Artificial Intelligence Lab Report

Submitted by

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Batch: 4

Course: Artificial Intelligence
Course Code: 20CS5PCAIP
Sem & Section: 5C

BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B. M. S. COLLEGE OF ENGINEERING
(Autonomous Institution under VTU)
BENGALURU-560019
2022-2023

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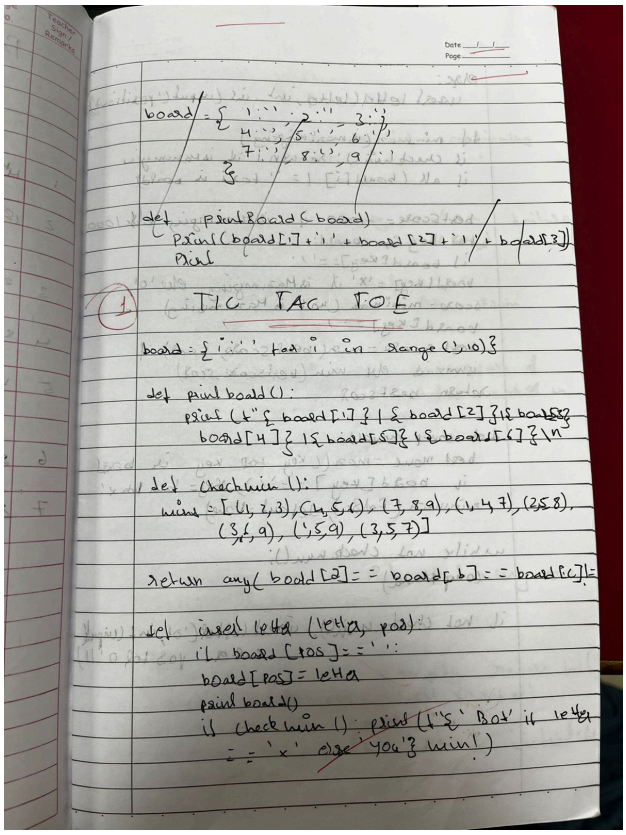
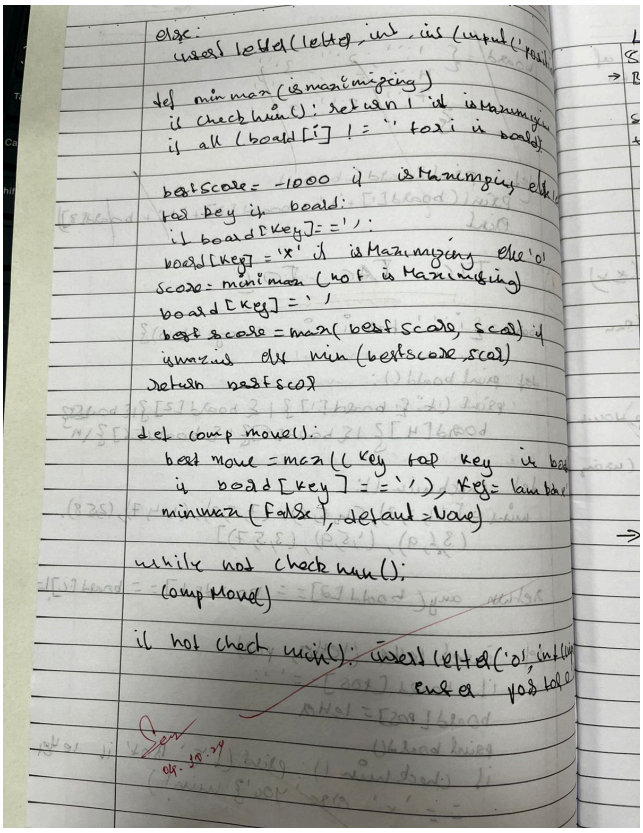




Code

```
board = {1: ' ', 2: ' ', 3: ' ',
         4: ' ', 5: ' ', 6: ' ',
         7: ' ', 8: ' ', 9: ' '}
```

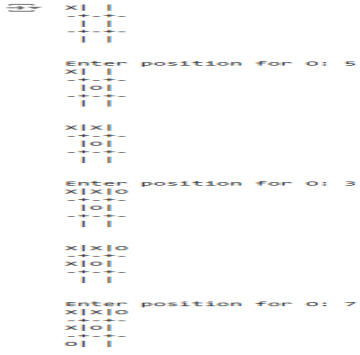
```
def printBoard(board):
    print(board[1] + '|' + board[2] + '|' + board[3])
    print('-+-+-')
    print(board[4] + '|' + board[5] + '|' + board[6])
    print('-+-+-')
    print(board[7] + '|' + board[8] + '|' + board[9])
    print('\n')


def spaceFree(pos):
    return board[pos] == ' '


def checkWin():
    win_conditions = [
        (1, 2, 3), (4, 5, 6), (7, 8, 9),  # Rows
        (1, 4, 7), (2, 5, 8), (3, 6, 9),  # Columns
        (1, 5, 9), (3, 5, 7)  # Diagonals
    ]
    for a, b, c in win_conditions:
        if board[a] == board[b] == board[c] and board[a] != ' ':
            return True
    return False


def checkMoveForWin(move):
    win_conditions = [
        (1, 2, 3), (4, 5, 6), (7, 8, 9),
        (1, 4, 7), (2, 5, 8), (3, 6, 9),
        (1, 5, 9), (3, 5, 7)
    ]
```

```
    for a, b, c in win_conditions:
        if board[a] == board[b] == move and board[a] != ' ':
            return True
    return False


def checkDraw():
    return all(board[key] != ' ' for key in board.keys())


def insertLetter(letter, position):
    if spaceFree(position):
        board[position] = letter
        printBoard(board)
        if checkDraw():
            print('Draw!')
        elif checkWin():
            if letter == 'X':
                print('Bot wins!')
            else:
                print('You win!')
            return
    else:
        print('Position taken, please pick a different position.')
        position = int(input('Enter new position: '))
        insertLetter(letter, position)


player = 'O'
bot = 'X'


def playerMove():
```

```
    position = int(input('Enter position for O: '))
    insertLetter(player, position)


def compMove():
    bestScore = -1000
    bestMove = 0
    for key in board.keys():
        if board[key] == ' ':
            board[key] = bot
            score = minimax(board, False)
            board[key] = ' '
            if score > bestScore:
                bestScore = score
                bestMove = key
    insertLetter(bot, bestMove)


def minimax(board, isMaximizing):
    if checkMoveForWin(bot):
        return 1
    elif checkMoveForWin(player):
        return -1
    elif checkDraw():
        return 0


    if isMaximizing:
        bestScore = -1000
        for key in board.keys():
            if board[key] == ' ':
                board[key] = bot
```

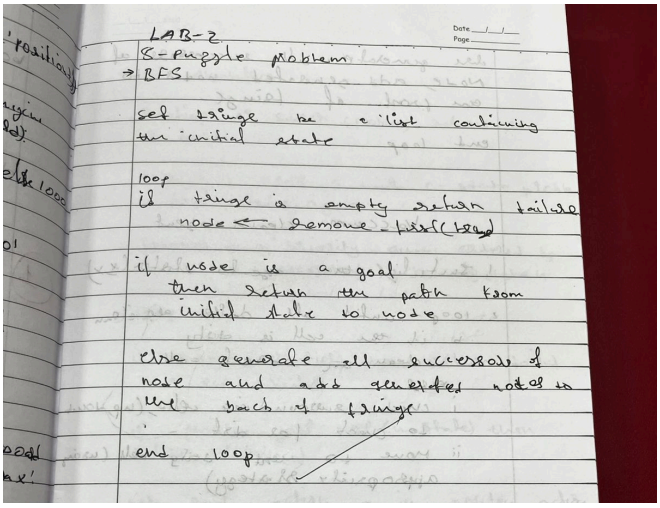
```
                score = minimax(board, False)
                board[key] = ' '
                bestScore = max(score, bestScore)
        return bestScore
    else:
        bestScore = 1000
        for key in board.keys():
            if board[key] == ' ':
                board[key] = player
                score = minimax(board, True)
                board[key] = ' '
                bestScore = min(score, bestScore)
        return bestScore


while not checkWin() and not checkDraw():
    compMove()
    if checkWin() or checkDraw():
        break
    playerMove()
```

Output Snapshot



Program 2 - 8 Puzzle Using BFS

Algorithm



Code

```
from collections import deque

# Define the goal state
GOAL_STATE = [[1, 2, 3], [8, 0, 4], [7, 6, 5]]

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

def get_neighbors(state):
    neighbors = []
    x, y = find_blank(state)
    directions = [(0, 1), (1, 0), (0, -1), (-1, 0)]  # right, down, left,
up

    for dx, dy in directions:
        new_x, new_y = x + dx, y + dy
        if 0 <= new_x < 3 and 0 <= new_y < 3:
            new_state = [row[:] for row in state]  # create a copy
            new_state[x][y], new_state[new_x][new_y] =
new_state[new_x][new_y], new_state[x][y]
            neighbors.append(new_state)
```

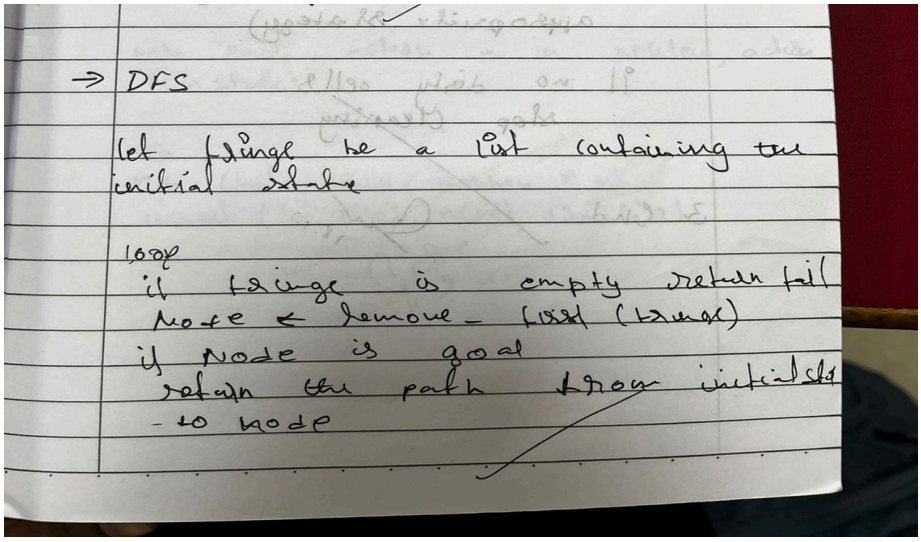
```
    return neighbors

def bfs(start_state):
    start_tuple = tuple(tuple(row) for row in start_state)
    goal_tuple = tuple(tuple(row) for row in GOAL_STATE)

    queue = deque([start_state])  # Use the list representation for the
queue
    visited = {start_tuple: None}

    while queue:
        current_state = queue.popleft()

        if tuple(tuple(row) for row in current_state) == goal_tuple:
            break

        for neighbor in get_neighbors(current_state):
            neighbor_tuple = tuple(tuple(row) for row in neighbor)
            if neighbor_tuple not in visited:
                visited[neighbor_tuple] = current_state
                queue.append(neighbor)

    # Backtrack to find the solution path
    path = []
    while current_state is not None:
        path.append(current_state)
        current_state = visited[tuple(tuple(row) for row in current_state)]

    return path[::-1]  # Return reversed path

def print_solution(path):
    for state in path:
        for row in state:
            print(row)
        print()

# Example usage
start_state = [[2, 8, 3], [1, 6, 4], [7 ,0 ,5]]
solution_path = bfs(start_state)
print_solution(solution_path)
```

Output Snapshot

```
[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 3 - 8 puzzle using DFS

Algorithm



Code

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

def get_neighbors(state):
    neighbors = []
    x, y = find_blank(state)
    directions = [(0, 1), (1, 0), (0, -1), (-1, 0)]  # right, down, left, up

    for dx, dy in directions:
        new_x, new_y = x + dx, y + dy
        if 0 <= new_x < 3 and 0 <= new_y < 3:
            new_state = [row[:] for row in state]  # Create a copy
            new_state[x][y], new_state[new_x][new_y] =
new_state[new_x][new_y], new_state[x][y]
            neighbors.append(new_state)

    return neighbors

def iterative_dfs(start_state):
    stack = [start_state]
    visited = set()
    path_map = {tuple(map(tuple, start_state)): None}

    while stack:
        current_state = stack.pop()

        if current_state == GOAL_STATE:
            return reconstruct_path(path_map, current_state)
```

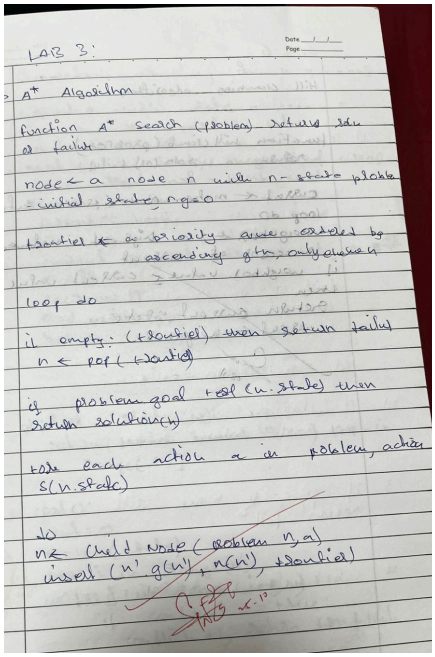
```
        visited.add(tuple(map(tuple, current_state)))

        for neighbor in get_neighbors(current_state):
            neighbor_tuple = tuple(map(tuple, neighbor))
            if neighbor_tuple not in visited and neighbor_tuple not in
path_map:
                path_map[neighbor_tuple] = current_state
                stack.append(neighbor)

    return None

def reconstruct_path(path_map, goal_state):
    path = []
    current = goal_state
    while current is not None:
        path.append(current)
        current = path_map[tuple(map(tuple, current))]
    return path[::-1]  # Reverse to get the correct order

def print_solution(path):
    if path:
        for state in path:
            for row in state:
                print(row)
            print()
    else:
        print("No solution found.")

# Example usage
GOAL_STATE = [[1, 2, 3], [4, 5, 6], [7, 8, 0]]
start_state = [[1, 2, 3], [4, 0, 6], [7, 5, 8]]

solution_path = iterative_dfs(start_state)
print_solution(solution_path)
```

Output Snapshot

```
[1, 2, 3]
[8, 7, 5]
[0, 4, 6]

[1, 2, 3]
[8, 7, 5]
[4, 0, 6]

[1, 2, 3]
[8, 0, 5]
[4, 7, 6]

[1, 2, 3]
[0, 8, 5]
[4, 7, 6]

[1, 2, 3]
[4, 8, 5]
[0, 7, 6]

[1, 2, 3]
[4, 8, 5]
[7, 0, 6]

[1, 2, 3]
[4, 0, 5]
[7, 8, 6]

[1, 2, 3]
[4, 5, 0]
[7, 8, 6]

[1, 2, 3]
[4, 5, 6]
[7, 8, 0]
```

Program 04 - 8 Puzzle Using A*

Algorithm



Code

```
import heapq

class PuzzleState:
    def __init__(self, board, depth=0, path=''):
        self.board = board
        self.blank_index = board.index(0)  # Index of the blank tile
        self.depth = depth
        self.path = path  # Path taken to reach this state
    def is_goal(self):
        return self.board == [1, 2, 3, 4, 5, 6, 7, 8, 0]
    def get_possible_moves(self):
        moves = []
        row, col = divmod(self.blank_index, 3)
        if row > 0:  # Up
            moves.append(-3)
        if row < 2:  # Down
            moves.append(3)
        if col > 0:  # Left
            moves.append(-1)
        if col < 2:  # Right
            moves.append(1)
        return moves
    def generate_new_state(self, move):
        new_index = self.blank_index + move
        new_board = self.board[:]
        new_board[self.blank_index], new_board[new_index] =
new_board[new_index], new_board[self.blank_index]
        return PuzzleState(new_board, self.depth + 1, self.path +
str(new_board))

    def heuristic_misplaced(self):
        return sum(1 for i in range(9) if self.board[i] != 0 and self.board[i]
!= i + 1)

    def heuristic_manhattan(self):
```

```
        distance = 0
        for i in range(9):
            if self.board[i] != 0:
                target_row, target_col = divmod(self.board[i] - 1, 3)
                current_row, current_col = divmod(i, 3)
                distance += abs(target_row - current_row) + abs(target_col -
current_col)
        return distance
    def __lt__(self, other):
        return False  # Needed for priority queue to compare states
def a_star(initial_board, heuristic_type='misplaced'):
    start_state = PuzzleState(initial_board)
    if start_state.is_goal():
        return start_state.path
    # Priority queue for open states
    open_set = []
    heapq.heappush(open_set, (0, start_state))
    # Set to track visited states
    visited = set()
    while open_set:
        current_cost, current_state = heapq.heappop(open_set)
        if current_state.is_goal():
            return current_state.path
        visited.add(tuple(current_state.board))
        for move in current_state.get_possible_moves():
            new_state = current_state.generate_new_state(move)
            if tuple(new_state.board) in visited:
                continue
            # Calculate h(n) based on selected heuristic
            if heuristic_type == 'misplaced':
                h = new_state.heuristic_misplaced()
            elif heuristic_type == 'manhattan':
                h = new_state.heuristic_manhattan()
            else:
                raise ValueError("Invalid heuristic type")
            # Calculate f(n)
            f = new_state.depth + h
            # Print f(n) for the current state
```

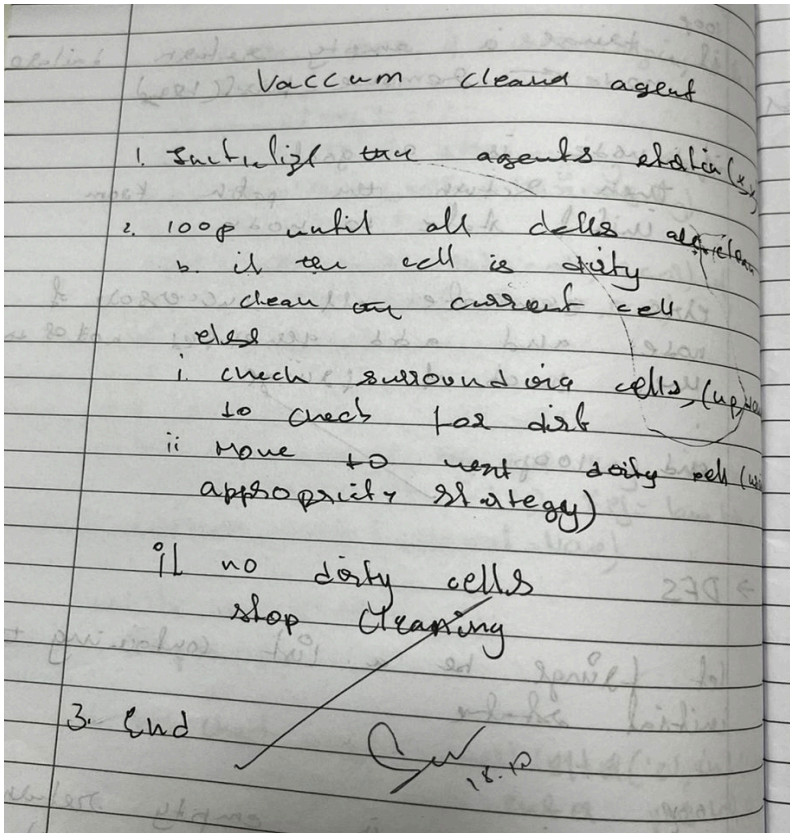
```
            print(f"Current State: {new_state.board}, g(n): {new_state.depth},
h(n): {h}, f(n): {f}")
            heapq.heappush(open_set, (f, new_state))
    return None  # No solution found
# Example usage
initial_board = [1, 2, 3, 4, 5, 6, 0, 7, 8]  # 0 represents the blank tile
print("Solution Path (Misplaced Tiles):", a_star(initial_board,
heuristic_type='misplaced'))
print("Solution Path (Manhattan Distance):", a_star(initial_board,
heuristic_type='manhattan'))
```

Output Snapshot

```
Current State: [1, 2, 3, 0, 5, 6, 4, 7, 8], g(n): 1, h(n): 3, f(n): 4
Current State: [1, 2, 3, 4, 5, 6, 7, 0, 8], g(n): 1, h(n): 1, f(n): 2
Current State: [1, 2, 3, 4, 0, 6, 7, 5, 8], g(n): 2, h(n): 2, f(n): 4
Current State: [1, 2, 3, 4, 5, 6, 7, 8, 0], g(n): 2, h(n): 0, f(n): 2
Solution Path (Misplaced Tiles): [1, 2, 3, 4, 5, 6, 7, 0, 8][1, 2, 3, 4, 5, 6, 7, 8, 0]
Current State: [1, 2, 3, 0, 5, 6, 4, 7, 8], g(n): 1, h(n): 3, f(n): 4
Current State: [1, 2, 3, 4, 5, 6, 7, 0, 8], g(n): 1, h(n): 1, f(n): 2
Current State: [1, 2, 3, 4, 0, 6, 7, 5, 8], g(n): 2, h(n): 2, f(n): 4
Current State: [1, 2, 3, 4, 5, 6, 7, 8, 0], g(n): 2, h(n): 0, f(n): 2
Solution Path (Manhattan Distance): [1, 2, 3, 4, 5, 6, 7, 0, 8][1, 2, 3, 4, 5, 6, 7, 8, 0]
```

Program 5 - Vacuum Cleaner

Algorithm



Code

```
def vacuum_world():
    # Initializing goal_state
    # 0 indicates Clean and 1 indicates Dirty
    goal_state = {'A': '0', 'B': '0'}
    cost = 0
    location_input = input("Enter Location of Vacuum: ")  # User input for
location vacuum is placed
    status_input = input("Enter status of " + location_input + " (0 for Clean,
1 for Dirty): ")  # User input if location is dirty or clean
    status_input_complement = input("Enter status of other room (0 for Clean,
1 for Dirty): ")

    print("Initial Location Condition: " + str(goal_state))

    if location_input == 'A':
        # Location A is Dirty.
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            # Suck the dirt and mark it as clean
            goal_state['A'] = '0'
            cost += 1  # Cost for suck
            print("Cost for CLEANING A: " + str(cost))
            print("Location A has been Cleaned.")

            if status_input_complement == '1':
                # If B is Dirty
                print("Location B is Dirty.")
                print("Moving right to Location B.")
                cost += 1  # Cost for moving right
                print("COST for moving RIGHT: " + str(cost))
                # Suck the dirt and mark it as clean
                goal_state['B'] = '0'
                cost += 1  # Cost for suck
                print("COST for SUCK: " + str(cost))
```

```
            print("Location B has been Cleaned.")
        else:
            print("No action needed; Location B is already clean.")
    else:
        print("Location A is already clean.")
        if status_input_complement == '1':  # If B is Dirty
            print("Location B is Dirty.")
            print("Moving RIGHT to Location B.")
            cost += 1  # Cost for moving right
            print("COST for moving RIGHT: " + str(cost))
            # Suck the dirt and mark it as clean
            goal_state['B'] = '0'
            cost += 1  # Cost for suck
            print("COST for SUCK: " + str(cost))
            print("Location B has been Cleaned.")
        else:
            print("No action needed; Location B is already clean.")

else:  # Vacuum is placed in location B
    print("Vacuum is placed in Location B")
    if status_input == '1':
        print("Location B is Dirty.")
        # Suck the dirt and mark it as clean
        goal_state['B'] = '0'
        cost += 1  # Cost for suck
        print("COST for CLEANING B: " + str(cost))
        print("Location B has been Cleaned.")

        if status_input_complement == '1':  # If A is Dirty
            print("Location A is Dirty.")
            print("Moving LEFT to Location A.")
            cost += 1  # Cost for moving left
            print("COST for moving LEFT: " + str(cost))
            # Suck the dirt and mark it as clean
            goal_state['A'] = '0'
            cost += 1  # Cost for suck
            print("COST for SUCK: " + str(cost))
            print("Location A has been Cleaned.")
```

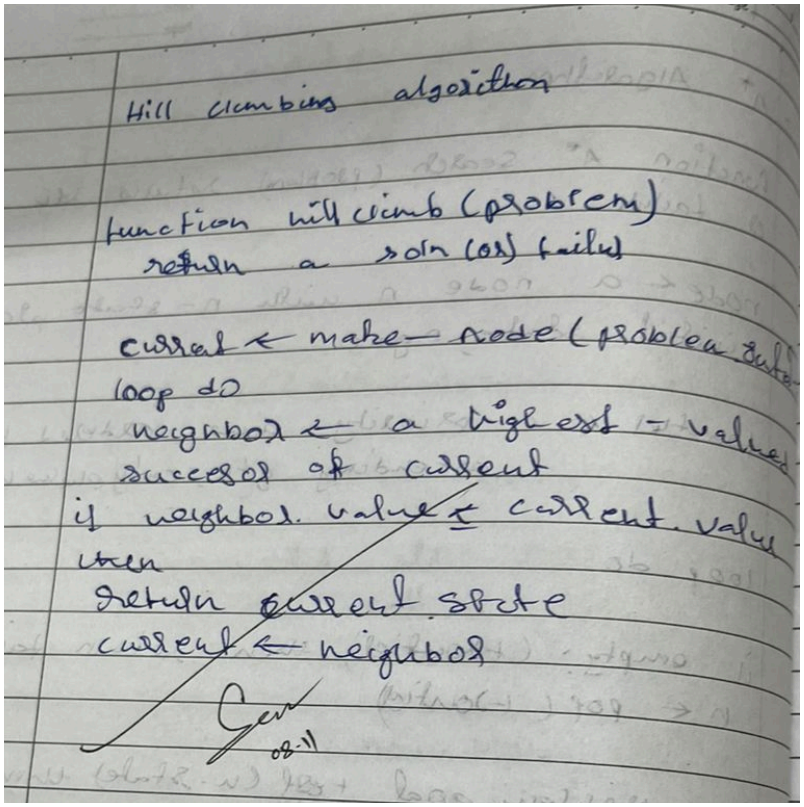
```
            else:
                print("No action needed; Location A is already clean.")
        else:
            print("Location B is already clean.")
            if status_input_complement == '1':  # If A is Dirty
                print("Location A is Dirty.")
                print("Moving LEFT to Location A.")
                cost += 1  # Cost for moving left
                print("COST for moving LEFT: " + str(cost))
                # Suck the dirt and mark it as clean
                goal_state['A'] = '0'
                cost += 1  # Cost for suck
                print("COST for SUCK: " + str(cost))
                print("Location A has been Cleaned.")
            else:
                print("No action needed; Location A is already clean.")

    # Done cleaning
    print("GOAL STATE: ")
    print(goal_state)
    print("Performance Measurement: " + str(cost))

# Call the function to run the vacuum world simulation
vacuum_world()
```


Output Snapshot

```
Enter Location of Vacuum: A
Enter status of A (0 for Clean, 1 for Dirty): 1
Enter status of other room (0 for Clean, 1 for Dirty): 0
Initial Location Condition: {'A': '0', 'B': '0'}
Vacuum is placed in Location A
Location A is Dirty.
Cost for CLEANING A: 1
Location A has been Cleaned.
No action needed; Location B is already clean.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 1
```

Program-06 Hill Climbing

Algorithm



Code

```
import random


def print_board(board, n):
    """Prints the current state of the board."""
    for row in range(n):
        line = ""
        for col in range(n):
            if board[col] == row:
                line += " Q "
            else:
                line += " . "
        print(line)
    print()
```

```
def calculate_conflicts(board, n):
    """Calculates the number of conflicts (attacks) between queens."""
    conflicts = 0
    for i in range(n):
        for j in range(i + 1, n):
            # Check if queens are in the same row or diagonal
            if board[i] == board[j] or abs(board[i] - board[j]) == abs(i -
j):
                conflicts += 1
    return conflicts

def get_best_neighbor(board, n):
    """
    Finds the best neighboring board with the fewest conflicts.
    Returns the best board and its conflict count.
    """
    current_conflicts = calculate_conflicts(board, n)
    best_board = board[:]
    best_conflicts = current_conflicts
    neighbors = []

    for col in range(n):
        original_row = board[col]
        for row in range(n):
            if row == original_row:
                continue
            # Move queen to a new row and calculate conflicts
            board[col] = row
            new_conflicts = calculate_conflicts(board, n)
            neighbors.append((board[:], new_conflicts))
        # Restore the original row before moving to the next column
        board[col] = original_row

    # Sort neighbors by the number of conflicts (ascending)
    neighbors.sort(key=lambda x: x[1])
    if neighbors:
        best_neighbor = neighbors[0]
        if best_neighbor[1] < best_conflicts:
```

```
            return best_neighbor
    return board, current_conflicts

def hill_climbing_with_restarts(n, initial_board, max_restarts=100):
    """
    Performs Hill Climbing with random restarts to solve the N-Queens
problem.
    Returns the final board configuration and its conflict count.
    """
    current_board = initial_board[:]
    current_conflicts = calculate_conflicts(current_board, n)

    print("Initial board:")
    print_board(current_board, n)
    print(f"Initial conflicts: {current_conflicts}\n")

    steps = 0
    restarts = 0

    while current_conflicts > 0 and restarts < max_restarts:
        new_board, new_conflicts = get_best_neighbor(current_board, n)

        steps += 1
        print(f"Step {steps}:")
        print_board(new_board, n)
        print(f"Conflicts: {new_conflicts}\n")

        if new_conflicts < current_conflicts:
            current_board = new_board
            current_conflicts = new_conflicts
        else:
            # If no better neighbor is found, perform a random restart
            restarts += 1
            print(f"Restarting... (Restart number {restarts})\n")
            current_board = [random.randint(0, n-1) for _ in range(n)]
            current_conflicts = calculate_conflicts(current_board, n)
            print("New initial board:")
            print_board(current_board, n)
```

```
            print(f"Conflicts: {current_conflicts}\n")

    return current_board, current_conflicts

# Main function
def main():
    n = 4
    print("Enter the initial positions of queens (row numbers from 0 to 3
for each column):")
    initial_board = []
    for i in range(n):
        while True:
            try:
                row = int(input(f"Column {i}: "))
                if 0 <= row < n:
                    initial_board.append(row)
                    break
                else:
                    print(f"Please enter a number between 0 and {n-1}.")
            except ValueError:
                print("Invalid input. Please enter an integer.")

    solution, conflicts = hill_climbing_with_restarts(n, initial_board)

    print("Final solution:")
    print_board(solution, n)
    if conflicts == 0:
        print("A solution was found with no conflicts!")
    else:
        print(f"No solution was found after {100} restarts. Final number of
conflicts: {conflicts}")

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

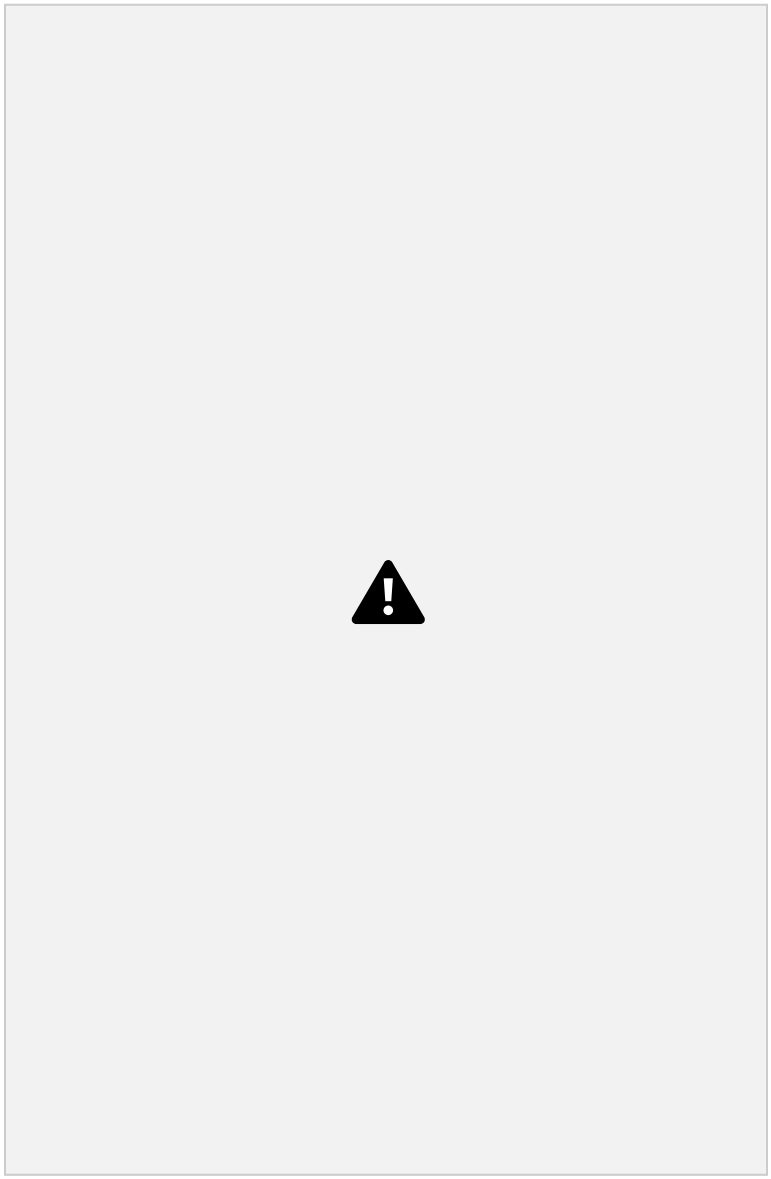
OUTPUT

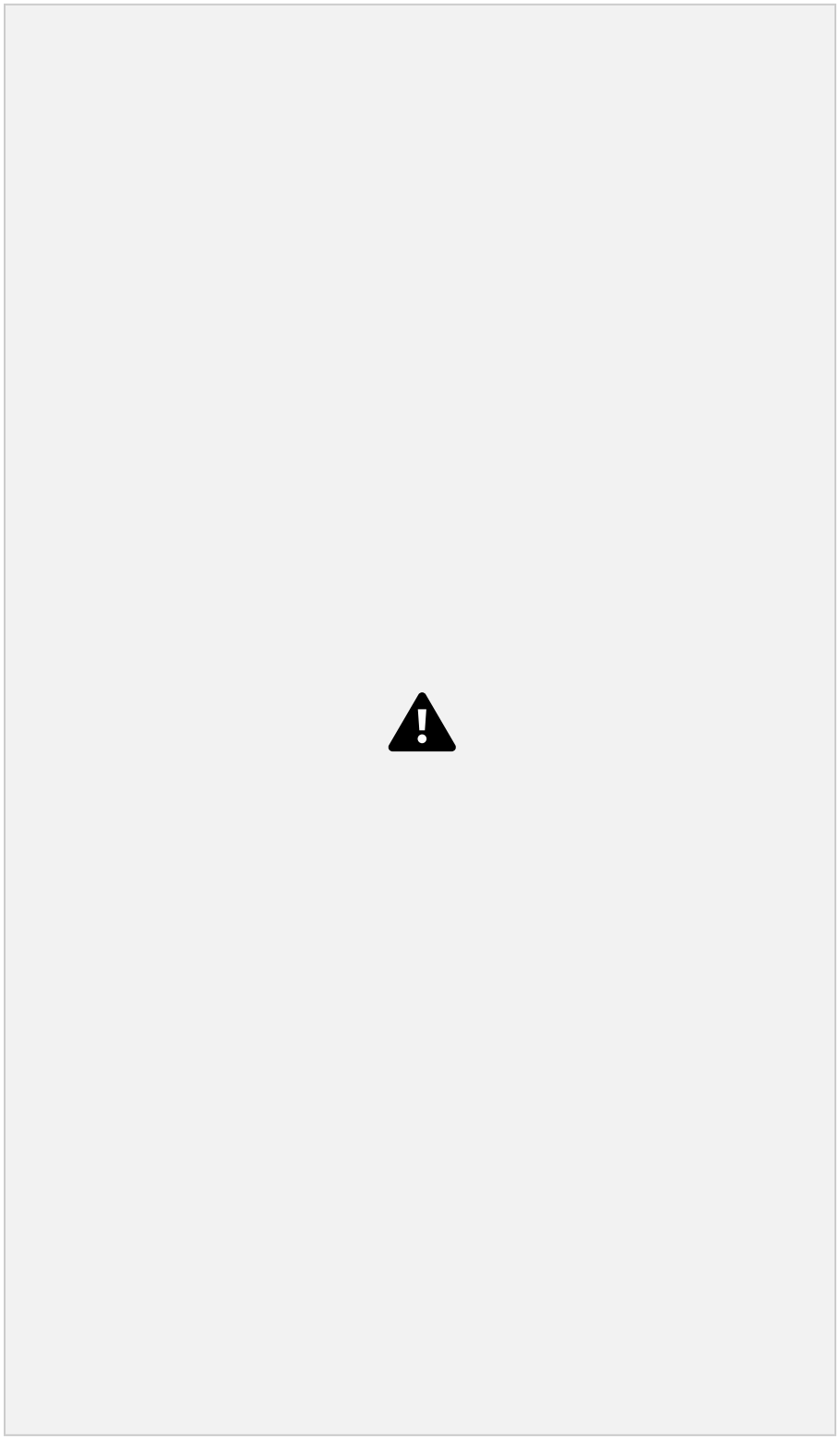
```
Enter the initial positions of queens (row numbers from 0 to 3 for each column):
Column 0: 3
Column 1: 1
Column 2: 2
Column 3: 0
Initial board:
 .  .  .  Q
 .  Q  .  .
 .  .  Q  .
 Q  .  .  .

Initial conflicts: 2
```

```
Step 6:
 Q  Q  -  -
 -  -  -  Q
 -  -  -  -
 -  -  Q  -

Conflicts: 1

Step 7:
 -  Q  -  -
 -  -  -  Q
 Q  -  -  -
 -  -  Q  -

Conflicts: 0

Final solution:
 -  Q  -  -
 -  -  -  Q
 Q  -  -  -
 -  -  Q  -

A solution was found with no conflicts!
```

Program-08 KnowledgeBase - Resolution

Algorithm





Code

```
# Function to negate a literal
def negate(literal):
    """Negate a literal."""
    if isinstance(literal, tuple) and literal[0] == "not":
        # If the literal is already negated, return the positive form
```

```
        return literal[1]
    else:
        # Otherwise, return the negated form
        return ("not", literal)

# Function to resolve two clauses
def resolve(clause1, clause2):
    """Return the resolvent of two clauses."""
    resolvents = set()
    for literal1 in clause1:
        for literal2 in clause2:
            if literal1 == negate(literal2):
                resolvent = (clause1 - {literal1}) | (clause2 - {literal2})
                print(f" Resolving literal: {literal1} with {literal2}")
                print(f" Resulting Resolvent: {resolvent}")
                resolvents.add(frozenset(resolvent))
    return resolvents

# Function to perform resolution on the KB and query with detailed output
def resolution_algorithm(KB, query):
    """Perform the resolution algorithm to check if the query can be
proven."""
    print("\n--- Step-by-Step Resolution Process ---")
    # Add the negation of the query to the knowledge base
    negated_query = negate(query)
    KB.append(frozenset([negated_query]))
    print(f"Negated Query Added to KB: {negated_query}")

    # Initialize the set of clauses to process
    clauses = set(KB)

    step = 1
    while True:
        new_clauses = set()
        print(f"\nStep {step}: Resolving Clauses")
        for c1 in clauses:
            for c2 in clauses:
                if c1 != c2:
                    print(f" Resolving clauses: {c1} and {c2}")
                    resolvent = resolve(c1, c2)

                    for res in resolvent:
                        if frozenset([]) in resolvent:
```

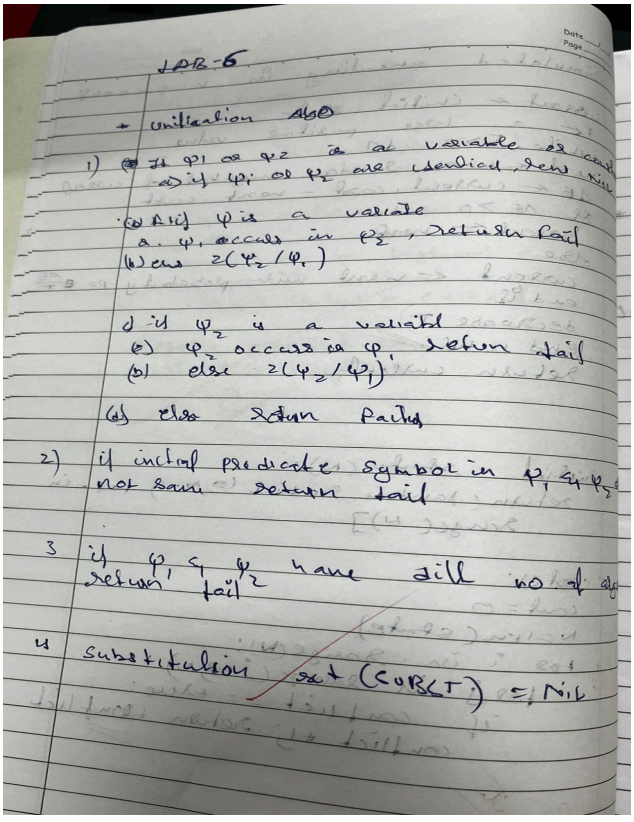
```
                            print("\nEmpty clause derived! The query is
provable.")
                            return True  # Empty clause found, contradiction,
query is provable

                        new_clauses.add(res)

        if new_clauses.issubset(clauses):
            print("\nNo new clauses can be derived. The query is not
provable.")
            return False  # No new clauses, query is not provable

        clauses.update(new_clauses)
        step += 1

# Knowledge Base (KB) from the image facts
KB = [
    frozenset([("not", "food(x)"), ("likes", "John", "x")]),  # 1
    frozenset([("food", "Apple")]),  # 2
    frozenset([("food", "vegetables")]),  # 3
    frozenset([("not", "eats(y, z)"), ("killed", "y"), ("food", "z")]),  # 4
    frozenset([("eats", "Anil", "Peanuts")]),  # 5
    frozenset([("alive", "Anil")]),  # 6
    frozenset([("not", "eats(Anil, w)"), ("eats", "Harry", "w")]),  # 7
    frozenset([("killed", "g"), ("alive", "g")]),  # 8
    frozenset([("not", "alive(k)"), ("not", "killed(k)")]),  # 9
    frozenset([("likes", "John", "Peanuts")])  # 10
]

# Query to prove
query = ("likes", "John", "Peanuts")

# Perform resolution to check if the query is provable
result = resolution_algorithm(KB, query)
if result:
    print("\nQuery is provable.")
else:
    print("\nQuery is not provable.")
```

Output Snapshot

```
Resolving clauses: frozenset({('eats', 'Anil', 'Peanuts')}) and frozenset({('not', 'food(x)'), ('likes', 'John', 'x')})
Resolving clauses: frozenset({('killed', 'g'), ('alive', 'g')}) and frozenset({('alive', 'Anil')})
Resolving clauses: frozenset({('killed', 'g'), ('alive', 'g')}) and frozenset({('eats', 'Anil', 'Peanuts')})
Resolving clauses: frozenset({('killed', 'g'), ('alive', 'g')}) and frozenset({('food', 'Apple')})
Resolving clauses: frozenset({('killed', 'g'), ('alive', 'g')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
Resolving clauses: frozenset({('killed', 'g'), ('alive', 'g')}) and frozenset({('eats', 'Harry', 'w'), ('not', 'eats(Anil, w)')})
Resolving clauses: frozenset({('killed', 'g'), ('alive', 'g')}) and frozenset({('food', 'vegetables')})
Resolving clauses: frozenset({('killed', 'g'), ('alive', 'g')}) and frozenset({('not', 'killed(k)'), ('not', 'alive(k)')})
Resolving clauses: frozenset({('killed', 'g'), ('alive', 'g')}) and frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')})
Resolving clauses: frozenset({('killed', 'g'), ('alive', 'g')}) and frozenset({('likes', 'John', 'Peanuts')})
Resolving clauses: frozenset({('killed', 'g'), ('alive', 'g')}) and frozenset({('not', 'food(x)'), ('likes', 'John', 'x')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('alive', 'Anil')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('eats', 'Anil', 'Peanuts')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('killed', 'g'), ('alive', 'g')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('eats', 'Harry', 'w'), ('not', 'eats(Anil, w)')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('food', 'vegetables')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('not', 'killed(k)'), ('not', 'alive(k)')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('likes', 'John', 'Peanuts')})
Resolving clauses: frozenset({('food', 'Apple')}) and frozenset({('not', 'food(x)'), ('likes', 'John', 'x')})
Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('alive', 'Anil')})
Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('eats', 'Anil', 'Peanuts')})
Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('killed', 'g'), ('alive', 'g')})
Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('food', 'Apple')})
Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('eats', 'Harry', 'w'), ('not', 'eats(Anil, w)')})
Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('food', 'vegetables')})
Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('not', 'killed(k)'), ('not', 'alive(k)')})
Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('not', 'eats(y, z)'), ('food', 'z'), ('killed', 'y')})
Resolving clauses: frozenset({('not', ('likes', 'John', 'Peanuts'))}) and frozenset({('likes', 'John', 'Peanuts')})
Resolving literal: ('not', ('likes', 'John', 'Peanuts')) with ('likes', 'John', 'Peanuts')
Resulting Resolvent: frozenset()

Empty clause derived! The query is provable.

Query is provable.
```

Program-09 Unification in first order logic

Algorithm



Code

```
import ast


from typing import Union, List, Dict, Tuple


from collections import deque


# Define Term Classes


class Term:


    def substitute(self, subs: Dict[str, 'Term']) -> 'Term':


        raise NotImplementedError


    def occurs(self, var: 'Variable') -> bool:


        raise NotImplementedError







    def __eq__(self, other):


        raise NotImplementedError
```

```
    def __str__(self):

        raise NotImplementedError

class Variable(Term):

    def __init__(self, name: str):

        self.name = name

    def substitute(self, subs: Dict[str, Term]) -> Term:

        if self.name in subs:

            return subs[self.name].substitute(subs)

        return self

    def occurs(self, var: 'Variable') -> bool:

        return self.name == var.name

    def __eq__(self, other):

        return isinstance(other, Variable) and self.name == other.name
```

```
    def __str__(self):

        return self.name

class Constant(Term):

    def __init__(self, name: str):

        self.name = name

    def substitute(self, subs: Dict[str, Term]) -> Term:

        return self

    def occurs(self, var: 'Variable') -> bool:

        return False

    def __eq__(self, other):

        return isinstance(other, Constant) and self.name == other.name

    def __str__(self):

        return self.name
```

```
class Function(Term):

    def __init__(self, name: str, args: List[Term]):

        self.name = name

        self.args = args

    def substitute(self, subs: Dict[str, Term]) -> Term:

        substituted_args = [arg.substitute(subs) for arg in self.args]

        return Function(self.name, substituted_args)

    def occurs(self, var: 'Variable') -> bool:

        return any(arg.occurs(var) for arg in self.args)




    def __eq__(self, other):

        return (

            isinstance(other, Function) and
```

```
            self.name == other.name and
            len(self.args) == len(other.args) and
            all(a == b for a, b in zip(self.args, other.args))
        )
    def __str__(self):
        return f"{self.name}({', '.join(str(arg) for arg in self.args)})"
def parse_expression(expr: List) -> Term:
    if not isinstance(expr, list) or not expr:
        raise ValueError("Expression must be a non-empty list")
    func_name = expr[0]
    args = expr[1:]


    parsed_args = []
```

```
    for arg in args:
        if isinstance(arg, list):
            parsed_args.append(parse_expression(arg))
        elif isinstance(arg, str):
            if arg[0].islower():
                parsed_args.append(Variable(arg))
            elif arg[0].isupper():
                parsed_args.append(Constant(arg))
            else:
                raise ValueError(f"Invalid argument format: {arg}")
        else:
            raise ValueError(f"Unsupported argument type: {arg}")
    return Function(func_name, parsed_args)
```

```
def unify_terms(term1: Term, term2: Term) -> Union[Dict[str, Term], str]:

    S: Dict[str, Term] = {}

    equations: deque[Tuple[Term, Term]] = deque()

    equations.append((term1, term2))

    while equations:

        s, t = equations.popleft()

        s = s.substitute(S)

        t = t.substitute(S)

        if s == t:

            continue

        elif isinstance(s, Variable):

            if t.occurs(s):

                return "FAILURE"
```

```
            S[s.name] = t

            for var in S:

                S[var] = S[var].substitute({s.name: t})

        elif isinstance(t, Variable):

            if s.occurs(t):

                return "FAILURE"

            S[t.name] = s

            for var in S:

                S[var] = S[var].substitute({t.name: s})

        elif isinstance(s, Function) and isinstance(t, Function):

            if s.name != t.name or len(s.args) != len(t.args):

                return "FAILURE"

            for s_arg, t_arg in zip(s.args, t.args):
```

```
                equations.append((s_arg, t_arg))

        elif isinstance(s, Constant) and isinstance(t, Constant):

            if s.name != t.name:

                return "FAILURE"

            # else, they are equal; continue

        else:

            return "FAILURE"

    return S

def format_substitution(S: Dict[str, Term]) -> str:

    if not S:

        return "{}"

    return "{ " + ", ".join(f"{var} = {term}" for var, term in S.items()) + "
}"

def unify(expression1: List, expression2: List) -> Union[Dict[str, Term],
str]:
```

```
    try:

        term1 = parse_expression(expression1)

        term2 = parse_expression(expression2)

    except ValueError as e:

        return f"FAILURE: {e}"

    result = unify_terms(term1, term2)




    return result

def main():

    print("=== Unification Algorithm ===\n")

    print("Please enter the expressions in list format.")

    print("Example: [\"Eats\", \"x\", \"Apple\"]\n")
```

```
try:
    expr1_input = input("Enter Expression 1: ")
    expression1 = ast.literal_eval(expr1_input)
    if not isinstance(expression1, list):
        raise ValueError("Expression must be a list.")


    expr2_input = input("Enter Expression 2: ")
    expression2 = ast.literal_eval(expr2_input)
    if not isinstance(expression2, list):
        raise ValueError("Expression must be a list.")
except (SyntaxError, ValueError) as e:
    print(f"Invalid input format: {e}")
    return
```

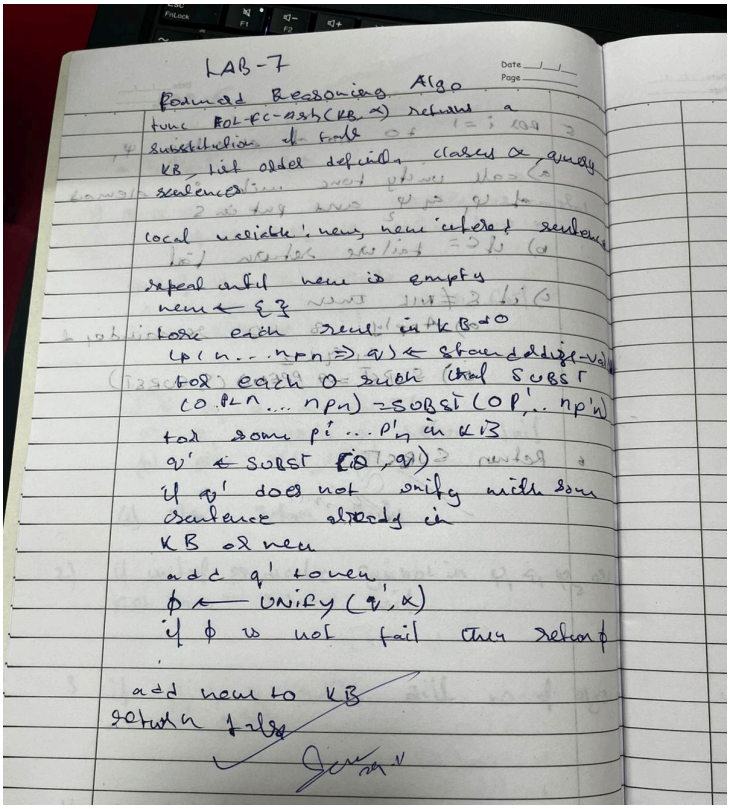
```
    result = unify(expression1, expression2)



    if isinstance(result, str):

        print("\nUnification Result:")

        print(result)

    else:

        print("\nUnification Successful:")

        print(format_substitution(result)

if __name__ == "__main__":

    main()
```

Output Snapshot

```
=== Unification Algorithm ===

Please enter the expressions in list format.
Example: ["Eats", "x", "Apple"]

Enter Expression 1:  ["Eats", "x", "Apple"]
Enter Expression 2:  ["Eats", "orange", "y"]

Unification Successful:
{ x = orange, y = Apple }
```

Program-10 First Order Logic to Conjunctive Normal Form

Algo:



Code

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

```
from sympy import symbols


def eliminate_implications(expr):
    """Eliminate implications and equivalences."""
    if isinstance(expr, Implies):
        return Or(Not(eliminate_implications(expr.args[0])),
                  eliminate_implications(expr.args[1]))
    elif isinstance(expr, Equivalent):
        left = eliminate_implications(expr.args[0])
        right = eliminate_implications(expr.args[1])
        return And(Or(Not(left), right), Or(Not(right), left))
    elif expr.is_Atom:
        return expr
    else:
        return expr.func(*[eliminate_implications(arg) for arg in expr.args])


def push_negations(expr):
    """Push negations inward using De Morgan's laws."""
    if expr.is_Not:
        arg = expr.args[0]
        if isinstance(arg, And):
            return Or(*[push_negations(Not(sub_arg)) for sub_arg in arg.args])
        elif isinstance(arg, Or):
            return And(*[push_negations(Not(sub_arg)) for sub_arg in
arg.args])
        elif isinstance(arg, Not):
            return push_negations(arg.args[0])
        else:
            return Not(push_negations(arg))
    elif expr.is_Atom:
        return expr
    else:
        return expr.func(*[push_negations(arg) for arg in expr.args])


def distribute_ands(expr):
    """Distribute AND over OR to obtain CNF."""
```

```
    if isinstance(expr, Or):
        and_args = [arg for arg in expr.args if isinstance(arg, And)]
        if and_args:
            first_and = and_args[0]
            rest = [arg for arg in expr.args if arg != first_and]
            return And(*[distribute_ands(Or(arg, *rest)) for arg in
first_and.args])
    elif isinstance(expr, And) or expr.is_Atom or expr.is_Not:
        return expr
    return expr.func(*[distribute_ands(arg) for arg in expr.args])

def to_cnf(expr):
    """Convert the given logical expression to CNF."""
    expr = eliminate_implications(expr)
    expr = push_negations(expr)
    expr = distribute_ands(expr)
    return expr

# Example usage:
A, B, C = symbols('A B C')
fol_expr = Implies(A, Or(B, Not(C)))  # Example FOL expression
cnf_expr = to_cnf(fol_expr)
print("FOL expression:", fol_expr)
print("CNF expression:", cnf_expr)
```

Output Snapshot

```
FOL expression: Implies(A, B | ~C)
CNF expression: B | ~A | ~C
```

Program-10 Forward Reasoning

Code

```
def fol_fc_ask(KB, query):
    """
    Implements the Forward Chaining algorithm.
    :param KB: The knowledge base, a list of first-order definite clauses.
    :param query: The query, an atomic sentence.
    :return: True if the query can be proven, otherwise False.
    """
    inferred = set()  # Keep track of inferred facts
    agenda = [fact for fact in KB if not fact.get('premises')]  # Initial
facts
    rules = [rule for rule in KB if rule.get('premises')]  # Rules with
premises

    # Debugging output: Initial agenda and inferred facts
    print(f"Initial agenda: {[fact['conclusion'] for fact in agenda]}")
    print(f"Initial inferred: {inferred}")

    while agenda:
        fact = agenda.pop(0)
        print(f"\nProcessing fact: {fact['conclusion']}")

        # Check if this fact matches the query
        if fact['conclusion'] == query:
            print(f"Found query match: {fact['conclusion']}")
            return True

        # Infer new facts if this fact hasn't been inferred before
        if fact['conclusion'] not in inferred:
            inferred.add(fact['conclusion'])
            print(f"Inferred facts: {inferred}")

            # Process rules that match this fact as a premise
            for rule in rules:
                if fact['conclusion'] in rule['premises']:
                    print(f"Rule premise satisfied: {rule['premises']} ->
```

```
{rule['conclusion']}")
                    rule['premises'].remove(fact['conclusion'])  # Remove
satisfied premise
                    if not rule['premises']:  # All premises satisfied
                        new_fact = {'conclusion': rule['conclusion']}
                        agenda.append(new_fact)  # Add new fact to agenda
                        print(f"New fact inferred: {new_fact['conclusion']}")

        # Debugging output after each iteration
        print(f"Current agenda: {[fact['conclusion'] for fact in agenda]}")
        print(f"Current inferred: {inferred}")

    # If the loop finishes without finding the query
    print(f"Query {query} not found.")
    return False


# Example Knowledge Base
KB = [
    {'premises': [], 'conclusion': 'American(Robert)'},
    {'premises': [], 'conclusion': 'Missile(T1)'},
    {'premises': [], 'conclusion': 'Owns(A, T1)'},
    {'premises': [], 'conclusion': 'Enemy(A, America)'},
    {'premises': ['Missile(T1)'], 'conclusion': 'Weapon(T1)'},
    {'premises': ['American(Robert)', 'Weapon(T1)', 'Sells(Robert, T1, A)',
'Hostile(A)'], 'conclusion': 'Criminal(Robert)'},
    {'premises': ['Owns(A, T1)', 'Enemy(A, America)'], 'conclusion':
'Hostile(A)'},
    {'premises': [], 'conclusion': 'Sells(Robert, T1, A)'}
]

# Query
query = 'Criminal(Robert)'

# Run the algorithm
result = fol_fc_ask(KB, query)
print("\nFinal Result:", result)
```

OutputSnapshot

```
Initial agenda: ['American(Robert)', 'Missile(T1)', 'Owns(A, T1)', 'Enemy(A, America)', 'Sells(Robert, T1, A)']
Initial inferred: set()

Processing fact: American(Robert)
Inferred facts: {'American(Robert)'}
Rule premise satisfied: ['American(Robert)', 'Weapon(T1)', 'Sells(Robert, T1, A)', 'Hostile(A)'] -> Criminal(Robert)
Current agenda: ['Missile(T1)', 'Owns(A, T1)', 'Enemy(A, America)', 'Sells(Robert, T1, A)']
Current inferred: {'American(Robert)'}

Processing fact: Missile(T1)
Inferred facts: {'American(Robert)', 'Missile(T1)'}
Rule premise satisfied: ['Missile(T1)'] -> Weapon(T1)
New fact inferred: Weapon(T1)
Current agenda: ['Owns(A, T1)', 'Enemy(A, America)', 'Sells(Robert, T1, A)', 'Weapon(T1)']
Current inferred: {'American(Robert)', 'Missile(T1)'}

Processing fact: Owns(A, T1)
Inferred facts: {'Owns(A, T1)', 'American(Robert)', 'Missile(T1)'}
Rule premise satisfied: ['Owns(A, T1)', 'Enemy(A, America)'] -> Hostile(A)
Current agenda: ['Enemy(A, America)', 'Sells(Robert, T1, A)', 'Weapon(T1)']
Current inferred: {'Owns(A, T1)', 'American(Robert)', 'Missile(T1)'}

Processing fact: Enemy(A, America)
Inferred facts: {'Owns(A, T1)', 'American(Robert)', 'Missile(T1)', 'Enemy(A, America)'}
Rule premise satisfied: ['Enemy(A, America)'] -> Hostile(A)
New fact inferred: Hostile(A)
Current agenda: ['Sells(Robert, T1, A)', 'Weapon(T1)', 'Hostile(A)']
Current inferred: {'Owns(A, T1)', 'American(Robert)', 'Missile(T1)', 'Enemy(A, America)'}

Processing fact: Sells(Robert, T1, A)
Inferred facts: {'American(Robert)', 'Missile(T1)', 'Owns(A, T1)', 'Sells(Robert, T1, A)', 'Enemy(A, America)'}
Rule premise satisfied: ['Weapon(T1)', 'Sells(Robert, T1, A)', 'Hostile(A)'] -> Criminal(Robert)
Current agenda: ['Weapon(T1)', 'Hostile(A)']
Current inferred: {'American(Robert)', 'Missile(T1)', 'Owns(A, T1)', 'Sells(Robert, T1, A)', 'Enemy(A, America)'}

Processing fact: Weapon(T1)
Inferred facts: {'American(Robert)', 'Missile(T1)', 'Owns(A, T1)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'Enemy(A, America)'}
Rule premise satisfied: ['Weapon(T1)', 'Hostile(A)'] -> Criminal(Robert)
Current agenda: ['Hostile(A)']
Current inferred: {'American(Robert)', 'Missile(T1)', 'Owns(A, T1)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'Enemy(A, America)'}

Processing fact: Hostile(A)
Inferred facts: {'American(Robert)', 'Missile(T1)', 'Owns(A, T1)', 'Hostile(A)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'Enemy(A, America)'}
Rule premise satisfied: ['Hostile(A)'] -> Criminal(Robert)
New fact inferred: Criminal(Robert)
Current agenda: ['Criminal(Robert)']
Current inferred: {'American(Robert)', 'Missile(T1)', 'Owns(A, T1)', 'Hostile(A)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'Enemy(A, America)'}

Processing fact: Criminal(Robert)
Found query match: Criminal(Robert)

Final Result: True
```