VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

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

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

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CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Shreya C Y(1BM22CS265),** who is bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

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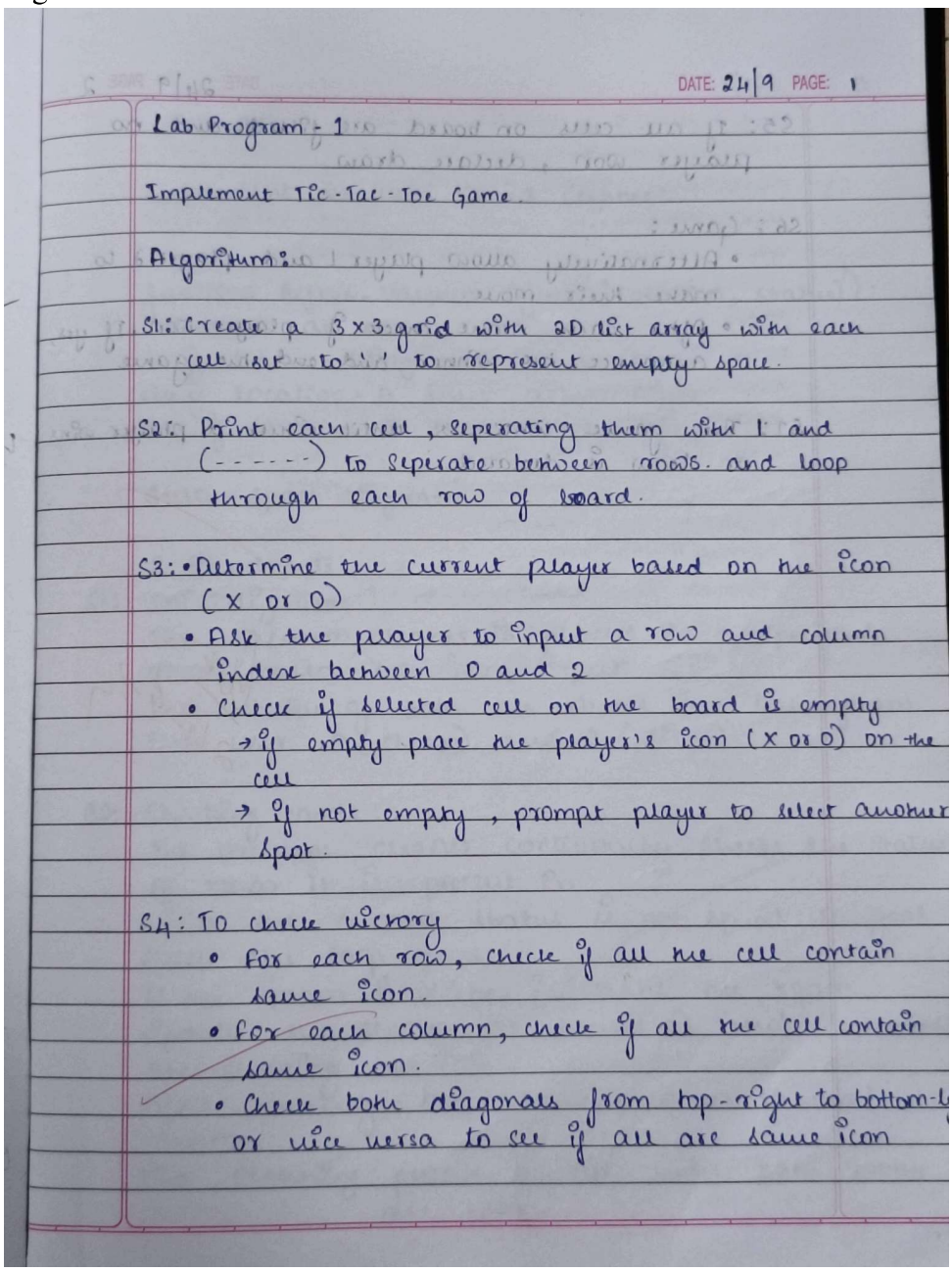
Github Link:
https://github.com/Shreyacy/AI-LAB

Program 1
Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

Algorithm:



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Lab Program - 1

Implement Tic-Tac-Toe Game.

Algorithm:

S1: Create a 3x3 grid with 2D list array with each cell set to ' ' to represent empty space.

S2: Print each cell, seperating them with | and (-----) to seperate between rows. and loop through each row of board.

S3:
- Determine the current player based on the icon (X or O)
- Ask the player to input a row and column index between 0 and 2
- Check if selected cell on the board is empty
  - → if empty place the player's icon (X or O) on the cell
  - → if not empty, prompt player to select another spot.

S4: To check victory
- For each row, check if all the cell contain same icon.
- For each column, check if all the cell contain same icon.
- Check both diagonals from top-right to bottom-l or vice versa to see if all are same icon

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S5: If all cells on board are filled and no player won, declare draw

S6: Game:
- Alternatively allow player 1 and player 2 to make their move
- After each move, check if player won. If yes, announce the winner and end the game

S7: The game continues until either a player wins or draw is declared

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Lab - 2

Implement Vacuum World Cleaner

function Reflex-Vacuum-Agent([location, status]).
returns an action
if status = Dirty then return suck
else if location = A then return Right
else if location = B then return left

State - space diagram

2 Quadrants:

S1: Initialization
The vacuum cleaner is placed in a specified room based on user input.
The status of both the rooms are taken from the user 0 (clean) and 1 (dirty).

S2: Cleaning condt:
The vacuum cleaner continously checks the status of room it is present in
While the current status is not equal to goal state the loop runs.
If the room is dirty, it cleans the room.
Update the status to clean (0) and increment the cleaning cost.
After cleaning the vacuum moves to next room.
The cleaning process repeats until both rooms are clean

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Each cleaning action costs 1 unit

S3: Once the goal state [0,0] is achieved the vacuum stops. The final state and total cleaning cost is printed.

O/P:
Enter Initial location : B
Enter status of room A : 1
Enter status of room B : 1
Location B is dirty: Cleaning Loc B
Loc B has been cleaned. Cost for such: 1
Moving to Loc A.
Loc A is dirty Cleaning Loc A
Loc A has been cleaned. Cost for such: 2
Moving to Loc B.
Goal state achieved [0,0] with total cost : 2.

Code:

```
TicTacToe
board = ["-", "-", "-",
         "-", "-", "-",
         "-", "-", "-"]

def print_board():
    print(board[0] + " | " + board[1] + " | " + board[2])
    print(board[3] + " | " + board[4] + " | " + board[5])
    print(board[6] + " | " + board[7] + " | " + board[8])

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
    while board[position] != "-":
        position = int(input("Position already taken. Choose a different position: ")) - 1
    board[position] = player
    print_board()

def check_game_over():

    if (board[0] == board[1] == board[2] != "-") or \
       (board[3] == board[4] == board[5] != "-") or \
       (board[6] == board[7] == board[8] != "-") or \
       (board[0] == board[3] == board[6] != "-") or \
       (board[1] == board[4] == board[7] != "-") or \
       (board[2] == board[5] == board[8] != "-") or \
       (board[0] == board[4] == board[8] != "-") or \
       (board[2] == board[4] == board[6] != "-"):
        return "win"

    elif "-" not in board:
        return "tie"

    else:
        return "play"

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 tie32")
            game_over = True
        else:
            current_player = "O" if current_player == "X" else "X"

play_game()
```

Output:

```
- | - | -
- | - | -
- | - | -
X's turn.
Choose a position from 1-9: 1
X | - | -
- | - | -
- | - | -
O's turn.
Choose a position from 1-9: 5
X | - | -
- | O | -
- | - | -
X's turn.
Choose a position from 1-9: 2
X | X | -
- | O | -
- | - | -
O's turn.
Choose a position from 1-9: 4
X | X | -
O | O | -
- | - | -
X's turn.
Choose a position from 1-9: 3
X | X | X
O | O | -
- | - | -
X wins!
```

Vacuum World-2Quad:

```
class VacuumCleaner:
    def __init__(self, location, status):
        self.location = location
        self.status = status
        self.goal_state = [0, 0]
        self.cost = 0

    def clean(self):
        while self.status != self.goal_state:
            if self.location == 'A':
                if self.status[0] == 1:
                    print("Location A is Dirty. Cleaning Location A.")
                    self.status[0] = 0
                    self.cost += 1
                    print(f"Location A has been Cleaned. COST for SUCK: {self.cost}")
                else:
                    print("Location A is already clean.")
                print("Moving to Location B.")
                self.location = 'B'

            elif self.location == 'B':
                if self.status[1] == 1:
                    print("Location B is Dirty. Cleaning Location B.")
                    self.status[1] = 0
                    self.cost += 1
                    print(f"Location B has been Cleaned. COST for SUCK: {self.cost}")
                else:
                    print("Location B is already clean.")
                print("Moving to Location A.")
                self.location = 'A'

        print(f"Goal state achieved: {self.status} with total cost: {self.cost}")

def get_user_input():
    location = input("Enter initial location (A or B): ").strip().upper()
    a_status = int(input("Enter status of Room A (0 for clean, 1 for dirty): "))
    b_status = int(input("Enter status of Room B (0 for clean, 1 for dirty): "))
    return location, [a_status, b_status]

def main():
    location, status = get_user_input()
    vacuum = VacuumCleaner(location, status)
    vacuum.clean()

main()
```

Output:
Output1
Enter initial location (A or B): A
Enter status of Room A (0 for clean, 1 for dirty): 1
Enter status of Room B (0 for clean, 1 for dirty): 0
Location A is Dirty. Cleaning Location A.
Location A has been Cleaned. COST for SUCK: 1
Moving to Location B.
Goal state achieved: [0, 0] with total cost: 1

Output2
Enter initial location (A or B): A
Enter status of Room A (0 for clean, 1 for dirty): 1
Enter status of Room B (0 for clean, 1 for dirty): 1
Location A is Dirty. Cleaning Location A.
Location A has been Cleaned. COST for SUCK: 1
Moving to Location B.
Location B is Dirty. Cleaning Location B.
Location B has been Cleaned. COST for SUCK: 2
Moving to Location A.
Goal state achieved: [0, 0] with total cost: 2

Vacuum World-4Quad

```
def vacuum_cleaner():

    location = input("Enter the initial location (A, B, C, or D): ").strip().upper()
    a_status = int(input("Enter the status of Room A (0 for clean, 1 for dirty): "))
    b_status = int(input("Enter the status of Room B (0 for clean, 1 for dirty): "))
    c_status = int(input("Enter the status of Room C (0 for clean, 1 for dirty): "))
    d_status = int(input("Enter the status of Room D (0 for clean, 1 for dirty): "))

    status = {'A': a_status, 'B': b_status, 'C': c_status, 'D': d_status}
    goal_state = {'A': 0, 'B': 0, 'C': 0, 'D': 0}
    cost = 0
    cleaning_limit = int(input("Enter the cleaning limit (number of rooms it can clean before
recharging): "))
    cleaned_rooms = 0

    while status != goal_state:
        if cleaned_rooms >= cleaning_limit:
            print("Cleaning limit reached. The vacuum needs to recharge.")

            cleaned_rooms = 0
            print("The vacuum is recharging...")
```

```
            continue

        if status[location] == 1:
            print(f"Location {location} is Dirty. Cleaning Location {location}.")
            status[location] = 0
            cost += 1
            cleaned_rooms += 1
            print(f"Location {location} has been Cleaned. COST for SUCK: {cost}.")
        else:
            print(f"Location {location} is already clean.")


        if location == 'A':
            location = 'B'
        elif location == 'B':
            location = 'C'
        elif location == 'C':
            location = 'D'
        elif location == 'D':
            location = 'A'

        print(f"Moving to Location {location}.")


        if status == goal_state:
            print(f"Goal state achieved: {status} with total cost: {cost}.")
            break

    print("Final Status of Rooms: {'A': 0, 'B': 0, 'C': 0, 'D': 0}  0")


vacuum_cleaner()
```

Output:

Output1
Enter initial location (A or B): A
Enter status of Room A (0 for clean, 1 for dirty): 1
Enter status of Room B (0 for clean, 1 for dirty): 0
Location A is Dirty. Cleaning Location A.
Location A has been Cleaned. COST for SUCK: 1
Moving to Location B.
Goal state achieved: [0, 0] with total cost: 1

Output2
Enter initial location (A or B): A

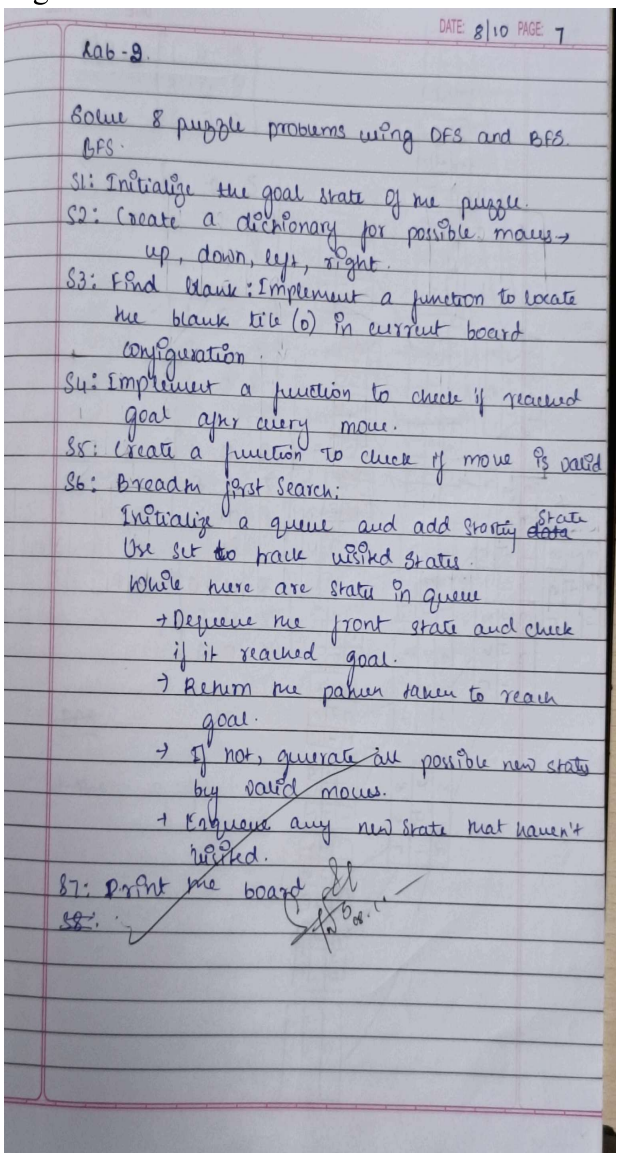
Enter status of Room A (0 for clean, 1 for dirty): 1
Enter status of Room B (0 for clean, 1 for dirty): 1
Location A is Dirty. Cleaning Location A.
Location A has been Cleaned. COST for SUCK: 1
Moving to Location B.
Location B is Dirty. Cleaning Location B.
Location B has been Cleaned. COST for SUCK: 2
Moving to Location A.
Goal state achieved: [0, 0] with total cost: 2

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)

Implement Iterative deepening search algorithm

Algorithm:



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Lab-2.

Solve 8 puzzle problems using DFS and BFS.

BFS:

S1: Initialize the goal state of the puzzle.

S2: Create a dictionary for possible moves → up, down, left, right.

S3: Find blank: Implement a function to locate the blank tile (0) in current board configuration.

S4: Implement a function to check if reached goal after every move.

S5: Create a function to check if move is valid

S6: Breadth first Search:

Initialize a queue and add starting ~~state~~ state

Use set to track visited states.

While there are states in queue

→ Dequeue the front state and check if it reached goal.

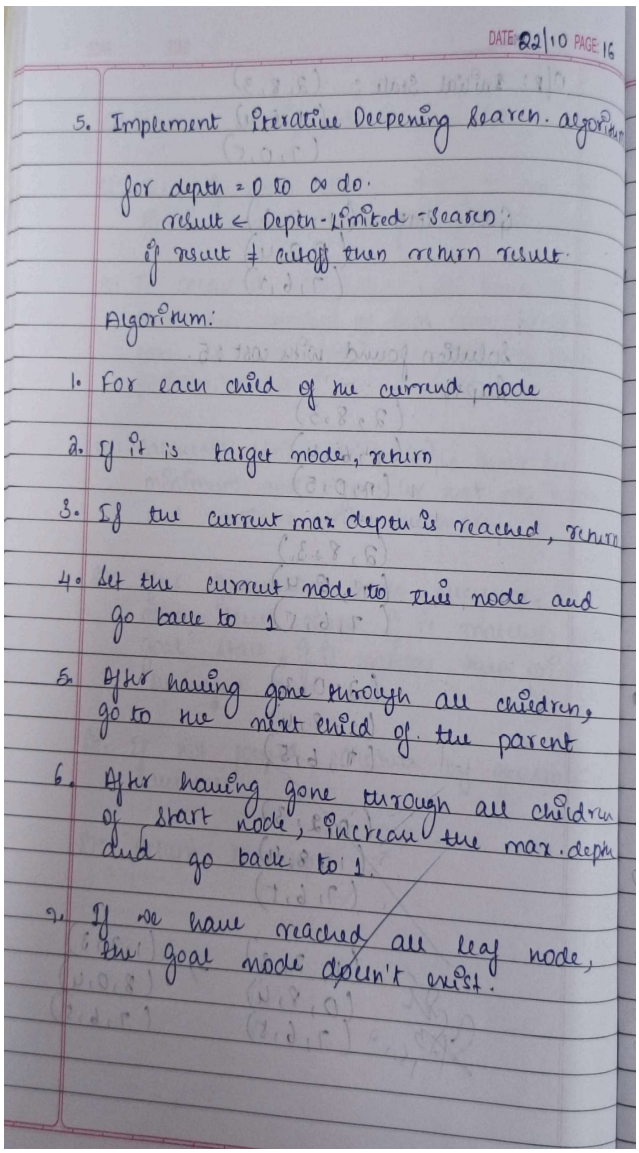
→ Return the path taken to reach goal.

→ If not, generate all possible new states by valid moves.

→ Enqueue any new state that haven't visited.

S7: Print the board

S8:



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5. Implement Iterative Deepening Search algorithm

for depth = 0 to ∞ do:

result ← Depth-Limited-Search

if result ≠ cutoff then return result

Algorithm:

1. For each child of the current node
2. If it is target node, return
3. If the current max depth is reached, return
4. Set the current node to this node and go back to 1
5. After having gone through all children, go to the next child of the parent
6. After having gone through all children of start node, increase the max. depth and go back to 1.
7. If we have reached all leaf node, the goal node doesn't exist.

Code:

DFS:

```
from copy import deepcopy

goal_state = [[0, 1, 2],
              [3, 4, 5],
              [6, 7, 8]]
moves = {
    'up': (-1, 0),
    'down': (1, 0),
    'left': (0, -1),
    'right': (0, 1)
}

def find_blank(board):
    for i in range(3):
        for j in range(3):
            if board[i][j] == 0:
                return i, j
    return None

def is_goal(state):
    return state == goal_state

def is_valid_move(x, y):
    return 0 <= x < 3 and 0 <= y < 3

def apply_move(board, move):
    x, y = find_blank(board)
    dx, dy = moves[move]
    new_x, new_y = x + dx, y + dy
    if is_valid_move(new_x, new_y):
        new_board = deepcopy(board)
        new_board[x][y], new_board[new_x][new_y] = new_board[new_x][new_y], new_board[x][y]
        return new_board
    return None

def dfs(start):
    stack = [(start, [], 0)]  # (state, path of moves, number of states explored)
    visited = set()
    explored_count = 0  # Count of unique states explored

    while stack:
        current_state, path, current_count = stack.pop()

        if is_goal(current_state):
```

```
            return path, explored_count  # Return path of moves and explored count

        # Create a unique representation of the state to store in visited
        state_tuple = tuple(tuple(row) for row in current_state)
        if state_tuple not in visited:
            visited.add(state_tuple)  # Add to visited states
            explored_count += 1
            for move in moves:
                new_state = apply_move(current_state, move)
                if new_state:  # Only consider valid new states
                    stack.append((new_state, path + [move], explored_count))  # Store the path and current
count

    return None, explored_count  # Return explored count if no solution is found

def print_board(board):
    for row in board:
        print(row)
    print()

def print_solution(solution, explored_count):
    if solution is not None:
        print(f"Goal achieved with the following moves:")
        current_board = initial_state
        for move in solution:
            print(f"Move: {move}")
            current_board = apply_move(current_board, move)
            print_board(current_board)
        print(f"Total number of  states explored: {explored_count}")
    else:
        print("No solution found")

initial_state = [[1, 2, 5],
                 [3, 4, 8],
                 [6, 7, 0]]
solution, explored_count = dfs(initial_state)
print_solution(solution, explored_count)
```

Iterative deepening Search:

```
from copy import deepcopy
DIRECTIONS = [(-1, 0), (1, 0), (0, -1), (0, 1)]

class PuzzleState:
    def __init__(self, board, parent=None, move=""):
        self.board = board
        self.parent = parent
```

```
        self.move = move

    def get_blank_position(self):
        for i in range(3):
            for j in range(3):
                if self.board[i][j] == 0:
                    return i, j

    def generate_successors(self):
        successors = []
        x, y = self.get_blank_position()

        for dx, dy in DIRECTIONS:
            new_x, new_y = x + dx, y + dy

            if 0 <= new_x < 3 and 0 <= new_y < 3:
                new_board = deepcopy(self.board)
                new_board[x][y], new_board[new_x][new_y] = new_board[new_x][new_y],
new_board[x][y]
                successors.append(PuzzleState(new_board, parent=self))

        return successors

    def is_goal(self, goal_state):
        return self.board == goal_state

    def __str__(self):
        return "\n".join([" ".join(map(str, row)) for row in self.board])

def depth_limited_search(current_state, goal_state, depth):
    if depth == 0 and current_state.is_goal(goal_state):
        return current_state

    if depth > 0:
        for successor in current_state.generate_successors():
            found = depth_limited_search(successor, goal_state, depth - 1)
            if found:
                return found
    return None

def iterative_deepening_search(start_state, goal_state):
    depth = 0
    while True:
        print(f"\nSearching at depth level: {depth}")
        result = depth_limited_search(start_state, goal_state, depth)
        if result:
            return result
```

```
        depth += 1

def get_user_input():
    print("Enter the start state (use 0 for the blank):")
    start_state = []
    for _ in range(3):
        row = list(map(int, input().split()))
        start_state.append(row)

    print("Enter the goal state (use 0 for the blank):")
    goal_state = []
    for _ in range(3):
        row = list(map(int, input().split()))
        goal_state.append(row)

    return start_state, goal_state

def main():
    start_board, goal_board = get_user_input()
    start_state = PuzzleState(start_board)
    goal_state = goal_board

    result = iterative_deepening_search(start_state, goal_state)


    if result:
        print("\nGoal reached!")
        path = []
        while result:
            path.append(result)
            result = result.parent
        path.reverse()
        for state in path:
            print(state, "\n")
    else:
        print("Goal state not found.")

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

Output:

```
Goal achieved with the following moves:
Move: left
[1, 2, 5]
```

[3, 4, 8]
[6, 0, 7]

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

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

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

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

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

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

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

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

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

Move: right
[1, 2, 5]
[8, 7, 0]
[4, 3, 6]
Move: up
[1, 2, 5]
[0, 6, 3]
[7, 8, 4]

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

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

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

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

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

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

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

Move: right
[1, 2, 5]

[3, 4, 0]
[6, 7, 8]

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

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

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

Total number of unique states explored: 32

Code:
Iterative Deepening Search

```
from copy import deepcopy
DIRECTIONS = [(-1, 0), (1, 0), (0, -1), (0, 1)]

class PuzzleState:
    def __init__(self, board, parent=None, move=""):
        self.board = board
        self.parent = parent
        self.move = move

    def get_blank_position(self):
        for i in range(3):
            for j in range(3):
                if self.board[i][j] == 0:
                    return i, j

    def generate_successors(self):
        successors = []
        x, y = self.get_blank_position()
```

```
        for dx, dy in DIRECTIONS:
            new_x, new_y = x + dx, y + dy

            if 0 <= new_x < 3 and 0 <= new_y < 3:
                new_board = deepcopy(self.board)
                new_board[x][y], new_board[new_x][new_y] = new_board[new_x][new_y],
new_board[x][y]
                successors.append(PuzzleState(new_board, parent=self))

        return successors

    def is_goal(self, goal_state):
        return self.board == goal_state

    def __str__(self):
        return "\n".join([" ".join(map(str, row)) for row in self.board])

def depth_limited_search(current_state, goal_state, depth):
    if depth == 0 and current_state.is_goal(goal_state):
        return current_state

    if depth > 0:
        for successor in current_state.generate_successors():
            found = depth_limited_search(successor, goal_state, depth - 1)
            if found:
                return found
    return None

def iterative_deepening_search(start_state, goal_state):
    depth = 0
    while True:
        print(f"\nSearching at depth level: {depth}")
        result = depth_limited_search(start_state, goal_state, depth)
        if result:
            return result
        depth += 1

def get_user_input():
    print("Enter the start state (use 0 for the blank):")
    start_state = []
    for _ in range(3):
        row = list(map(int, input().split()))
        start_state.append(row)

    print("Enter the goal state (use 0 for the blank):")
    goal_state = []
```

```
    for _ in range(3):
        row = list(map(int, input().split()))
        goal_state.append(row)

    return start_state, goal_state

def main():
    start_board, goal_board = get_user_input()
    start_state = PuzzleState(start_board)
    goal_state = goal_board

    result = iterative_deepening_search(start_state, goal_state)


    if result:
        print("\nGoal reached!")
        path = []
        while result:
            path.append(result)
            result = result.parent
        path.reverse()
        for state in path:
            print(state, "\n")
    else:
        print("Goal state not found.")

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

Output:

```
Enter the start state (use 0 for the blank):
1 2 3
4 0 5
6 7 8
Enter the goal state (use 0 for the blank):
1 2 0
3 4 5
6 7 8

Searching at depth level: 0

Searching at depth level: 1

Searching at depth level: 2
```

Searching at depth level: 3

Searching at depth level: 4

Searching at depth level: 5

Searching at depth level: 6

Searching at depth level: 7

Searching at depth level: 8

Searching at depth level: 9

Searching at depth level: 10

Searching at depth level: 11

Searching at depth level: 12

Goal reached!
1 2 3
4 0 5
6 7 8

1 2 3
0 4 5
6 7 8

0 2 3
1 4 5
6 7 8

2 0 3
1 4 5
6 7 8

2 3 0
1 4 5
6 7 8

2 3 5
1 4 0
6 7 8

2 3 5
1 0 4

6 7 8

2 0 5
1 3 4
6 7 8

0 2 5
1 3 4
6 7 8

1 2 5
0 3 4
6 7 8

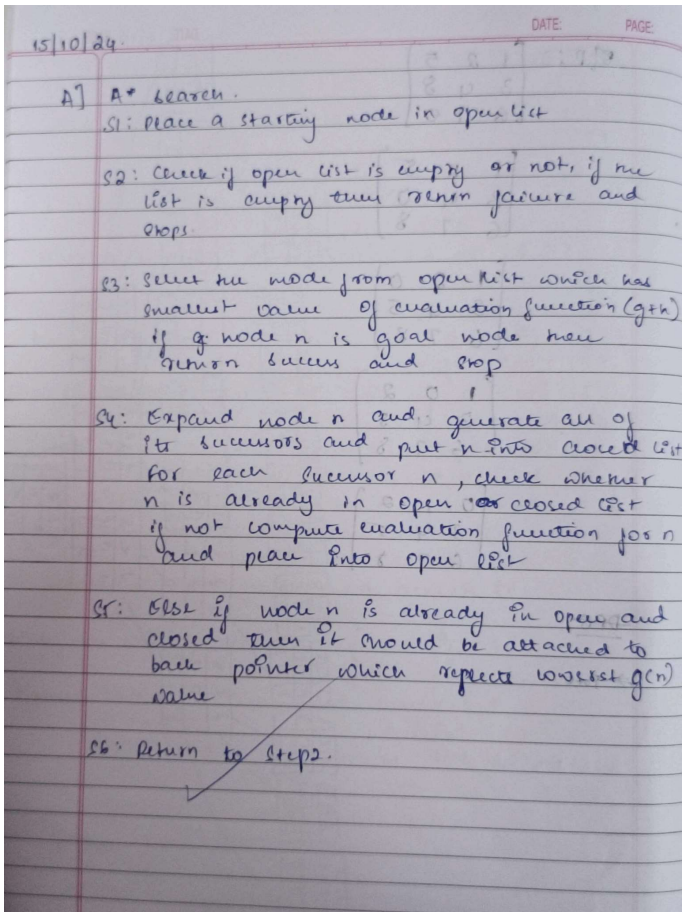
1 2 5
3 0 4
6 7 8

1 2 5
3 4 0
6 7 8

1 2 0
3 4 5
6 7 8

Program 3
Implement A* Algorithm

Algorithm


15/10/24

A] A* search.

S1: Place a starting node in open list

S2: Check if open list is empty or not, if the list is empty then return failure and stops.

S3: Select the node from open list which has smallest value of evaluation function (g+h) if g node n is goal node then return success and stop

S4: Expand node n and generate all of its successors and put n into closed list for each successor n, check whether n is already in open or closed list if not compute evaluation function for n and place into open list

S5: Else if node n is already in open and closed then it should be attached to back pointer which reflects lowest g(n) value

S6: Return to Step2.

Code:

```
import heapq
GOAL_STATE = ((1, 2, 3),
              (8, 0, 4),
              (7, 6, 5))
def misplaced_tile(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):
    open_list = []
    heapq.heappush(open_list, (0 + misplaced_tile(start), 0, start))

    g_score = {start: 0}
    came_from = {}

    visited = set()

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

        if current == GOAL_STATE:
            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)  # 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()


if __name__ == "__main__":
    start_state = ((2, 8, 3),
                   (1, 6, 4),
                   (7, 0, 5))

    print("Initial State:")
    print_state(start_state)

    print("Goal State:")
    print_state(GOAL_STATE)

    solution, cost = a_star(start_state)
            if solution:
        print(f"Solution found with cost: {cost}")
        print("Steps:")
        for step in solution:
            print_state(step)
    else:
        print("No solution found.")
```

Output:

```
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)

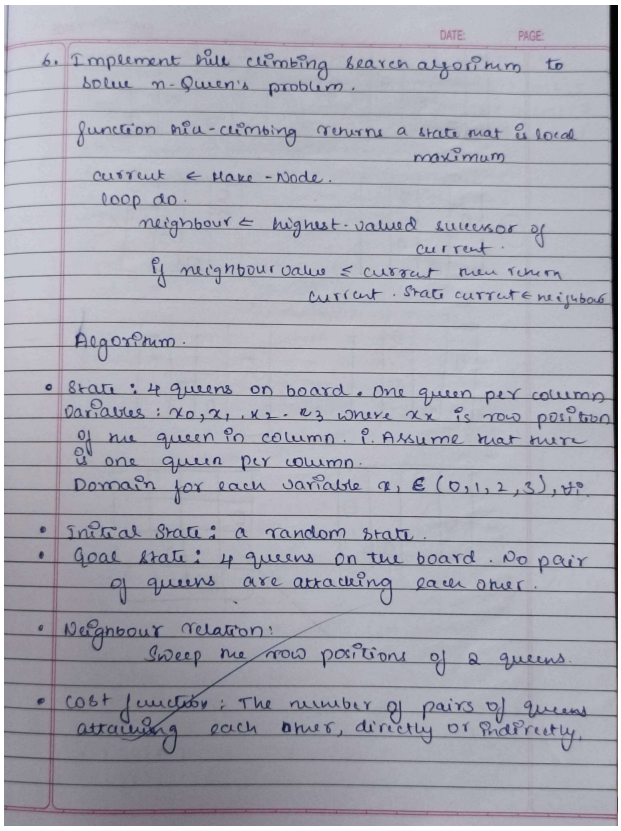
(1, 2, 3)
(0, 8, 4)
(7, 6, 5)

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

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:



6. Implement hill climbing search algorithm to solve n-Queen's problem.

function hill-climbing returns a state that is local maximum

current ← Make-Node.

loop do.

neighbour ← highest-valued successor of current.

if neighbour value ≤ current then return current. State current ← neighbour

Algorithm.

- State : 4 queens on board. One queen per column. Variables : x_0, x_1, x_2, x_3 where x_x is row position of the queen in column. i. Assume that there is one queen per column.
  Domain for each variable $x_i \in (0,1,2,3)$, ∀i.
- Initial State : a random state.
- Goal State : 4 queens on the board. No pair of queens are attacking each other.
- Neighbour relation:
  Sweep the row positions of 2 queens.
- Cost function : The number of pairs of queens attacking each other, directly or indirectly.

Code:

```
import random

def get_attacking_pairs(state):
    """Calculates the number of attacking pairs of queens."""
    attacks = 0
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            if state[i] == state[j]:
                attacks += 1
            if abs(state[i] - state[j]) == abs(i - j):
                attacks += 1
    return attacks

def generate_successors(state):
    """Generates all possible successors by moving each queen to every other column in its row."""
```

```
    n = len(state)
    successors = []
    for row in range(n):
        for col in range(n):
            if col != state[row]:
                new_state = state[:]
                new_state[row] = col
                successors.append(new_state)
    return successors

def hill_climbing(n):
    """Hill climbing algorithm for n-queens problem."""
    current = [random.randint(0, n - 1) for _ in range(n)]
    while True:
        current_attacks = get_attacking_pairs(current)
        successors = generate_successors(current)
        neighbor = min(successors, key=get_attacking_pairs)
        neighbor_attacks = get_attacking_pairs(neighbor)
        if neighbor_attacks >= current_attacks:
            return current, current_attacks
        current = neighbor

def print_board(state):
    """Prints the board with queens placed."""
    n = len(state)
    board = [["." for _ in range(n)] for _ in range(n)]
    for row in range(n):
        board[row][state[row]] = "Q"
    for row in board:
        print(" ".join(row))
    print("\n")

n = 4
solution, attacks = hill_climbing(n)
print("Final State (Solution):", solution)
print("Number of Attacking Pairs:", attacks)
print_board(solution)
```

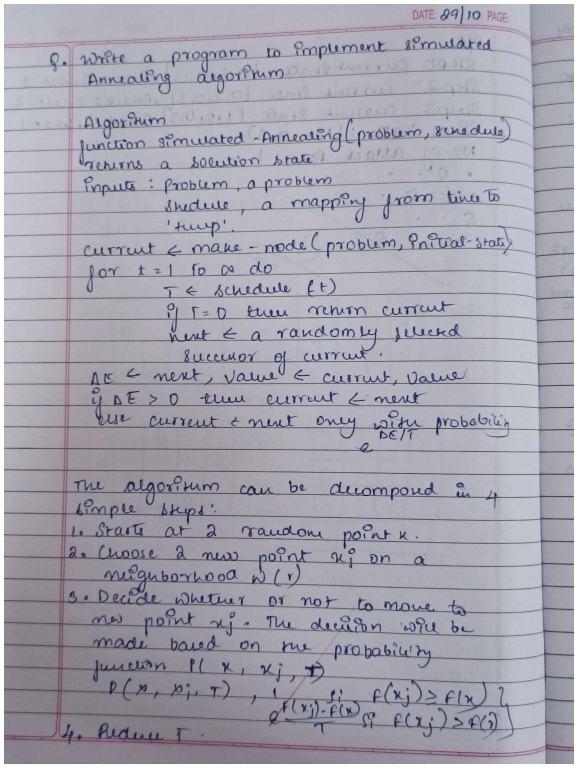
Output:

```
Final State (Solution): [3, 0, 2, 1]
Number of Attacking Pairs: 1
. . . Q
Q . . .
. . Q .
. Q
```

Program 5

Simulated Annealing to Solve 8-Queens problem

Algorithm:



Code:

```
!pip install joblib==1.2.0
import mlrose_hiive as mlrose
import numpy as np

# Define the objective function
def queens_max(position):
    no_attack_on_j = 0
    queen_not_attacking = 0
    for i in range(len(position) - 1):
        no_attack_on_j = i
        for j in range(i + 1, len(position)):
            if (position[j] != position[i] and
                position[j] != position[i] + (j - i) and
                position[j] != position[i] - (j - i)):
                no_attack_on_j += 1
            if (no_attack_on_j == len(position) - i - 1):
                queen_not_attacking += 1
    if(queen_not_attacking == 7):
        queen_not_attacking += 1
    return queen_not_attacking
```

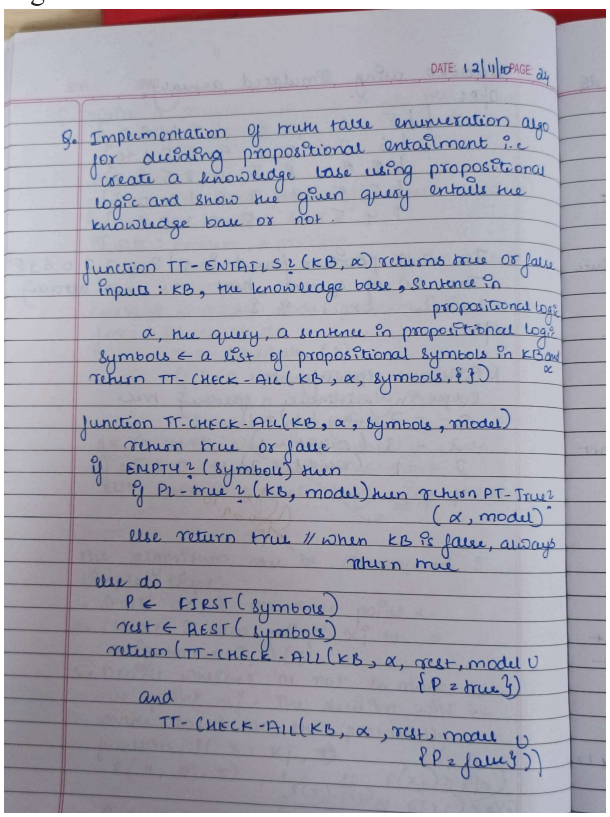
```
# Define the fitness function
objective = mlrose.CustomFitness(queens_max)

# Define the optimization problem
problem = mlrose.DiscreteOpt(length=8, fitness_fn=objective, maximize=True, max_val=8)

# Define the annealing schedule and other parameters
T = mlrose.ExpDecay()
initial_position = np.array([4, 6, 1, 5, 2, 0, 3, 7])

# Run simulated annealing, assigning the extra return value to _
best_position, best_objective, _ = mlrose.simulated_annealing(problem=problem,
schedule=T,max_attempts=500, max_iters=1000, init_state=initial_position)

# Print the results
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: [0 7 5 1 6 1 1 5]
The number of queens that are not attacking each other is: 9.0
In [32]:

Program 6

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

Algorithm



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(alpha_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}")
```

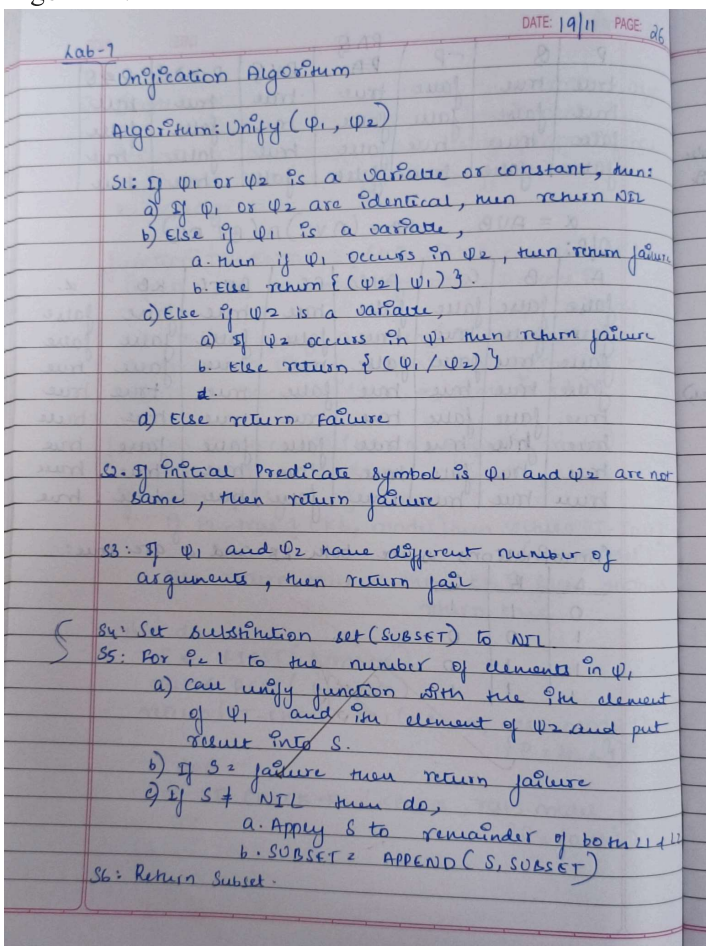
Output:

```
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:



Lab-7

Unification Algorithm

Algorithm: Unify (ψ_1, ψ_2)

S1: If ψ_1 or ψ_2 is a variable or constant, then:
a) If ψ_1 or ψ_2 are identical, then return NIL
b) Else if ψ_1 is a variable,
a. then if ψ_1 occurs in ψ_2, then return failure
b. Else return {(ψ_2/ψ_1)}.
c) Else if ψ_2 is a variable,
a) If ψ_2 occurs in ψ_1 then return failure
b. Else return {(ψ_1/ψ_2)}
d.
a) Else return Failure

S2. If Initial Predicate Symbol is ψ_1 and ψ_2 are not same, then return failure

S3: If ψ_1 and ψ_2 have different number of arguments, then return fail

S4: Set substitution set (SUBSET) to NIL
S5: For i = 1 to the number of elements in ψ_1
a) Call unify function with the ith element of ψ_1 and ith element of ψ_2 and put result into S.
b) If S = failure then return failure
c) If S ≠ NIL then do,
a. Apply S to remainder of both L1 and L2
b. SUBSET = APPEND (S, SUBSET)
S6: Return Subset.

Code:

```
def unify(term1, term2):
    """
    Unifies two terms using the unification algorithm.

    Args:
        term1: The first term.
        term2: The second term.

    Returns:
        A substitution set if the terms are unifiable,
        otherwise None.
    """

    # Step 1: Handle variables and constants
    if isinstance(term1, str) or isinstance(term2, str):
```

```
        if term1 == term2:
            return {}  # NIL
        elif term1.isupper():  # term1 is a variable
            if term1 in term2:
                return None  # FAILURE
            return {term1: term2}
        elif term2.isupper():  # term2 is a variable
            if term2 in term1:
                return None  # FAILURE
            return {term2: term1}
        else:
            return None  # FAILURE

    # Step 2: Check predicate symbols
    if term1[0] != term2[0]:
        return None  # FAILURE

    # Step 3: Check number of arguments
    if len(term1[1:]) != len(term2[1:]):
        return None  # FAILURE

    # Step 4: Initialize substitution set
    substitution_set = {}

    # Step 5: Recursively unify arguments
    for i in range(len(term1[1:])):
        result = unify(term1[1:][i], term2[1:][i])
        if result is None:
            return None  # FAILURE
        else:
            substitution_set = apply_substitution(substitution_set, result)

    # Step 6: Return substitution set
    return substitution_set

def apply_substitution(substitution_set, new_substitution):
    """
    Applies a new substitution to the existing substitution set.

    Args:
        substitution_set: The current substitution set.
        new_substitution: The new substitution to be applied.

    Returns:
        The updated substitution set.
    """
```

```
    for var, value in new_substitution.items():
        # Apply the new substitution to the existing values
        for key, val in substitution_set.items():
            # Replace variables in the existing substitution set
            if key == var:
                substitution_set[key] = value
            elif isinstance(val, str) and val == var:
                substitution_set[key] = value

        # Add the new substitution to the set
        substitution_set[var] = value

    return substitution_set

def parse_term(term_str):
    """
    Parses a term string into a structured format.

    Args:
        term_str: The string representation of the term.

    Returns:
        A structured term (list).
    """
    term_str = term_str.strip()
    if '(' not in term_str:
        return term_str  # Return variable or constant

    # Split the term into the function and its arguments
    func_name, args_str = term_str.split('(', 1)
    args_str = args_str.rstrip(')')  # Remove the closing parenthesis

    # Split arguments by commas, accounting for nested terms
    args = []
    bracket_count = 0
    current_arg = []

    for char in args_str:
        if char == ',' and bracket_count == 0:
            args.append(''.join(current_arg).strip())
            current_arg = []
        else:
            if char == '(':
                bracket_count += 1
            elif char == ')':
                bracket_count -= 1
            current_arg.append(char)
```

```
    if current_arg:
        args.append(''.join(current_arg).strip())

    return [func_name] + [parse_term(arg) for arg in args]

def apply_substitution_to_term(term, substitution_set):
    """
    Applies a substitution set to a term.

    Args:
        term: The term to which the substitution is applied.
        substitution_set: The substitution set.

    Returns:
        The term after applying substitutions.
    """
    if isinstance(term, str):
        return substitution_set.get(term, term)  # Return the substituted value or the term itself

    # Apply substitution recursively to the term's components
    return [term[0]] + [apply_substitution_to_term(arg, substitution_set) for arg in term[1:]]

def main():
    # Take input from the user for the expressions
    term1_str = input("Enter the first term : ")
    term2_str = input("Enter the second term: ")

    # Parse the input terms
    term1 = parse_term(term1_str)
    term2 = parse_term(term2_str)

    # Perform unification
    substitution_set = unify(term1, term2)

    if substitution_set is not None:
        # Apply the substitution to the original terms
        unified_term1 = apply_substitution_to_term(term1, substitution_set)
        unified_term2 = apply_substitution_to_term(term2, substitution_set)

        # Print the final unified expressions
        print("Unified Term 1:", unified_term1)
        print("Unified Term 2:", unified_term2)
    else:
        print("The terms are not unifiable.")

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

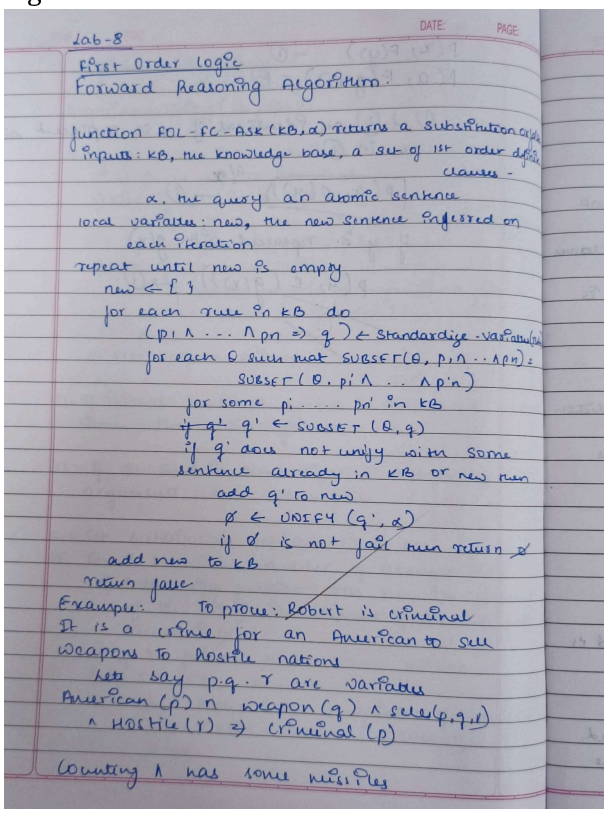
Output:
Enter the first term : f(X,f(Y))
Enter the second term: f(a,f(g(X))
Unified Term 1: ['f', 'a', ['f', ['g', 'X']]]
Unified Term 2: ['f', 'a', ['f', ['g', 'a']]]

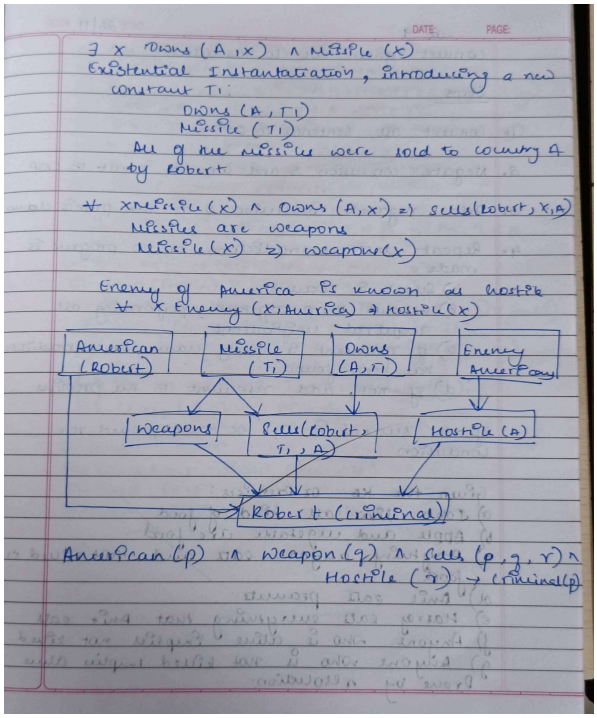
Enter the first term : f(f(a,g(Y))
Enter the second term: f(X,X)
The terms are not unifiable.

Program 8:

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

Algorithm:





Code:

```
# Define the knowledge base as a list of rules and facts

class KnowledgeBase:
    def __init__(self):
        self.facts = set()   # Set of known facts
        self.rules = []      # List of rules

    def add_fact(self, fact):
        self.facts.add(fact)

    def add_rule(self, rule):
        self.rules.append(rule)

    def infer(self):
        inferred = True
        while inferred:
            inferred = False
            for rule in self.rules:
                if rule.apply(self.facts):
                    inferred = True

# Define the Rule class
class Rule:
    def __init__(self, premises, conclusion):
        self.premises = premises  # List of conditions
        self.conclusion = conclusion  # Conclusion to add if premises are met

    def apply(self, facts):
        if all(premise in facts for premise in self.premises):
            if self.conclusion not in facts:
                facts.add(self.conclusion)
                print(f"Inferred: {self.conclusion}")
                return True
        return False

# Initialize the knowledge base
kb = KnowledgeBase()

# Facts in the problem
kb.add_fact("American(Robert)")
kb.add_fact("Missile(T1)")
kb.add_fact("Owns(A, T1)")
kb.add_fact("Enemy(A, America)")

# Rules based on the problem
```

```
# 1. Missile(x) implies Weapon(x)
kb.add_rule(Rule(["Missile(T1)"], "Weapon(T1)"))

# 2. Enemy(x, America) implies Hostile(x)
kb.add_rule(Rule(["Enemy(A, America)"], "Hostile(A)"))

# 3. Missile(x) and Owns(A, x) imply Sells(Robert, x, A)
kb.add_rule(Rule(["Missile(T1)", "Owns(A, T1)"], "Sells(Robert, T1, A)"))

# 4. American(p) and Weapon(q) and Sells(p, q, r) and Hostile(r) imply Criminal(p)
kb.add_rule(Rule(["American(Robert)", "Weapon(T1)", "Sells(Robert, T1, A)", "Hostile(A)"],
"Criminal(Robert)"))

# Infer new facts based on the rules
kb.infer()

# Check if Robert is a criminal
if "Criminal(Robert)" in kb.facts:
    print("Conclusion: Robert is a criminal.")
else:
    print("Conclusion: Unable to prove Robert is a criminal.")
```

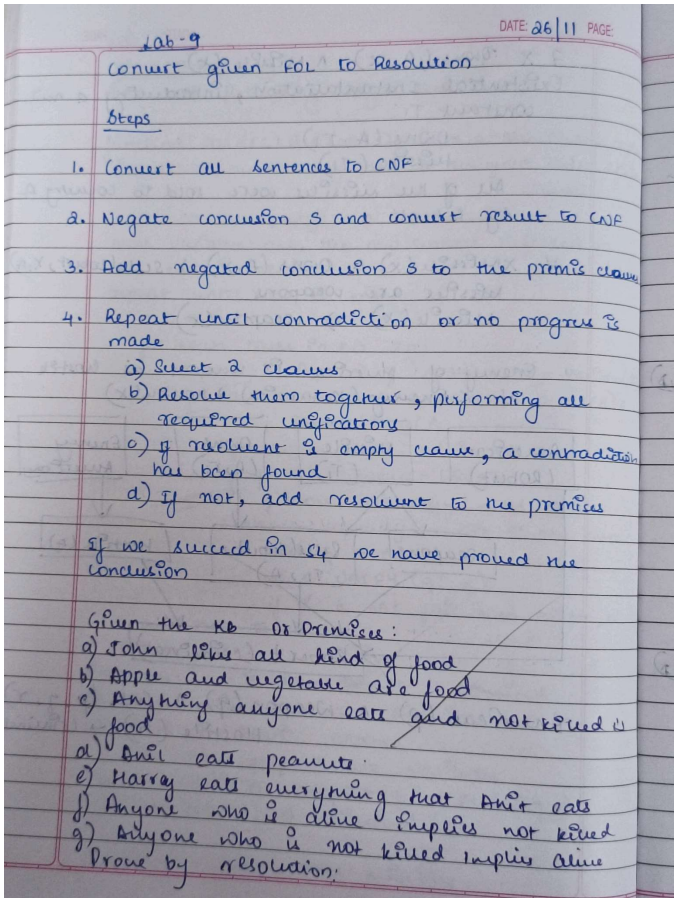
Output:

```
Inferred: Weapon(T1)
Inferred: Hostile(A)
Inferred: Sells(Robert, T1, A)
Inferred: Criminal(Robert)
Conclusion: Robert is a criminal.
```

Program 9:

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

Algorithm:



Lab-9

DATE: 26/11 PAGE:

Convert given FOL to Resolution

Steps

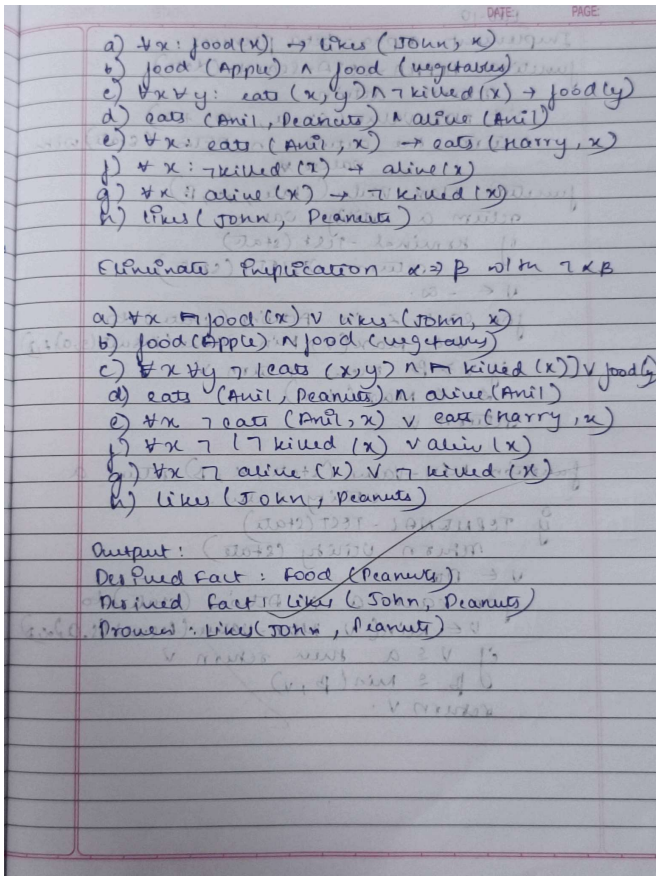
1. Convert all sentences to CNF
2. Negate conclusion S and convert result to CNF
3. Add negated conclusion S to the premis clause
4. Repeat until contradiction or no progress is made
   a) Select 2 clauses
   b) Resolve them together, performing all required unifications
   c) If resolvent is empty clause,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

If we succeed in S4 we have proved the conclusion

Given the KB or Premises:

a) John like all kind of food
b) Apple and vegetable are food
c) Anything anyone eats and not killed is food
d) Anil eats peanuts
e) Harry eats everything that Anil eats
f) Anyone who is alive implies not killed
g) Anyone who is not killed implies alive

Prove by resolution.



Code:

```
class CNFReasoner:
    def __init__(self, clauses):
        """
        Initializes the CNF Reasoner.

        Parameters:
            clauses (list of sets): List of clauses in CNF format.
        """
        self.clauses = [set(clause) for clause in clauses]

    def resolve(self, clause1, clause2):
        """
        Resolve two clauses to produce new clauses if possible.

        Parameters:
            clause1 (set): The first clause (set of literals).
            clause2 (set): The second clause (set of literals).

        Returns:
            list: A list of resolved clauses (sets of literals).
        """
```

```
        resolvents = []
        for literal in clause1:
            neg_literal = f"~{literal}" if not literal.startswith("~") else literal[1:]
            if neg_literal in clause2:
                # Create a new clause by removing complementary literals
                new_clause = (clause1 - {literal}) | (clause2 - {neg_literal})
                resolvents.append(new_clause)
        return resolvents

    def infer(self, goal):
        """
        Infer whether the goal is provable using resolution.

        Parameters:
            goal (set): The negation of the goal to be proved.

        Returns:
            bool: True if the goal is provable, False otherwise.
        """
        goal_clause = {f"~{literal}" for literal in goal}
        clauses = self.clauses + [goal_clause]  # Add the negated goal to clauses
        new = set()

        while True:
            pairs = [(clauses[i], clauses[j]) for i in range(len(clauses)) for j in range(i + 1, len(clauses))]
            for (clause1, clause2) in pairs:
                resolvents = self.resolve(clause1, clause2)
                for resolvent in resolvents:
                    if not resolvent:  # Found an empty clause, goal is proved
                        return True
                    new.add(frozenset(resolvent))

            # Check if no new information is being added
            if new.issubset(set(map(frozenset, clauses))):
                return False

            # Add new resolvents to the clauses
            for clause in new:
                if clause not in clauses:
                    clauses.append(set(clause))


# Define the CNF clauses based on the FOL premises
cnf_clauses = [
    {"~Food(X)", "Likes(John, X)"},  # Rule 1: If Food(X), then Likes(John, X)
    {"~Eats(Anil, Peanuts)", "Food(Peanuts)"},  # Rule 2.1: If Anil eats peanuts, peanuts are food
    {"~Alive(Anil)", "Food(Peanuts)"},  # Rule 2.2: If Anil is alive, peanuts are food
```

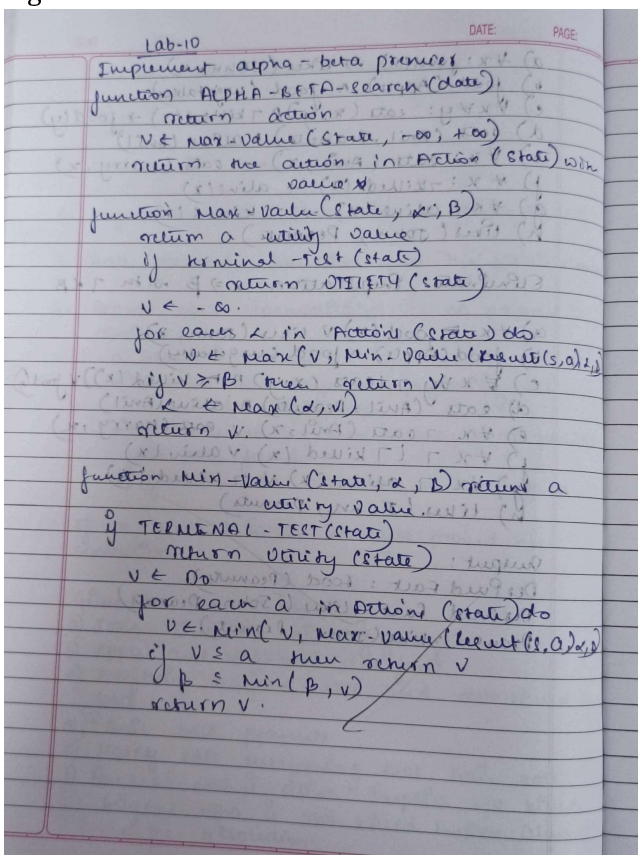
```
    {"~Food(Peanuts)", "Likes(John, Peanuts)"},  # Rule 3: If peanuts are food, John likes peanuts
    {"Eats(Anil, Peanuts)"},  # Fact 1: Anil eats peanuts
    {"Alive(Anil)"},  # Fact 2: Anil is alive
]

# Define the goal: Prove that John likes peanuts
goal = {"Likes(John, Peanuts)"}

# Initialize the reasoner and infer
reasoner = CNFReasoner(cnf_clauses)
if reasoner.infer(goal):
    print("Proved: John likes peanuts.")
else:
    print("Could not prove: John likes peanuts.")
```

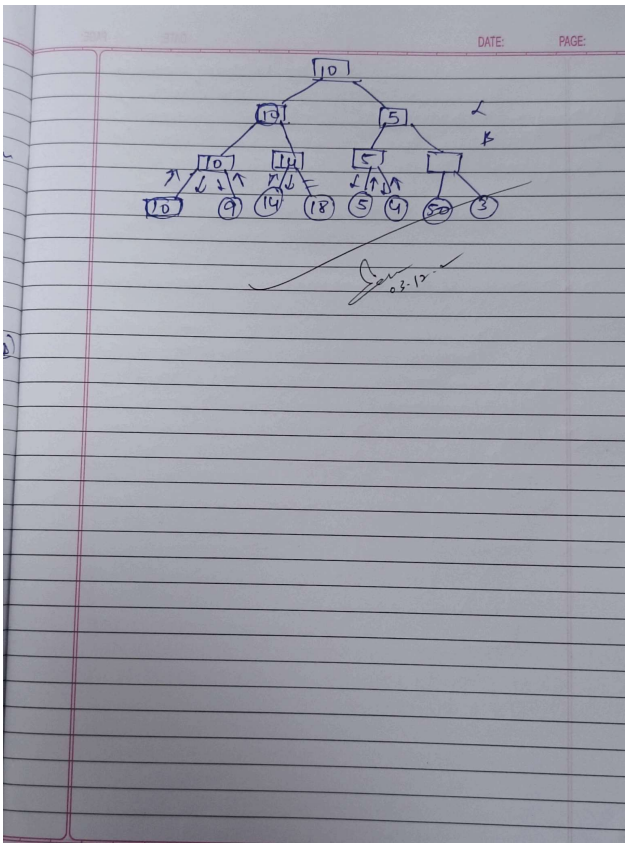
Output:
Proved: John likes peanuts.

Program 10:

Implement Alpha-Beta Pruning.

Algorithm:





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
```