    neighbors = []
    x, y = find_blank(state)
    directions = [(0, 1), (0, -1), (1, 0), (-1, 0)]

    for dx, dy in directions:
        nx, ny = x + dx, y + dy
        if 0 <= nx < 3 and 0 <= ny < 3:
            new_state = [list(row) for row in state]
            new_state[x][y], new_state[nx][ny] = new_state[nx][ny], new_state[x][y]
            neighbors.append(tuple(tuple(row) for row in new_state))

    return neighbors

def reconstruct_path(came_from, current):

    path = [current]
    while current in came_from:
        current = came_from[current]
        path.append(current)
    path.reverse()
    return path

def a_star(start, goal):
    open_list = []
    heapq.heappush(open_list, (0 + misplaced_tile(start, goal), 0, start))

    g_score = {start: 0}
    came_from = {}

    visited = set()

    while open_list:
        _, g, current = heapq.heappop(open_list)

        if current == goal:
            path = reconstruct_path(came_from, current)
            return path, g

        visited.add(current)

        for neighbor in generate_neighbors(current):
            if neighbor in visited:
                continue
            tentative_g = g_score[current] + 1

            if tentative_g < g_score.get(neighbor, float('inf')):
                came_from[neighbor] = current
```

```
                g_score[neighbor] = tentative_g
                f_score = tentative_g + misplaced_tile(neighbor, goal)  # f(n) = g(n) + h(n)

                heapq.heappush(open_list, (f_score, tentative_g, neighbor))

    return None, None

def print_state(state):

    for row in state:
        print(row)
    print()

def get_state_from_user(prompt):

    state = []
    for i in range(3):
        row = input(f"{prompt} row {i+1} (space-separated): ")
        state.append(tuple(map(int, row.split())))
    return tuple(state)

if __name__ == "__main__":
    print("Enter the initial state:")
    start_state = get_state_from_user("Initial state")
    print("\nEnter the goal state:")
    goal_state = get_state_from_user("Goal state")

    print("\nInitial State:")
    print_state(start_state)

    print("\nGoal State:")
    print_state(goal_state)

    solution, cost = a_star(start_state, goal_state)

    if solution:
        print(f"\nSolution found with cost: {cost}")
        print("Steps:")
        for step in solution:
            print_state(step)
    else:
        print("\nNo solution found.")
```

Output:

Enter the initial state:
Initial state row 1 (space-separated): 2 8 3
Initial state row 2 (space-separated): 1 6 4
Initial state row 3 (space-separated): 7 0 5

Enter the goal state:
Goal state row 1 (space-separated): 1 2 3
Goal state row 2 (space-separated): 8 0 4
Goal state row 3 (space-separated): 7 6 5

Initial State:
(2, 8, 3)
(1, 6, 4)
(7, 0, 5)

Goal State:
(1, 2, 3)
(8, 0, 4)
(7, 6, 5)

Solution found with cost: 5
Steps:
(2, 8, 3)
(1, 6, 4)
(7, 0, 5)

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

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

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

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

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

```
import heapq

def manhattan_distance(state, goal_state):
    distance = 0
    for i in range(3):
```

```
        for j in range(3):
            value = state[i][j]
            if value != 0:
                goal_i, goal_j = find_position(value, goal_state)
                distance += abs(i - goal_i) + abs(j - goal_j)
    return distance

def find_position(value, state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == value:
                return i, j

def find_blank(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j

def generate_neighbors(state):
    neighbors = []
    x, y = find_blank(state)
    directions = [(0, 1), (0, -1), (1, 0), (-1, 0)]

    for dx, dy in directions:
        nx, ny = x + dx, y + dy
        if 0 <= nx < 3 and 0 <= ny < 3:
            new_state = [list(row) for row in state]
            new_state[x][y], new_state[nx][ny] = new_state[nx][ny], new_state[x][y]
            neighbors.append(tuple(tuple(row) for row in new_state))

    return neighbors

def reconstruct_path(came_from, current):
    path = [current]
    while current in came_from:
        current = came_from[current]
        path.append(current)
    path.reverse()
    return path

def a_star(start, goal):
    open_list = []
    heapq.heappush(open_list, (0 + manhattan_distance(start, goal), 0, start))

    g_score = {start: 0}
    came_from = {}
```

```
    visited = set()

    while open_list:
        _, g, current = heapq.heappop(open_list)

        if current == goal:
            path = reconstruct_path(came_from, current)
            return path, g

        visited.add(current)

        for neighbor in generate_neighbors(current):
            if neighbor in visited:
                continue
            tentative_g = g_score[current] + 1

            if tentative_g < g_score.get(neighbor, float('inf')):
                came_from[neighbor] = current
                g_score[neighbor] = tentative_g
                f_score = tentative_g + manhattan_distance(neighbor, goal)

                heapq.heappush(open_list, (f_score, tentative_g, neighbor))

    return None, None

def print_state(state):
    for row in state:
        print(row)
    print()

def get_state_from_user(prompt):
    state = []
    for i in range(3):
        row = input(f"{prompt} row {i+1} (space-separated): ")
        state.append(tuple(map(int, row.split())))
    return tuple(state)

if __name__ == "__main__":
    print("Enter the initial state:")
    start_state = get_state_from_user("Initial state")
    print("\nEnter the goal state:")
    goal_state = get_state_from_user("Goal state")

    print("\nInitial State:")
    print_state(start_state)

    print("\nGoal State:")
    print_state(goal_state)
```

```
    solution, cost = a_star(start_state, goal_state)

    if solution:
        print(f"\nSolution found with cost: {cost}")
        print("Steps:")
        for step in solution:
            print_state(step)
    else:
        print("\nNo solution found.")
```

Output:

```
Enter the initial state:
Initial state row 1 (space-separated): 2 8 3
Initial state row 2 (space-separated): 1 6 4
Initial state row 3 (space-separated): 7 0 5

Enter the goal state:
Goal state row 1 (space-separated): 1 2 3
Goal state row 2 (space-separated): 8 0 4
Goal state row 3 (space-separated): 7 6 5

Initial State:
(2, 8, 3)
(1, 6, 4)
(7, 0, 5)


Goal State:
(1, 2, 3)
(8, 0, 4)
(7, 6, 5)

Solution found with cost: 5
Steps:
(2, 8, 3)
(1, 6, 4)
(7, 0, 5)

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

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

(0, 2, 3)
```

(1, 8, 4)
(7, 6, 5)

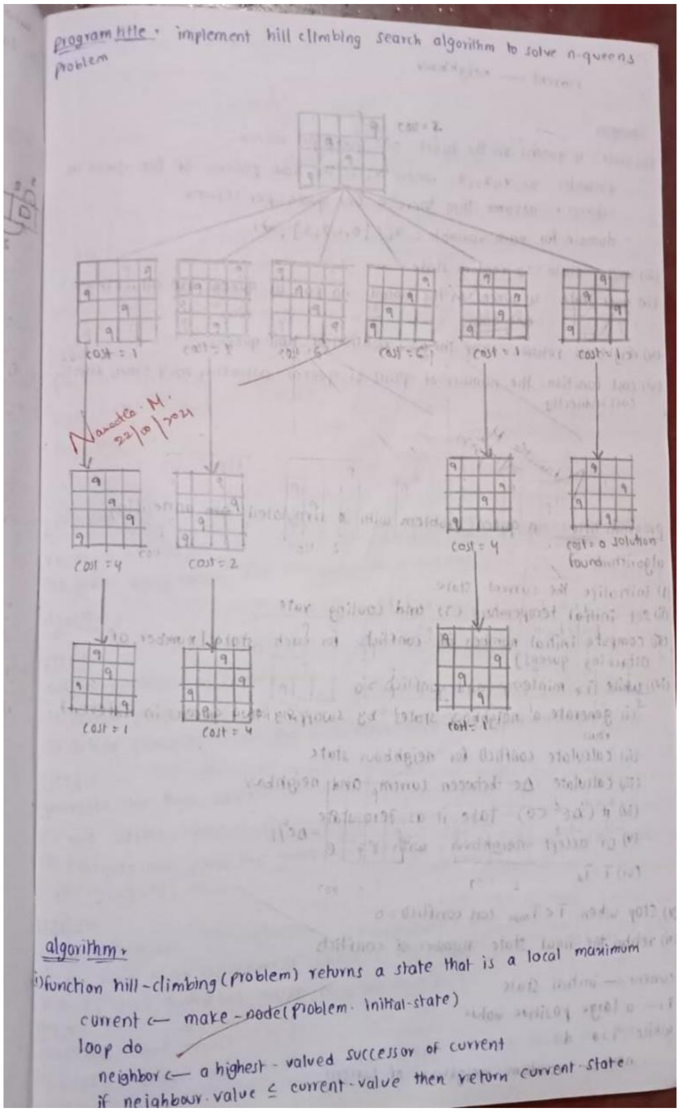
(1, 2, 3)
(0, 8, 4)
(7, 6, 5)

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

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:



program title: implement hill climbing search algorithm to solve n-queens problem

cost = 2

cost = 1

cost = 4

cost = 2

cost = 1

cost = 4

cost = 1

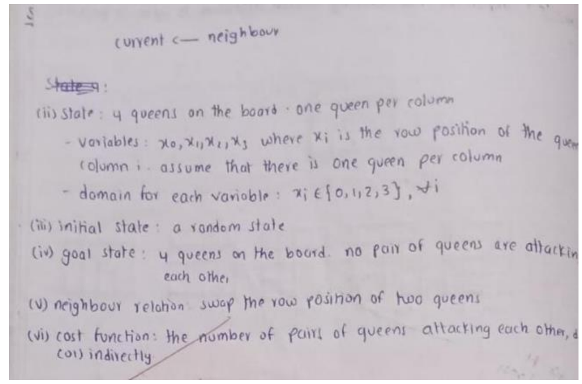
cost = 4

cost = 0 solution found

cost = 1

algorithm:

1) function hill-climbing (problem) returns a state that is a local maximum
 current ← make-node(problem. initial-state)
 loop do
 neighbor ← a highest-valued successor of current
 if neighbour.value ≤ current.value then return current.state



current ← neighbour

State:

(ii) State: 4 queens on the board. one queen per column
 - variables: x_0, x_1, x_2, x_3 where x_i is the row position of the queen column i. assume that there is one queen per column
 - domain for each variable: $x_i \in \{0,1,2,3\}, \forall i$

(iii) initial state: a random state

(iv) goal state: 4 queens on the board. no pair of queens are attacking each other

(v) neighbour relation: swap the row position of two queens

(vi) cost function: the number of pairs of queens attacking each other, directly or indirectly

Code:

```
from random import randint
N = int(input("Enter the number of queens:"))

def configureRandomly(board, state):
	for i in range(N):
		state[i] = randint(0, 100000) % N;
		board[state[i]][i] = 1;

def printBoard(board):
```

```
        for i in range(N):
                print(*board[i])

def printState( state):
        print(*state)

def compareStates(state1, state2):
        for i in range(N):
                if (state1[i] != state2[i]):
                        return False;

        return True;

def fill(board, value):
        for i in range(N):
                for j in range(N):
                        board[i][j] = value;

def calculateObjective( board, state):
        attacking = 0;
        for i in range(N):
                row = state[i]
                col = i - 1;
                while (col >= 0 and board[row][col] != 1) :
                        col -= 1
                if (col >= 0 and board[row][col] == 1) :
                        attacking += 1;

                row = state[i]
                col = i + 1;
                while (col < N and board[row][col] != 1):
                        col += 1;

                if (col < N and board[row][col] == 1) :
                        attacking += 1;
                row = state[i] - 1
                col = i - 1;
                while (col >= 0 and row >= 0 and board[row][col] != 1) :
                        col-= 1;
                        row-= 1;

                if (col >= 0 and row >= 0 and board[row][col] == 1) :
```

```
                attacking+= 1;

            row = state[i] + 1
            col = i + 1;
            while (col < N and row < N and board[row][col] != 1) :
                col+= 1;
                row+= 1;

            if (col < N and row < N and board[row][col] == 1) :
                attacking += 1;

            row = state[i] + 1
            col = i - 1;
            while (col >= 0 and row < N and board[row][col] != 1) :
                col -= 1;
                row += 1;

            if (col >= 0 and row < N and board[row][col] == 1) :
                attacking += 1;

            row = state[i] - 1
            col = i + 1;
            while (col < N and row >= 0 and board[row][col] != 1) :
                col += 1;
                row -= 1;

            if (col < N and row >= 0 and board[row][col] == 1) :
                attacking += 1;
        return int(attacking / 2);

def generateBoard( board, state):
    fill(board, 0);
    for i in range(N):
        board[state[i]][i] = 1;

def copyState( state1, state2):

    for i in range(N):
        state1[i] = state2[i];

def getNeighbour(board, state):
```

```
    opBoard = [[0 for _ in range(N)] for _ in range(N)]
    opState = [0 for _ in range(N)]

    copyState(opState, state);
    generateBoard(opBoard, opState);

    opObjective = calculateObjective(opBoard, opState);

    NeighbourBoard = [[0 for _ in range(N)] for _ in range(N)]

    NeighbourState = [0 for _ in range(N)]
    copyState(NeighbourState, state);
    generateBoard(NeighbourBoard, NeighbourState);

    for i in range(N):
        for j in range(N):
            if (j != state[i]) :
                NeighbourState[i] = j;
                NeighbourBoard[NeighbourState[i]][i] = 1;
                NeighbourBoard[state[i]][i] = 0;
                temp = calculateObjective( NeighbourBoard, NeighbourState);

                if (temp <= opObjective) :
                    opObjective = temp;
                    copyState(opState, NeighbourState);
                    generateBoard(opBoard, opState);

                NeighbourBoard[NeighbourState[i]][i] = 0;
                NeighbourState[i] = state[i];
                NeighbourBoard[state[i]][i] = 1;


    copyState(state, opState);
    fill(board, 0);
    generateBoard(board, state);

def hillClimbing(board, state):


    neighbourBoard = [[0 for _ in range(N)] for _ in range(N)]
    neighbourState = [0 for _ in range(N)]
```

```
        copyState(neighbourState, state);
        generateBoard(neighbourBoard, neighbourState);

        while True:

                # Copying the neighbour board and
                # state to the current board and
                # state, since a neighbour
                # becomes current after the jump.

                copyState(state, neighbourState);
                generateBoard(board, state);

                # Getting the optimal neighbour

                getNeighbour(neighbourBoard, neighbourState);

                if (compareStates(state, neighbourState)) :

                        printBoard(board);
                        break;

                elif (calculateObjective(board, state) == calculateObjective(
neighbourBoard,neighbourState)):

                        # Random neighbour
                        neighbourState[randint(0, 100000) % N] = randint(0, 100000) % N;
                        generateBoard(neighbourBoard, neighbourState);

# Driver code
state = [0] * N
board = [[0 for _ in range(N)] for _ in range(N)]
configureRandomly(board, state);
hillClimbing(board, state);
```

Output:

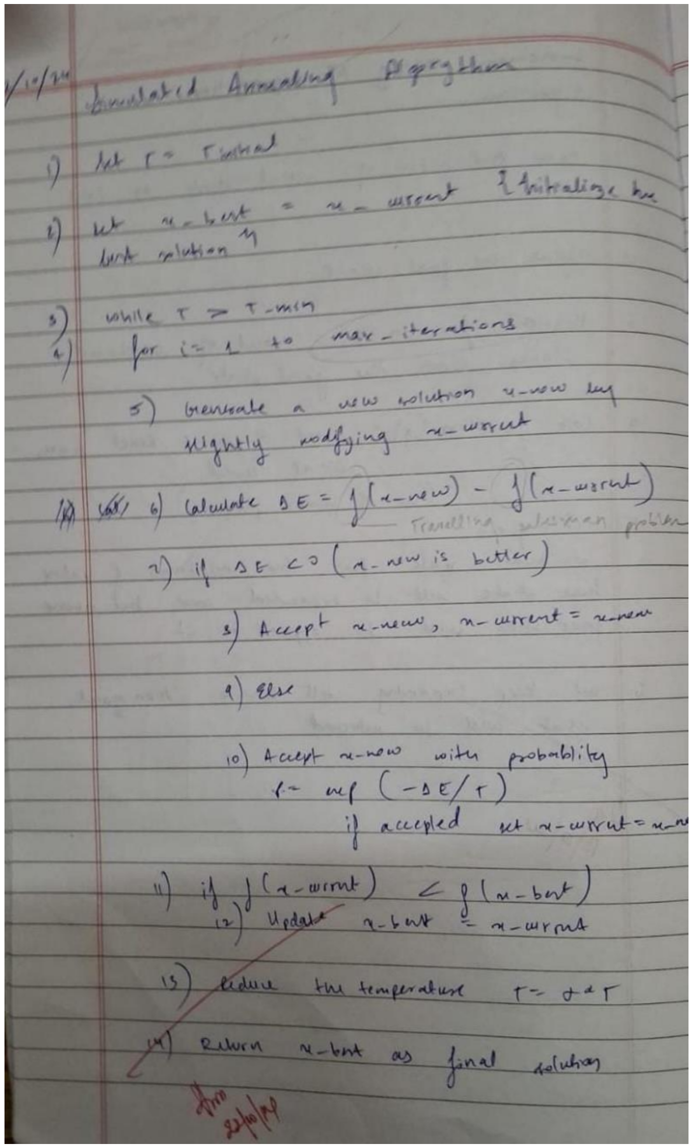
```
Enter the number of queens:8
0 0 0 0 1 0 0 0
0 1 0 0 0 0 0 0
0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0
0 0 0 1 0 0 0 0
```

0 0 0 0 0 0 1 0
0 0 1 0 0 0 0 0
0 0 0 0 0 1 0 0

Program 5

Simulated Annealing to Solve 8-Queens problem

Algorithm:



Simulated Annealing Algorithm

1) Set T = T_initial
2) Set x_best = x_current {Initialize the best solution}
3) while T > T_min
4) for i = 1 to max_iterations
5) Generate a new solution x_new by slightly modifying x_current
6) Calculate ΔE = f(x_new) − f(x_current)
7) if ΔE < 0 (x_new is better)
8) Accept x_new, x_current = x_new
9) Else
10) Accept x_new with probability P = exp(−ΔE/T)
if accepted set x_current = x_new
11) if f(x_current) < f(x_best)
12) Update x_best = x_current
13) Reduce the temperature T = α * T
14) Return x_best as final solution

Code:

```
import numpy as np
from scipy.optimize import dual_annealing

def queens_max(position):
    # This function calculates the number of pairs of queens that are not attacking each other
    position = np.round(position).astype(int)  # Round and convert to integers for queen positions
    n = len(position)
    queen_not_attacking = 0
```

```
    for i in range(n - 1):
        no_attack_on_j = 0
        for j in range(i + 1, n):
            # Check if queens are on the same row or on the same diagonal
            if position[i] != position[j] and abs(position[i] - position[j]) != (j - i):
                no_attack_on_j += 1
        if no_attack_on_j == n - 1 - i:
            queen_not_attacking += 1
    if queen_not_attacking == n - 1:
        queen_not_attacking += 1

    return -queen_not_attacking  # Negative because we want to maximize this value

# Bounds for each queen's position (0 to 7 for an 8x8 chessboard)
bounds = [(0, 7) for _ in range(8)]

# Use dual_annealing for simulated annealing optimization
result = dual_annealing(queens_max, bounds)

# Display the results
best_position = np.round(result.x).astype(int)
best_objective = -result.fun  # Flip sign to get the number of non-attacking queens

print('The best position found is:', best_position)
print('The number of queens that are not attacking each other is:', best_objective)
```

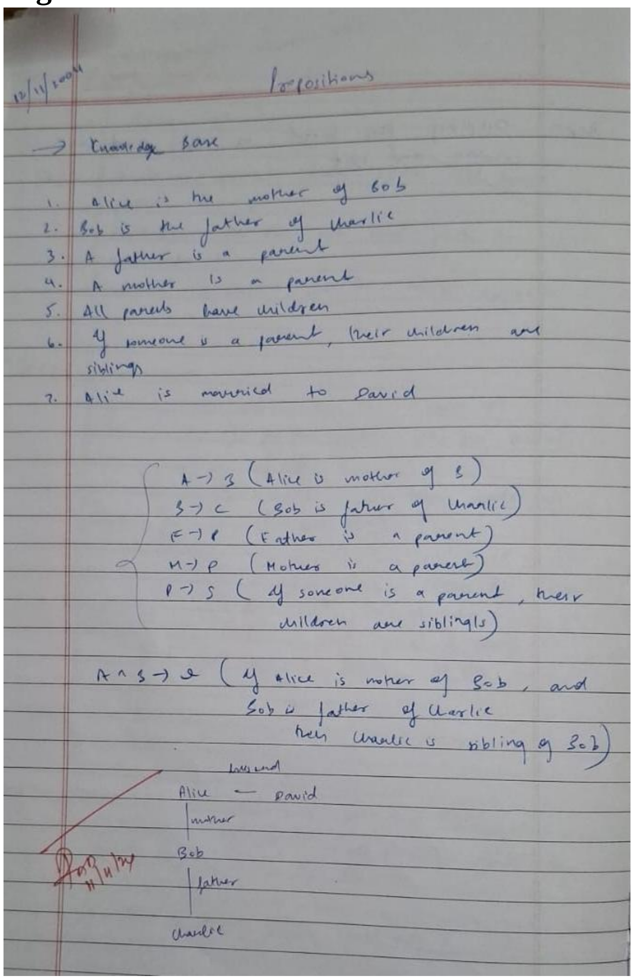
Output:

The best position found is: [1 4 6 0 2 7 5 3]
The number of queens that are not attacking each other is: 8

Program 6

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

Algorithm:


12/11/2024 Propositions

→ Knowledge Base

1. Alice is the mother of Bob
2. Bob is the father of Charlie
3. A father is a parent
4. A mother is a parent
5. All parents have children
6. If someone is a parent, their children are siblings
7. Alice is married to David

A → B (Alice is mother of B)
B → C (Bob is father of Charlie)
F → P (Father is a parent)
M → P (Mother is a parent)
P → S (If someone is a parent, their children are siblings)

A ^ B → C (If Alice is mother of Bob, and Bob is father of Charlie then Charlie is sibling of Bob)

Code:

```
import itertools

def evaluate_formula(formula, valuation):
    """
    Evaluate the propositional formula under the given truth assignment (valuation).
    The formula is a string of logical operators like 'AND', 'OR', 'NOT', and can contain variables 'A', 'B', 'C'.
    """
    # Create a local environment (dictionary) for variable assignments
    env = {var: valuation[i] for i, var in enumerate(['A', 'B', 'C'])}

    # Replace logical operators with Python equivalents
    formula = formula.replace('AND', 'and').replace('OR', 'or').replace('NOT', 'not')

    # Replace variables in the formula with their corresponding truth values
```

```
    for var in env:
        formula = formula.replace(var, str(env[var]))

    # Evaluate the formula and return the result (True or False)
    try:
        return eval(formula)
    except Exception as e:
        raise ValueError(f"Error in evaluating formula: {e}")

def truth_table(variables):
    """
    Generate all possible truth assignments for the given variables.
    """
    return list(itertools.product([False, True], repeat=len(variables)))

def entails(KB, alpha):
    """
    Decide if KB entails alpha using a truth-table enumeration algorithm.
    KB is a propositional formula (string), and alpha is another propositional formula (string).
    """
    # Generate all possible truth assignments for A, B, and C
    assignments = truth_table(['A', 'B', 'C'])

    print(f"{'A':<10}{'B':<10}{'C':<10}{'KB':<15}{'alpha':<15}{'KB entails alpha?'}")  # Header for the truth
table
    print("-" * 70)  # Separator for readability

    for assignment in assignments:
        # Evaluate KB and alpha under the current assignment
        KB_value = evaluate_formula(KB, assignment)
        alpha_value = evaluate_formula(alpha, assignment)

        # Print the current truth assignment and the results for KB and alpha

print(f"{str(assignment[0]):<10}{str(assignment[1]):<10}{str(assignment[2]):<10}{str(KB_value):<15}{str(al
pha_value):<15}{'Yes' if KB_value and alpha_value else 'No'}")

        # If KB is true and alpha is false, then KB does not entail alpha
        if KB_value and not alpha_value:
            return False

    # If no counterexample was found, then KB entails alpha
    return True

# Define the formulas for KB and alpha
alpha = 'A OR B'
KB = '(A OR C) AND (B OR NOT C)'
```

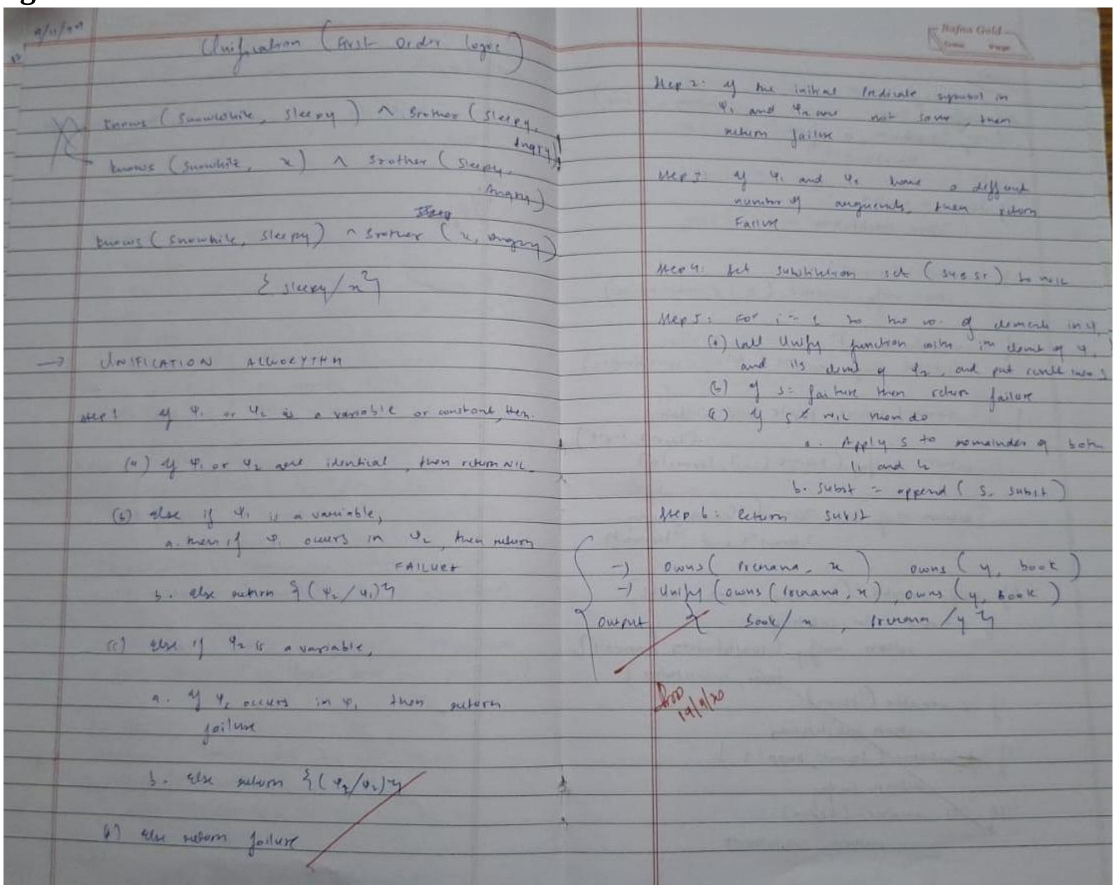
```
# Check if KB entails alpha
result = entails(KB, alpha)

# Print the final result of entailment
print(f"\nDoes KB entail alpha? {result}")
```

Output:

```
A      B      C      KB        alpha     KB entails alpha?
----------------------------------------------------------------------
False  False  False  False     False     No
False  False  True   False     False     No
False  True   False  False     True      No
False  True   True   True      True      Yes
True   False  False  True      True      Yes
True   False  True   False     True      No
True   True   False  True      True      Yes
True   True   True   True      True      Yes

Does KB entail alpha? True
```

Program 7
Implement unification in first order logic

Algorithm:



Code:

```
class Term:
    def __init__(self, symbol, args=None):
        self.symbol = symbol
        self.args = args if args else []

    def __str__(self):
        if not self.args:
            return str(self.symbol)
        return f"{self.symbol}({','.join(str(arg) for arg in self.args)})"

    def is_variable(self):
        return isinstance(self.symbol, str) and self.symbol.isupper() and not self.args

def occurs_check(var, term, substitution):
    """Check if variable occurs in term"""
    if term.is_variable():
        if term.symbol in substitution:
```

```
        return occurs_check(var, substitution[term.symbol], substitution)
    return var.symbol == term.symbol
  return any(occurs_check(var, arg, substitution) for arg in term.args)

def substitute(term, substitution):
  """Apply substitution to term"""
  if term.is_variable() and term.symbol in substitution:
    return substitute(substitution[term.symbol], substitution)
  if not term.args:
    return term
  return Term(term.symbol, [substitute(arg, substitution) for arg in term.args])

def unify(term1, term2, substitution=None, iteration=1):
  """Unify two terms with detailed iteration steps"""
  if substitution is None:
    substitution = {}

  print(f"\nIteration {iteration}:")
  print(f"Attempting to unify: {term1} and {term2}")
  print(f"Current substitution: {', '.join(f'{k}->{v}' for k,v in substitution.items()) or 'empty'}")

  term1 = substitute(term1, substitution)
  term2 = substitute(term2, substitution)

  if term1.symbol == term2.symbol and not term1.args and not term2.args:
    print("Terms are identical - no substitution needed")
    return substitution

  if term1.is_variable():
    if occurs_check(term1, term2, substitution):
      print(f"Occurs check failed: {term1.symbol} occurs in {term2}")
      return None
    substitution[term1.symbol] = term2
    print(f"Added substitution: {term1.symbol} -> {term2}")
    return substitution

  if term2.is_variable():
    if occurs_check(term2, term1, substitution):
      print(f"Occurs check failed: {term2.symbol} occurs in {term1}")
      return None
    substitution[term2.symbol] = term1
    print(f"Added substitution: {term2.symbol} -> {term1}")
    return substitution

  if term1.symbol != term2.symbol or len(term1.args) != len(term2.args):
    print(f"Unification failed: Different predicates or argument lengths")
    return None
```

```
    for arg1, arg2 in zip(term1.args, term2.args):
        result = unify(arg1, arg2, substitution, iteration + 1)
        if result is None:
            return None
        substitution = result

    return substitution

def parse_term(s):
    """Parse terms like P(X,f(Y)) or X"""
    s = s.strip()
    if '(' not in s:
        return Term(s)

    pred = s[:s.index('(')]
    args_str = s[s.index('(')+1:s.rindex(')')]

    args = []
    current = ''
    depth = 0
    for c in args_str:
        if c == '(' or c == '[':
            depth += 1
        elif c == ')' or c == ']':
            depth -= 1
        elif c == ',' and depth == 0:
            args.append(parse_term(current.strip()))
            current = ''
            continue
        current += c
    if current:
        args.append(parse_term(current.strip()))

    return Term(pred, args)

def print_examples():
    print("\nExample format:")
    print("1. Simple terms: P(X,Y)")
    print("2. Nested terms: P(f(X),g(Y))")
    print("3. Mixed terms: Knows(John,X)")
    print("4. Complex nested terms: P(f(g(X)),h(Y,Z))")
    print("\nNote: Use capital letters for variables (X,Y,Z) and lowercase for constants and predicates.")

def validate_input(expr):
    """Basic validation for input expressions"""
    if not expr:
        return False
```

```
    # Check balanced parentheses
    count = 0
    for char in expr:
        if char == '(':
            count += 1
        elif char == ')':
            count -= 1
        if count < 0:
            return False
    return count == 0

def main():
    while True:
        print("\n=== First Order Predicate Logic Unification ===")
        print("1. Start Unification")
        print("2. Show Examples")
        print("3. Exit")

        choice = input("\nEnter your choice (1-3): ")

        if choice == '1':
            print("\nEnter two expressions to unify.")
            print_examples()

            while True:
                expr1 = input("\nEnter first expression (or 'back' to return): ")
                if expr1.lower() == 'back':
                    break

                if not validate_input(expr1):
                    print("Invalid expression! Please check the format and try again.")
                    continue

                expr2 = input("Enter second expression: ")
                if not validate_input(expr2):
                    print("Invalid expression! Please check the format and try again.")
                    continue

                try:
                    term1 = parse_term(expr1)
                    term2 = parse_term(expr2)

                    print("\nUnification Process:")
                    result = unify(term1, term2)

                    print("\nFinal Result:")
                    if result is None:
                        print("Unification failed!")
```

```
            else:
                print("Unification successful!")
                print("Final substitutions:", ', '.join(f'{k}->{v}' for k,v in result.items()))

            retry = input("\nTry another unification? (y/n): ")
            if retry.lower() != 'y':
                break

        except Exception as e:
            print(f"Error processing expressions: {str(e)}")
            print("Please check your input format and try again.")

    elif choice == '2':
        print("\n=== Example Expressions ===")
        print("1. P(X,h(Y)) and P(a,f(Z))")
        print("2. P(f(a),g(Y)) and P(X,X)")
        print("3. Knows(John,X) and Knows(X,Elisabeth)")
        print("\nPress Enter to continue...")
        input()

    elif choice == '3':
        print("\nThank you for using the Unification Program!")
        break

    else:
        print("\nInvalid choice! Please enter 1, 2, or 3.")

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

Output:

```
=== First Order Predicate Logic Unification ===
1. Start Unification
2. Show Examples
3. Exit

Enter your choice (1-3): 1

Enter two expressions to unify.

Example format:
1. Simple terms: P(X,Y)
2. Nested terms: P(f(X),g(Y))
3. Mixed terms: Knows(John,X)
4. Complex nested terms: P(f(g(X)),h(Y,Z))

Note: Use capital letters for variables (X,Y,Z) and lowercase for constants and predicates.
```

Enter first expression (or 'back' to return): p(X,f(Y))
Enter second expression: p(a,f(g(x)))

Unification Process:

Iteration 1:
Attempting to unify: p(X,f(Y)) and p(a,f(g(x)))
Current substitution: empty

Iteration 2:
Attempting to unify: X and a
Current substitution: empty
Added substitution: X -> a

Iteration 2:
Attempting to unify: f(Y) and f(g(x))
Current substitution: X->a

Iteration 3:
Attempting to unify: Y and g(x)
Current substitution: X->a
Added substitution: Y -> g(x)

Final Result:
Unification successful!
Final substitutions: X->a, Y->g(x)

Try another unification? (y/n): y

Enter first expression (or 'back' to return): q(a,g(X,a),f(Y))
Enter second expression: q(a,g(f(h),a),X)

Unification Process:

Iteration 1:
Attempting to unify: q(a,g(X,a),f(Y)) and q(a,g(f(h),a),X)
Current substitution: empty

Iteration 2:
Attempting to unify: a and a
Current substitution: empty
Terms are identical - no substitution needed

Iteration 2:
Attempting to unify: g(X,a) and g(f(h),a)
Current substitution: empty

Iteration 3:

Attempting to unify: X and f(h)
Current substitution: empty
Added substitution: X -> f(h)

Iteration 3:
Attempting to unify: a and a
Current substitution: X->f(h)
Terms are identical - no substitution needed

Iteration 2:
Attempting to unify: f(Y) and X
Current substitution: X->f(h)

Iteration 3:
Attempting to unify: Y and h
Current substitution: X->f(h)
Added substitution: Y -> h

Final Result:
Unification successful!
Final substitutions: X->f(h), Y->h

Try another unification? (y/n): y

Enter first expression (or 'back' to return): p(b,X,f(g(Z)))
Enter second expression: p(Z,f(Y),f(Y))

Unification Process:

Iteration 1:
Attempting to unify: p(b,X,f(g(Z))) and p(Z,f(Y),f(Y))
Current substitution: empty

Iteration 2:
Attempting to unify: b and Z
Current substitution: empty
Added substitution: Z -> b

Iteration 2:
Attempting to unify: X and f(Y)
Current substitution: Z->b
Added substitution: X -> f(Y)

Iteration 2:
Attempting to unify: f(g(Z)) and f(Y)
Current substitution: Z->b, X->f(Y)

Iteration 3:

Attempting to unify: g(b) and Y
Current substitution: Z->b, X->f(Y)
Added substitution: Y -> g(b)

Final Result:
Unification successful!
Final substitutions: Z->b, X->f(Y), Y->g(b)

Try another unification? (y/n): y

Enter first expression (or 'back' to return): p(f(a),g(Y))
Enter second expression: p(X,X)

Unification Process:

Iteration 1:
Attempting to unify: p(f(a),g(Y)) and p(X,X)
Current substitution: empty

Iteration 2:
Attempting to unify: f(a) and X
Current substitution: empty
Added substitution: X -> f(a)

Iteration 2:
Attempting to unify: g(Y) and X
Current substitution: X->f(a)
Unification failed: Different predicates or argument lengths

Final Result:
Unification failed!

Try another unification? (y/n): n

=== First Order Predicate Logic Unification ===
1. Start Unification
2. Show Examples
3. Exit

Enter your choice (1-3): 2

=== Example Expressions ===
1. P(X,h(Y)) and P(a,f(Z))
2. P(f(a),g(Y)) and P(X,X)
3. Knows(John,X) and Knows(X,Elisabeth)

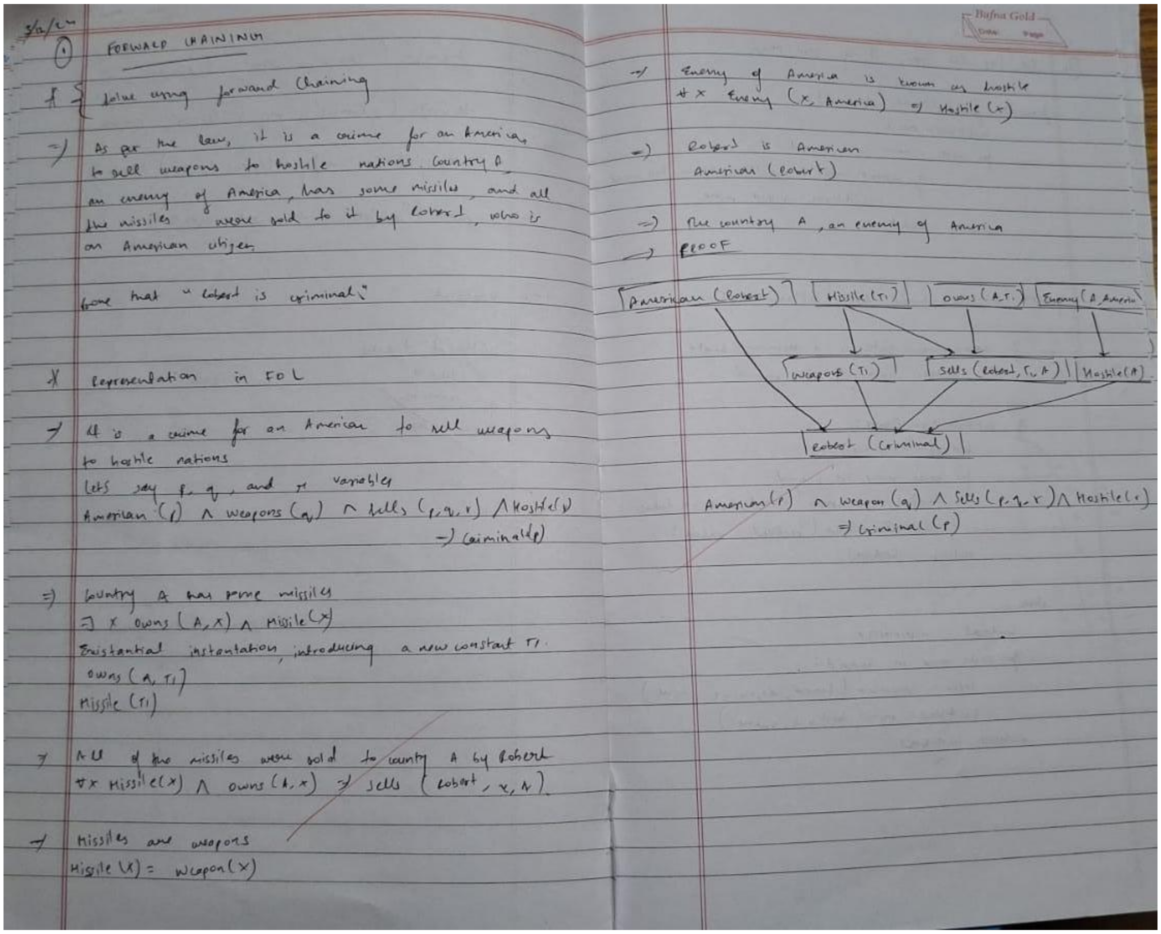
Press Enter to continue...

```
=== First Order Predicate Logic Unification ===
1. Start Unification
2. Show Examples
3. Exit

Enter your choice (1-3): 3
```

Program 8

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

Algorithm:



3/12/24

FORWARD CHAINING

Solve using forward Chaining

As per the law, it is a crime for an America, to sell weapons to hostile nations. Country A, an enemy of America, has some missiles, and all the missiles were sold to it by Robert, who is an American citizen.

Prove that "Robert is criminal."

Representation in FOL

It is a crime for an American to sell weapons to hostile nations

Lets say p, q, and r variables

American (p) ∧ weapons (q) ∧ sells (p,q,r) ∧ Hostile(r) → Criminal(p)

Country A has some missiles

∃ x Owns (A, x) ∧ Missile(x)

Existantial instantation, introducing a new constant T1.

Owns (A, T1)

Missile (T1)

All of the missiles were sold to country A by Robert

∀x Missile(x) ∧ Owns (A, x) ⇒ Sells (Robert, x, A).

Missiles are weapons

Missile (x) ⇒ Weapon(x)

Enemy of America is known as hostile

∀ x Enemy (x, America) ⇒ Hostile (x)

Robert is American

American (Robert)

The country A, an enemy of America

PROOF

American (Robert) | Missile (T1) | Owns (A, T1) | Enemy (A, America)

Weapons (T1) | Sells (Robert, T1, A) | Hostile(A)

Robert (Criminal)

American (p) ∧ Weapon (q) ∧ Sells (p, q, r) ∧ Hostile (r) ⇒ Criminal (p)

Code:

```
class ForwardReasoning:
    def __init__(self, rules, facts):
        """
        Initializes the ForwardReasoning system.

        Parameters:
            rules (list): List of rules as tuples (condition, result),
                          where 'condition' is a set of facts.
            facts (set): Set of initial known facts.
        """
        self.rules = rules  # List of rules (condition -> result)
        self.facts = set(facts)  # Known facts

    def infer(self, query):
        """
```

```
        Applies forward reasoning to infer new facts based on rules and initial facts.

        Parameters:
            query (str): The fact to verify if it can be inferred.

        Returns:
            bool: True if the query can be inferred, False otherwise.
        """
        applied_rules = True

        while applied_rules:
            applied_rules = False
            for condition, result in self.rules:
                # Check if all conditions are met in the current facts
                if condition.issubset(self.facts) and result not in self.facts:
                    self.facts.add(result)  # Add the inferred result
                    applied_rules = True
                    print(f"Applied rule: {condition} -> {result}")
                    # If the query is inferred, return True immediately
                    if query in self.facts:
                        return True

        # Return whether the query can be inferred from the facts
        return query in self.facts


# Define the Knowledge Base (KB) with rules as (condition, result)
rules = [
    ({"American(Robert)", "Missile(m1)", "Owns(CountryA, m1)"}, "Sells(Robert, m1, CountryA)"),  # Sells(Robert, m1, CountryA) based on facts
    ({"Sells(Robert, m1, CountryA)", "American(Robert)", "Hostile(CountryA)"}, "Criminal(Robert)"),  # Criminal inference
]

# Define initial facts
facts = {
    "American(Robert)",
    "Hostile(CountryA)",
    "Missile(m1)",
    "Owns(CountryA, m1)",
}

# Query
query = "Criminal(Robert)"

# Initialize and run forward reasoning
reasoner = ForwardReasoning(rules, facts)
result = reasoner.infer(query)
```

```python
# Final output
print("\nFinal facts:")
print(reasoner.facts)
print(f"\nQuery '{query}' inferred: {result}")
```

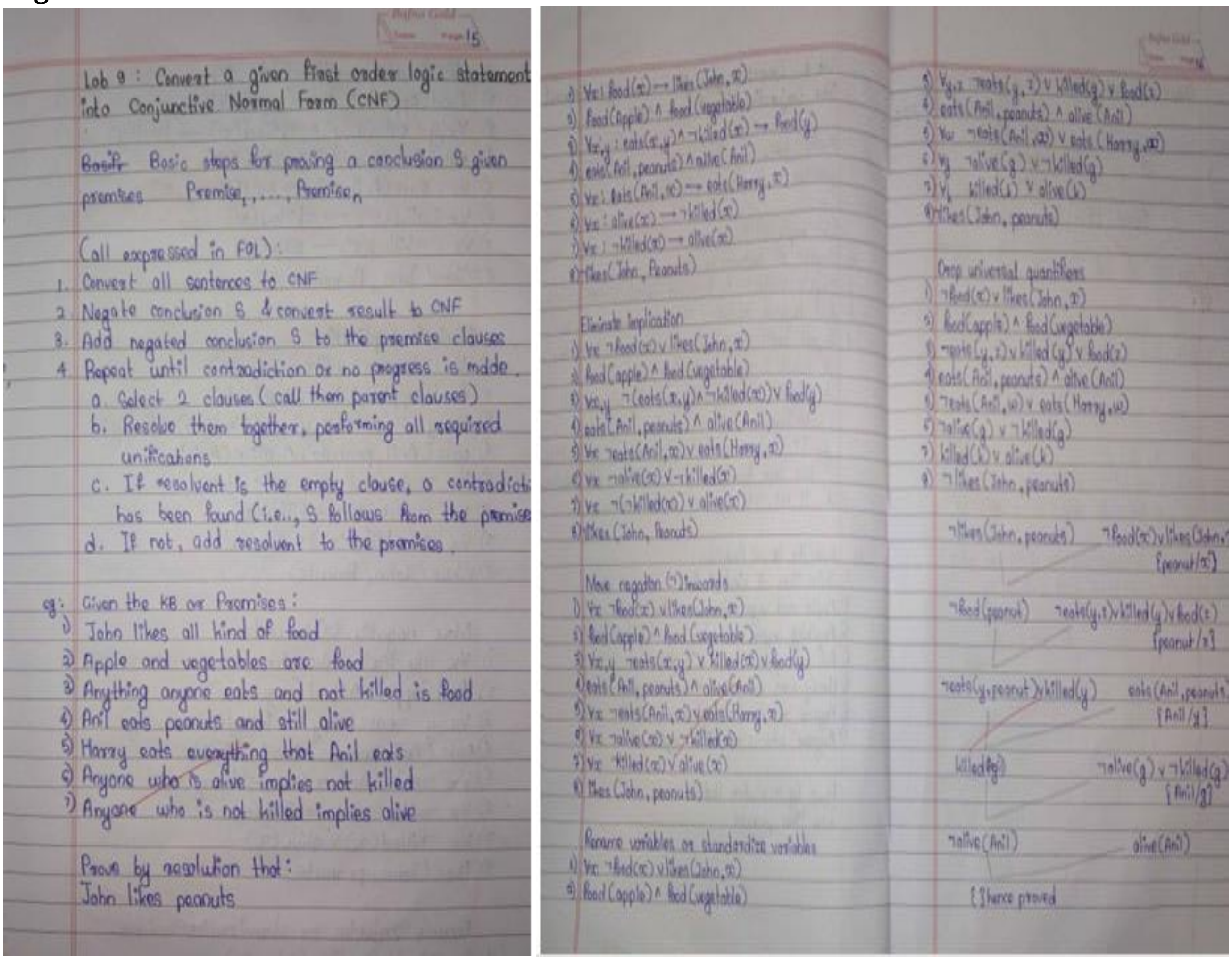
Output:

```
Applied rule: {'Missile(m1)', 'American(Robert)', 'Owns(CountryA, m1)'} -> Sells(Robert, m1, CountryA)
Applied rule: {'American(Robert)', 'Sells(Robert, m1, CountryA)', 'Hostile(CountryA)'} -> Criminal(Robert)

Final facts:
{'Criminal(Robert)', 'Missile(m1)', 'Owns(CountryA, m1)', 'Sells(Robert, m1, CountryA)', 'Hostile(CountryA)', 'American(Robert)'}

Query 'Criminal(Robert)' inferred: True
```

Program 9

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

Algorithm:



Lab 9 : Convert a given first order logic statement into Conjunctive Normal Form (CNF)

Basic steps for proving a conclusion S given premises Premise1, ..., Premisen

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

eg: Given the KB or Premises:
1) John likes all kind of food
2) Apple and vegetables are food
3) Anything anyone eats and not killed is food
4) Anil eats peanuts and still alive
5) Harry eats everything that Anil eats
6) Anyone who is alive implies not killed
7) Anyone who is not killed implies alive

Prove by resolution that:
John likes peanuts

1) ∀x: food(x) → likes(John, x)
2) food(Apple) ∧ food(vegetable)
3) ∀x,y : eats(x,y) ∧ ¬killed(x) → food(y)
4) eats(Anil, peanuts) ∧ alive(Anil)
5) ∀x: eats(Anil, x) → eats(Harry, x)
6) ∀x: alive(x) → ¬killed(x)
7) ∀x: ¬killed(x) → alive(x)
8) likes(John, Peanuts)

Eliminate Implication
1) ∀x ¬food(x) ∨ likes(John, x)
2) food(apple) ∧ food(vegetable)
3) ∀x,y ¬(eats(x,y) ∧ ¬killed(x)) ∨ food(y)
4) eats(Anil, peanuts) ∧ alive(Anil)
5) ∀x ¬eats(Anil, x) ∨ eats(Harry, x)
6) ∀x ¬alive(x) ∨ ¬killed(x)
7) ∀x ¬(¬killed(x)) ∨ alive(x)
8) likes(John, Peanuts)

Move negation (¬) inwards
1) ∀x ¬food(x) ∨ likes(John, x)
2) food(apple) ∧ food(vegetable)
3) ∀x,y ¬eats(x,y) ∨ killed(x) ∨ food(y)
4) eats(Anil, peanuts) ∧ alive(Anil)
5) ∀x ¬eats(Anil, x) ∨ eats(Harry, x)
6) ∀x ¬alive(x) ∨ ¬killed(x)
7) ∀x killed(x) ∨ alive(x)
8) likes(John, peanuts)

Rename variables or standardize variables
1) ∀x ¬food(x) ∨ likes(John, x)
2) food(apple) ∧ food(vegetable)
3) ∀y,z ¬eats(y, z) ∨ killed(y) ∨ food(z)
4) eats(Anil, peanuts) ∧ alive(Anil)
5) ∀w ¬eats(Anil, w) ∨ eats(Harry, w)
6) ∀g ¬alive(g) ∨ ¬killed(g)
7) ∀k killed(k) ∨ alive(k)
8) likes(John, peanuts)

Drop universal quantifiers
1) ¬food(x) ∨ likes(John, x)
2) food(apple) ∧ food(vegetable)
3) ¬eats(y, z) ∨ killed(y) ∨ food(z)
4) eats(Anil, peanuts) ∧ alive(Anil)
5) ¬eats(Anil, w) ∨ eats(Harry, w)
6) ¬alive(g) ∨ ¬killed(g)
7) killed(k) ∨ alive(k)
8) ¬likes(John, peanuts)

¬likes(John, peanuts)   ¬food(x) ∨ likes(John, x)
{peanut/x}
¬food(peanut)   ¬eats(y,z) ∨ killed(y) ∨ food(z)
{peanut/z}
¬eats(y, peanut) ∨ killed(y)   eats(Anil, peanuts)
{Anil/y}
killed(Anil)   ¬alive(g) ∨ ¬killed(g)
{Anil/g}
¬alive(Anil)   alive(Anil)
{} hence proved

Code:

```
# Knowledge Base (KB)
facts = {
    "Eats(Anil, Peanuts)": True,
    "not Killed(Anil)": True,
    "Food(Apple)": True,
    "Food(Vegetables)": True,
}

rules = [
    # Rule: Food(X) :- Eats(Y, X) and not Killed(Y)
    {"conditions": ["Eats(Y, X)", "not Killed(Y)"], "conclusion": "Food(X)"},
    # Rule: Likes(John, X) :- Food(X)
```

```
    {"conditions": ["Food(X)"], "conclusion": "Likes(John, X)"},
]

# Query
query = "Likes(John, Peanuts)"

# Helper function to substitute variables in a rule
def substitute(rule_part, substitutions):
    for var, value in substitutions.items():
        rule_part = rule_part.replace(var, value)
    return rule_part

# Function to resolve the query
def resolve_query(facts, rules, query):
    working_facts = facts.copy()
    while True:
        new_facts_added = False
        for rule in rules:
            conditions = rule["conditions"]
            conclusion = rule["conclusion"]

            # Try all substitutions for variables (X, Y) in the rules
            for entity in ["Apple", "Vegetables", "Peanuts", "Anil", "John"]:
                substitutions = {"X": "Peanuts", "Y": "Anil"}  # Fixed for this problem
                resolved_conditions = [substitute(cond, substitutions) for cond in conditions]
                resolved_conclusion = substitute(conclusion, substitutions)

                # Check if all conditions are true
                if all(working_facts.get(cond, False) for cond in resolved_conditions):
                    if resolved_conclusion not in working_facts:
                        working_facts[resolved_conclusion] = True
                        new_facts_added = True
                        print(f"Derived Fact: {resolved_conclusion}")

        if not new_facts_added:
            break

    # Check if the query is resolved
    return working_facts.get(query, False)

# Run the resolution process
if resolve_query(facts, rules, query):
    print(f"Proven: {query}")
else:
    print(f"Not Proven: {query}")
```

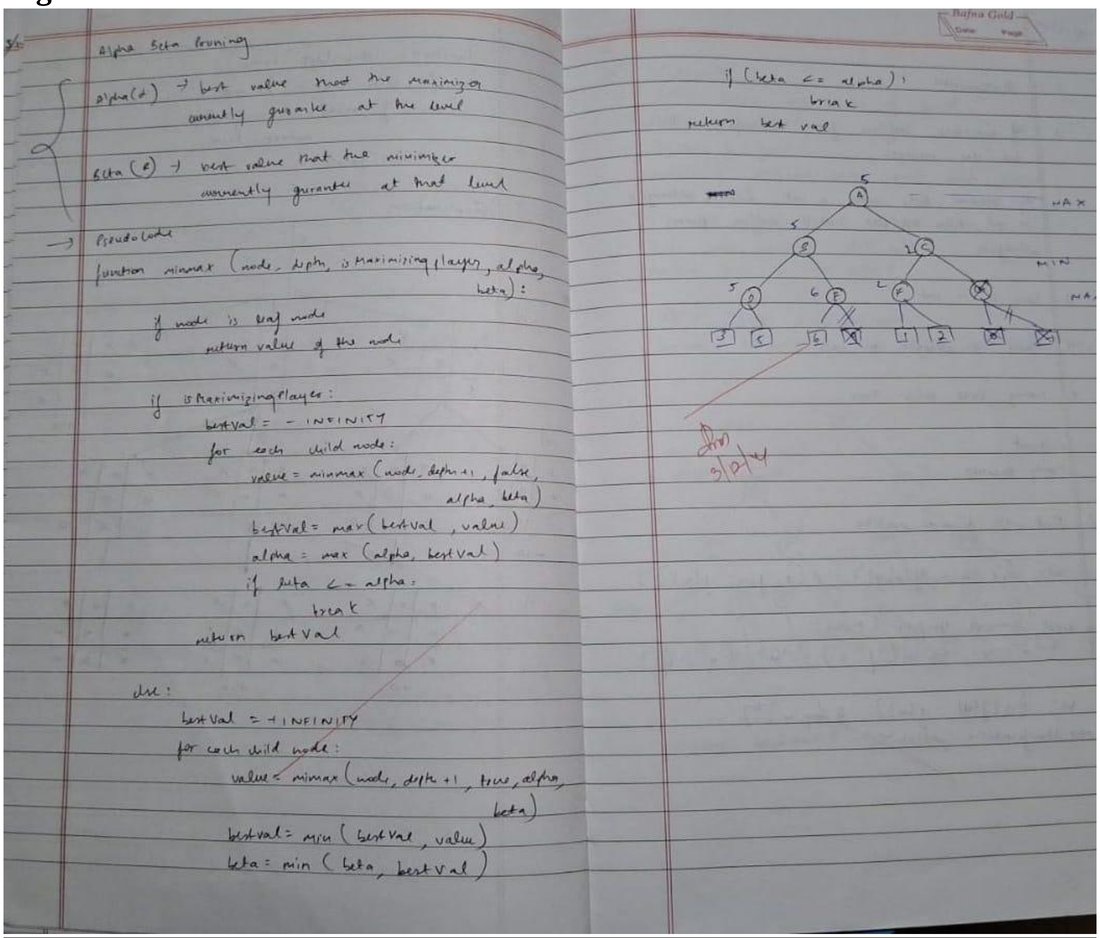
Output:

Derived Fact: Food(Peanuts)

Derived Fact: Likes(John, Peanuts)
Proven: Likes(John, Peanuts)

<u>Program 10</u>
Implement Alpha-Beta Pruning.

Algorithm:


Alpha Beta Pruning

alpha(α) → best value that the maximizer currently guarantee at the level

beta (β) → best value that the minimizer currently guarantee at that level

→ Pseudocode

```
function minimax (node, depth, isMaximizingPlayer, alpha,
                                                   beta):
    if node is leaf node
        return value of the node

    if isMaximizingPlayer:
        bestVal = - INFINITY
        for each child node:
            value = minimax (node, depth+1, false,
                                      alpha, beta)
            bestVal = max (bestVal , value)
            alpha = max (alpha, bestVal)
            if beta <= alpha:
                break
        return bestVal

    else:
        bestVal = +INFINITY
        for each child node:
            value = minimax (node, depth+1, true, alpha,
                                                  beta)
            bestVal = min (bestVal , value)
            beta = min (beta, bestVal)
            if (beta <= alpha):
                break
        return best val
```


Code:

```
import math

def minimax(depth, index, maximizing_player, values, alpha, beta):
    # Base case: when we've reached the leaf nodes
    if depth == 0:
        return values[index]

    if maximizing_player:
        max_eval = float('-inf')
        for i in range(2):  # 2 children per node
            eval = minimax(depth - 1, index * 2 + i, False, values, alpha, beta)
            max_eval = max(max_eval, eval)
            alpha = max(alpha, eval)
            if beta <= alpha:  # Beta cutoff
                break
```

```
        return max_eval
    else:
        min_eval = float('inf')
        for i in range(2):  # 2 children per node
            eval = minimax(depth - 1, index * 2 + i, True, values, alpha, beta)
            min_eval = min(min_eval, eval)
            beta = min(beta, eval)
            if beta <= alpha:  # Alpha cutoff
                break
        return min_eval


# Accept values from the user
leaf_values = list(map(int, input("Enter the leaf node values separated by spaces: ").split()))

# Check if the number of values is a power of 2
if math.log2(len(leaf_values)) % 1 != 0:
    print("Error: The number of leaf nodes must be a power of 2 (e.g., 2, 4, 8, 16).")
else:
    # Calculate depth of the tree
    tree_depth = int(math.log2(len(leaf_values)))

    # Run Minimax with Alpha-Beta Pruning
    optimal_value = minimax(depth=tree_depth, index=0, maximizing_player=True, values=leaf_values,
alpha=float('-inf'), beta=float('inf'))

    print("Optimal value calculated using Minimax:", optimal_value)
```

Output:

Enter the leaf node values separated by spaces: -1 8 -3 -1 2 1 -3 4
Optimal value calculated using Minimax: 2