VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

Srinidhi B V(1BM23CS339)

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

B.M.S. COLLEGE OF ENGINEERING
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B.M.S. College of Engineering,
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Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Srinidhi B V(1BM23CS339),** 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/srinidhibv1403/1BM23CS339-AI

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Program 1

Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

Algorithm:

Implement Tic –Tac –Toe Game

Implement vacuum cleaner agent

Code:

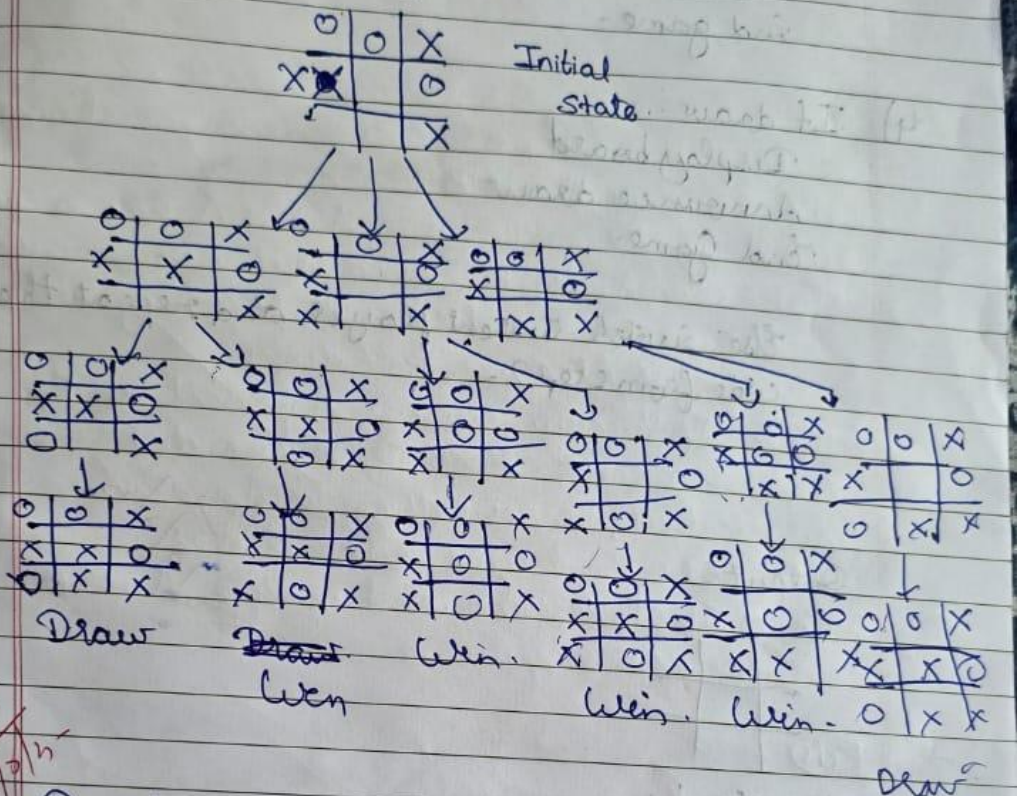
```
# Tic-Tac-Toe (Player vs Player)

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

def check_winner(board, player):
    # Winning combinations
    win_combos = [
        [0, 1, 2], [3, 4, 5], [6, 7, 8],  # rows
        [0, 3, 6], [1, 4, 7], [2, 5, 8],  # columns
        [0, 4, 8], [2, 4, 6]              # diagonals
    ]
    return any(all(board[i] == player for i in combo) for combo in win_combos)

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

def play_game():
    board = [" "] * 9
    current_player = "X"

    print("Welcome to Tic Tac Toe (PvP)!")
    print("Positions are numbered as follows:")
    print(" 1 | 2 | 3 ")
    print("---|---|---")
    print(" 4 | 5 | 6 ")
    print("---|---|---")
    print(" 7 | 8 | 9 ")

    while True:
        print_board(board)
        try:
            move = int(input(f"Player {current_player}, choose a position (1-9): ")) - 1
            if move < 0 or move > 8:
                print("Invalid position. Choose between 1 and 9.")
                continue
            if board[move] != " ":
                print("That spot is already taken. Try again.")
                continue
        except ValueError:
            print("Please enter a valid number (1-9).")
            continue

        board[move] = current_player

        if check_winner(board, current_player):
            print_board(board)
            print(f"🎉 Player {current_player} wins! 🎉")
            break

        if is_draw(board):
            print_board(board)
            print("It's a draw!")
            break

        # Switch player
        current_player = "O" if current_player == "X" else "X"

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

```
Welcome to Tic Tac Toe (PvP)!
Positions are numbered as follows:
 1 | 2 | 3
---|---|---
 4 | 5 | 6
---|---|---
 7 | 8 | 9

   |   |
---|---|---
   |   |
---|---|---
   |   |

Player X, choose a position (1-9): 5

   |   |
---|---|---
   | X |
---|---|---
   |   |

Player O, choose a position (1-9): 2

   | O |
---|---|---
   | X |
---|---|---
   |   |

Player X, choose a position (1-9): 1

 X | O |
---|---|---
   | X |
---|---|---
   |   |

Player O, choose a position (1-9): 3

 X | O | O
---|---|---
   | X |
---|---|---
   |   |

Player X, choose a position (1-9): 9

 X | O | O
---|---|---
   | X |
---|---|---
   |   | X

🎉 Player X wins! 🎉
Srinidhi B V Usn:1BM23CS339
```

classmate
Date 18/8/25
Page

Week-1

Implement a Tic-Tac-Toe Problem.



Pseudo code

START

Create a 3×3 board filled with empty spaces.

Set current player to 'X'.

→ Loop until a player wins or draws.

→ Display board

~~Announce current player as winner.~~

→ Get row & column input from current player

→ If move is valid, place mark on board.

→ Check if current player wins or it's

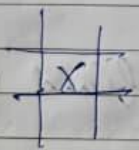
3. If win:-
'Display board'
- Announce current player as winner.
End game.

4) If draw:
Display board
Announce draw
End Game.

Else: Switch current player and repeat the code from step 2.

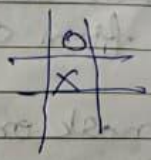
Output:

It's Xs turn
Enter your move (row, col): (1,1)



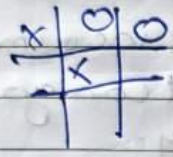
Its Os turn

Enter your move (row, col): (0,1)

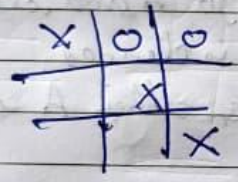


It's X's turn.
Enter your move (0,0)

It's O's turn.
Enter your move (0,2)



It's X's turn
Enter your ~~move~~ move (2,2)



X wins.
Game over.

Implement vacuum cleaner agent

```
def vacuum_simulator():
    # Get initial status of rooms
    rooms = {}
    for room in ['A', 'B']:
        while True:
            status = input(f"Enter status of room {room} (C for clean, D for dirty): ").strip().upper()
            if status in ['C', 'D']:
                rooms[room] = status
                break
            else:
                print("Invalid input. Please enter 'C' or 'D'.")

    total_cost = 0

    while True:
        # Check if all rooms are clean
        if all(status == 'C' for status in rooms.values()):
            print("All rooms are clean. Exiting.")
            break

        move = input("Which room to move to? (A or B): ").strip().upper()
        if move not in rooms:
            print("Invalid room. Please enter 'A' or 'B'.")
            continue

        total_cost += 1

        if rooms[move] == 'C':
            print(f"Room {move} is clean. Continuing...")
        else:
            print(f"Room {move} is dirty. Cleaning now.")
            rooms[move] = 'C'

    print(f"Total cost of moves: {total_cost}")

vacuum_simulator()
print("srinidhi")
```

```
Enter status of room A (C for clean, D for dirty): c
Enter status of room B (C for clean, D for dirty): d
Which room to move to? (A or B): b
Room B is dirty. Cleaning now.
All rooms are clean. Exiting.
Total cost of moves: 1
srinidhi
```

Lab-2

Vacuum Cleaner.

Algorithm:

START

STEP 1: There are ~~four~~ two locations and one vacuum cleaner locations A and B.

STEP 2: If the vacuum is in A and A has a dirt, clean A. When B has a dirt vacuum will move to B and clean B. It can go to B and clean if A & B are both dirty.

STEP 3: If vacuum cleaner is present in B, it cleans the dirt. If A has dirt, the vacuum cleaner will go to A and clean. Repeat until the desired dirt is cleaned.

STEP 4: If there is no dirt in either A or B the program exits.

END

Output:

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

Current state: {'A': 0, 'B': 1}
Vacuum cleaner is in Room A
Enter command {clean, switch}: switch
Vacuum cleaner moved to B.

Current state of Rooms: {'A': 0 'B': 1}
Vacuum cleaner is in Room B.
Enter command: clean.

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)
Implement Iterative deepening search algorithm

Algorithm:

```
from collections import deque


GOAL_STATE = (1, 2, 3,
              8, 0, 4,
              7, 6, 5)  # 0 represents the blank tile


MOVES = {
    'Up':    (-1, 0),
    'Down':  (1, 0),
    'Left':  (0, -1),
    'Right': (0, 1)
}

def index_to_pos(index):
    return index // 3, index % 3

def pos_to_index(row, col):
    return row * 3 + col

def get_neighbors(state):
    neighbors = []
    zero_index = state.index(0)
    zero_row, zero_col = index_to_pos(zero_index)

    for move, (dr, dc) in MOVES.items():
        new_row, new_col = zero_row + dr, zero_col + dc
        if 0 <= new_row < 3 and 0 <= new_col < 3:
            new_zero_index = pos_to_index(new_row, new_col)
            new_state = list(state)

            new_state[zero_index], new_state[new_zero_index] = new_state[new_zero_index], new_state[zero_index]
            neighbors.append((tuple(new_state), move))
    return neighbors

def bfs(start_state, max_depth=50):
    queue = deque([(start_state, [], [start_state])])
    visited = set([start_state])

    while queue:
        state, path_moves, path_states = queue.popleft()

        if state == GOAL_STATE:
            return path_moves, path_states

        if len(path_moves) < max_depth:
            for neighbor, move in get_neighbors(state):
                if neighbor not in visited:
                    visited.add(neighbor)
                    queue.append((neighbor, path_moves + [move], path_states + [neighbor]))
    return None, None

def print_puzzle(state):
    for i in range(0, 9, 3):
        print(state[i:i+3])
    print()



name = input("Enter your name: ")
usn = input("Enter your USN: ")


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

print(f"\nSolver started for {name} (USN: {usn})")
print("\nStart State:")
print_puzzle(start_state)

moves, states = bfs(start_state, max_depth=50)

if moves is not None:
    print(f"Solution found in {len(moves)} moves!\n")

    print("States passed through from start to goal:")
    for i, state in enumerate(states):
        print(f"Step {i}:")
        print_puzzle(state)

    print("Moves to solve the puzzle:")
    print(moves)
else:
    print("No solution found within the depth limit.")
```

```
Enter your name: srinidhi
Enter your USN: 1BM21CS109

Solver started for srinidhi (USN: 1BM21CS109)

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

Solution found in 5 moves!

States passed through from start to goal:
Step 0:
(2, 8, 3)
(1, 6, 4)
(7, 0, 5)

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

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

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

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

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

Moves to solve the puzzle:
['Up', 'Up', 'Left', 'Down', 'Right']
```

1/9/25

Using BFS to solve 8 puzzle without Heuristic

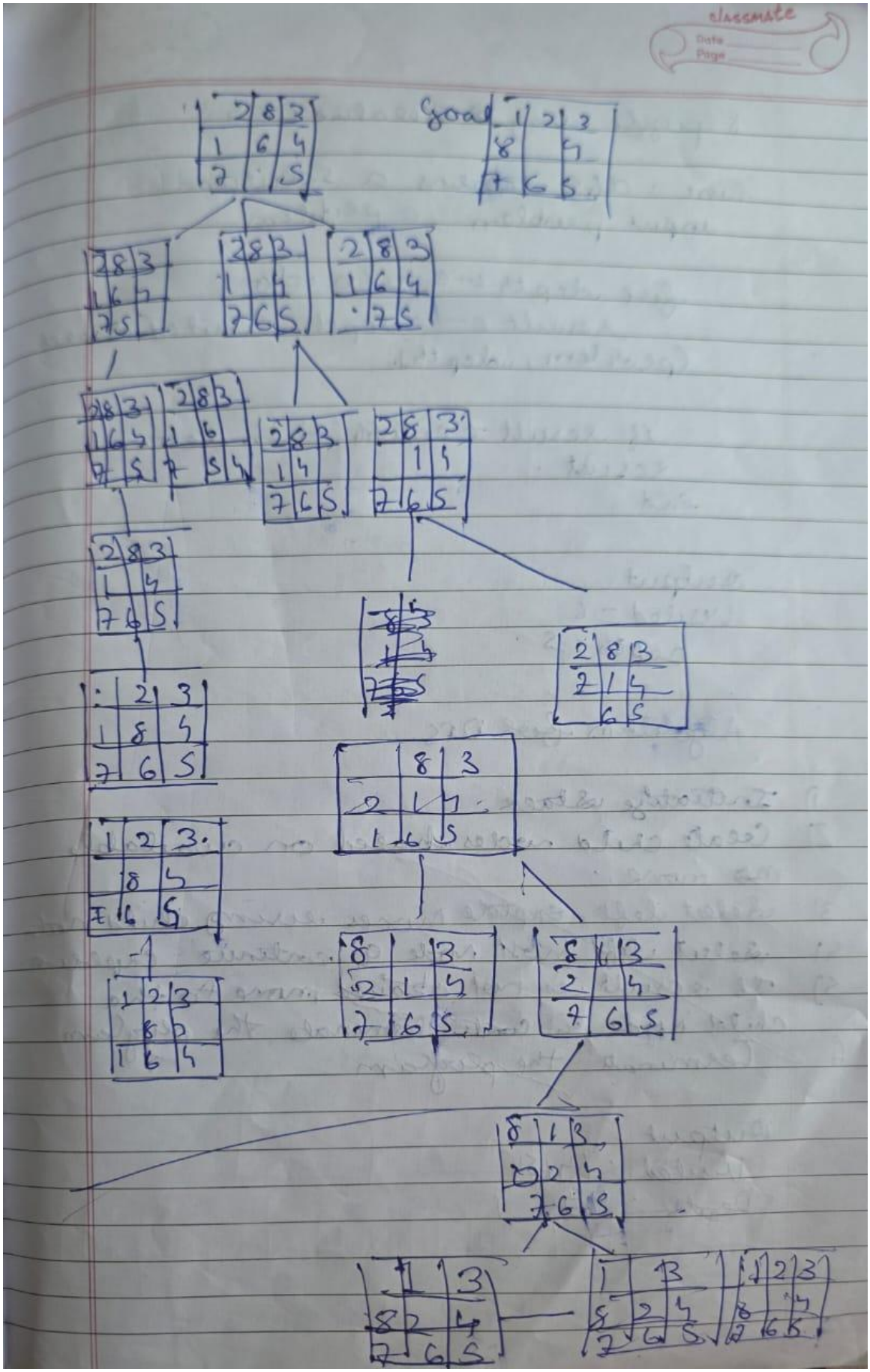
Algorithm

1) Consider the partial state of the 8 puzzle and note down the position of the empty box in box [i][j]

2) Take 4 movements, up, down, left right and move the box position accordingly

3) After moving check for i and j. initial [i][j] = goal [i][j]

4) If Initial = goal, end program, else return to the function.


Goal

Implement 9 Puzzle Problem Using DFS using Iterative DFS

```
from collections import deque

# Define the goal state
GOAL_STATE = (1, 2, 3,
              8, 0, 4,
              7, 6, 5)  # 0 represents the blank tile

MOVES = {
    'Up':    (-3, 0),
    'Down':  (3, 0),
    'Left':  (0, -1),
    'Right': (0, 1)
}

def index_to_pos(index):
    return index // 3, index % 3

def pos_to_index(row, col):
    return row * 3 + col

def get_neighbors(state):
    neighbors = []
    zero_index = state.index(0)
    zero_row, zero_col = index_to_pos(zero_index)

    for move, (dr, dc) in MOVES.items():
        new_row, new_col = zero_row + dr, zero_col + dc
        if 0 <= new_row < 3 and 0 <= new_col < 3:
            new_zero_index = pos_to_index(new_row, new_col)
            new_state = list(state)
            new_state[zero_index], new_state[new_zero_index] = new_state[new_zero_index], new_state[zero_index]
            neighbors.append((tuple(new_state), move))
    return neighbors

def dls(state, goal_state, limit, path_moves, path_states, visited):
    """
    Depth-limited DFS.
    - state: current state
    - goal_state: goal state tuple
    - limit: current depth limit
    - path_moves: list of moves taken so far
    - path_states: list of states on the path so far
    - visited: set of visited states for current path (to avoid cycles)
    Returns (moves, states) if goal found else None
    """
    if state == goal_state:
        return path_moves, path_states
    if limit <= 0:
        return None
    visited.add(state)

    for neighbor, move in get_neighbors(state):
        if neighbor not in visited:
            result = dls(neighbor, goal_state, limit - 1,
                         path_moves + [move], path_states + [neighbor], visited)
            if result is not None:
                return result
    visited.remove(state)
    return None

def iddfs(start_state, goal_state, max_depth=50):
    for depth in range(max_depth + 1):
        visited = set()
        result = dls(start_state, goal_state, depth, [], [start_state], visited)
        if result is not None:
            return result
    return None, None

def print_puzzle(state):
    for i in range(0, 9, 3):
        print(state[i:i+3])
    print()

# --- Main ---

# Input user info
name = input("Enter your name: ")
usn = input("Enter your USN: ")

# Define a start state (make sure it is solvable)
start_state = (2, 8, 3,
               1, 6, 4,
               7, 0, 5)

print(f"\nSolver started for {name} (USN: {usn})")
print("\nStart State:")
print_puzzle(start_state)

moves, states = iddfs(start_state, GOAL_STATE, max_depth=50)

if moves is not None:
    print(f"Solution found in {len(moves)} moves!\n")

    print("States passed through from start to goal:")
    for i, state in enumerate(states):
        print(f"Step {i}:")
        print_puzzle(state)

    print("Moves to solve the puzzle:")
    print(moves)
else:
    print("No solution found within the max depth limit.")
```

```
Enter your name: srinidhi
Enter your USN: 1bm23cs339

Solver started for srinidhi (USN: 1bm23cs339)

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

Solution found in 5 moves!

States passed through from start to goal:
Step 0:
(2, 8, 3)
(1, 6, 4)
(7, 0, 5)

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

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

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

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

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

Moves to solve the puzzle:
['Up', 'Up', 'Left', 'Down', 'Right']
```

8 puzzle using Iterative DFS:

func · dfs returns a solution.
input problem / a problem

for depth ← 0 to ∞ do
result ← depth - limited search
(problem, depth).

if result ≠ cutoff then return
result.
end

Output.
Visited = 6
Depth = 5.

Algorithm for DFS.

1) Initialize stack.
2) Create child nodes based on available moves.
3) Select left, explore moves using child node.
4) Select left most node & continue exploring.
5) If result is not obtained move to the child node & terminate the program
6) Terminate the program

Output:
Visited : 14654
Depth : 49

Implement A* search algorithm

Code:

```
MisplaceType
goal_state = '123804765' moves = {
'U': -3,
‘D': 3,
'L': -1,
'R': 1
}

invalid_moves = {
0: ['U', 'L'], 1: ['U'], 2: ['U', 'R'],
3: ['L'],                    5: ['R'],
6: ['D', 'L'], 7: ['D'], 8: ['D', 'R']
}

def move_tile(state, direction): index = state.index('0')
if direction in invalid_moves.get(index, []): return None

new_index = index + moves[direction] if new_index < 0 or new_index >= 9:
return None

state_list = list(state)
state_list[index], state_list[new_index] = state_list[new_index], state_list[index] return
''.join(state_list)

def print_state(state): for i in range(0, 9, 3):
print(' '.join(state[i:i+3]).replace('0', ' ')) print()

def misplaced_tiles(state):
"""Heuristic: count of tiles not in their goal position (excluding zero)."""" return sum(1 for i, val in
enumerate(state) if val != '0' and val != goal_state[i])


heapq.heappush(open_set, (misplaced_tiles(start_state), 0, start_state, [])) visited = set()

while open_set:
f, g, current_state, path = heapq.heappop(open_set) visited_count += 1

if current_state == goal_state: return path, visited_coun0t
if current_state in visited: continue
```

```
visited.add(current_state)

for direction in moves:
new_state = move_tile(current_state, direction) if new_state and new_state not in visited:
new_g = g + 1
new_f = new_g + misplaced_tiles(new_state)
heapq.heappush(open_set, (new_f, new_g, new_state, path + [direction])) return None,
visited_count
# Main
start = input("Enter start state (e.g., 724506831): ")

if len(start) == 9 and set(start) == set('012345678'): print("Start state:")
print_state(start)
result, visited_states = a_star(start) print(f"Total states visited: {visited_states}") if result is not None:
print("Solution found!")
print("Moves:", ' '.join(result)) print("Number of moves:", len(result)) print("1BM23CS345 Suhas B
P\n")

current_state = start
g = 0 # initialize cost so far
for i, move in enumerate(result, 1):
new_state = move_tile(current_state, move)
g += 1
h = misplaced_tiles(new_state) f = g + h
print(f"Move {i}: {move}") print_state(new_state)
print(f"g(n) = {g}, h(n) = {h}, f(n) = g(n) + h(n) = {f}\n") current_state = new_state
else:
print("No solution exists for the given start state.")
else:
print("Invalid input! Please enter a 9-digit string using digits 0-8 without repetition.")
```

Output:

```
Enter start state (e.g., 724506831): 283164705 Start state:
2 8 3
1 6 4
7  5

Total states visited: 7 Solution found!
Moves: U U L D R Number of
Move 1: U
2 8 3
1  4
7 6 5
g(n) = 1, h(n) = 3, f(n) = g(n) + h(n) = 4 Move 2: U
2  3
```

1 8 4
7 6 5
g(n) = 2, h(n) = 3, f(n) = g(n) + h(n) = 5 Move 3: L
2 3
1 8 4
7 6 5
g(n) = 3, h(n) = 2, f(n) = g(n) + h(n) = 5 Move 4: D
1 2 3
8 4
7 6 5
g(n) = 4, h(n) = 1, f(n) = g(n) + h(n) = 5 Move 5: R
1 2 3
8 4
7 6 5

g(n) = 5, h(n) = 0, f(n) = g(n) + h(n) = 5
b.Manhattan distance.
import heapq
goal_state = '123456780' moves = {
'U': -3,
'D': 3,
'L': -1,
'R': 1
}

invalid_moves = {
0: ['U', 'L'], 1: ['U'], 2: ['U', 'R'],
3: ['L'], 5: ['R'],
6: ['D', 'L'], 7: ['D'], 8: ['D', 'R']
}

def move_tile(state, direction): index = state.index('0')
if direction in invalid_moves.get(index, []): return None

new_index = index + moves[direction] if new_index < 0 or new_index >= 9:
return None

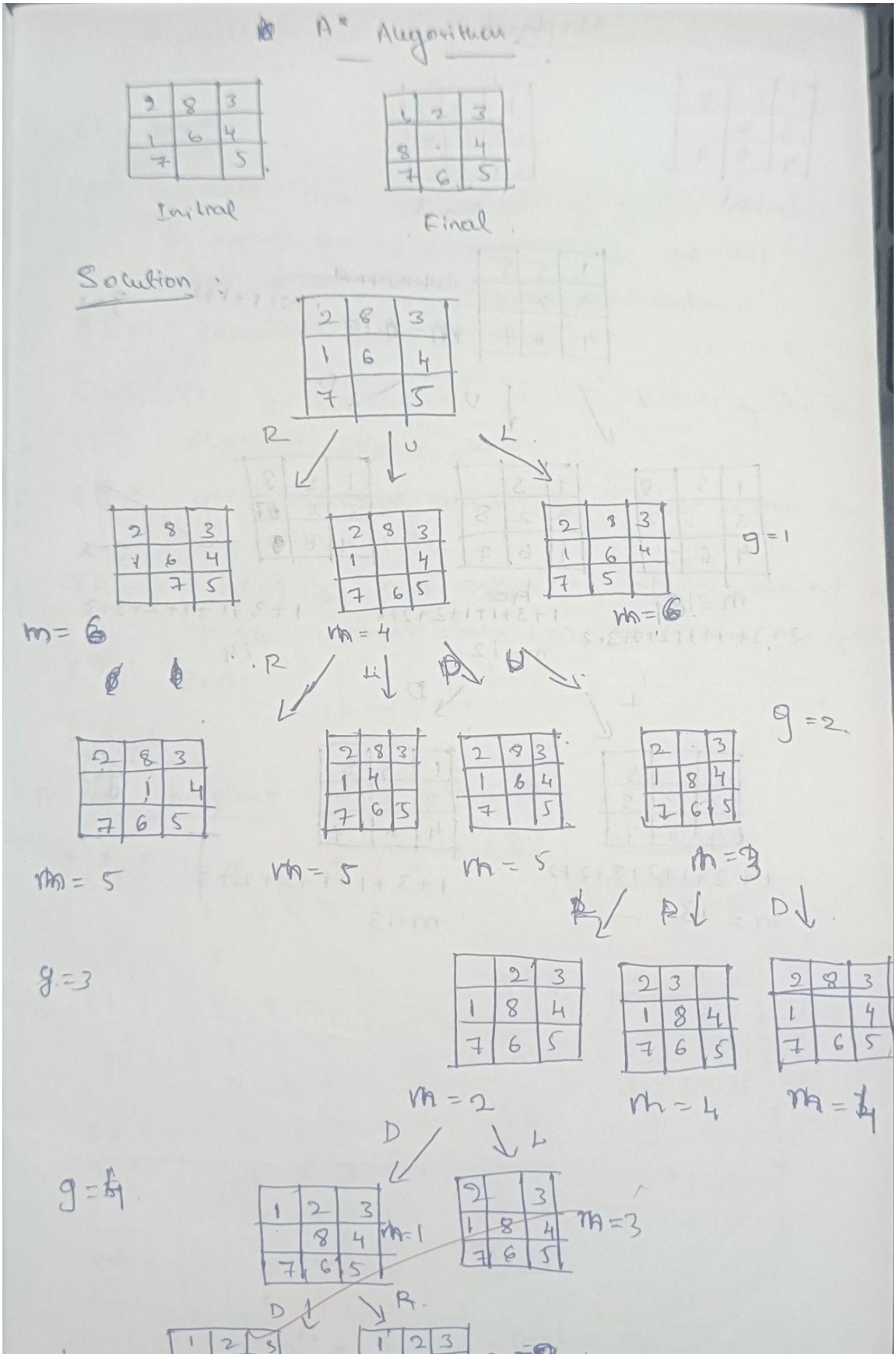
state_list = list(state)
state_list[index], state_list[new_index] = state_list[new_index], state_list[index] return
''.join(state_list)

def print_state(state): for i in range(0, 9, 3):
print(' '.join(state[i:i+3]).replace('0', ' ')) print()

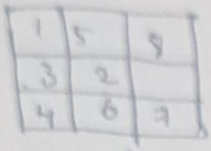
```
def manhattan_distance(state): distance = 0
```

```
for i, val in enumerate(state): if val == '0':continue
goal_pos = int(val) - 1
current_row, current_col = divmod(i, 3) goal_row, goal_col = divmod(goal_pos, 3)
distance += abs(current_row - goal_row) + abs(current_col - goal_col) return distance


heapq.heappush(open_set, (manhattan_distance(start_state), 0, start_state, [])) visited = set()

while open_set:
f, g, current_state, path = heapq.heappop(open_set) visited_count += 1

if current_state == goal_state: return path, visited_count

if current_state in visited: continue
visited.add(current_state)

for direction in moves:
new_state = move_tile(current_state, direction) if new_state and new_state not in visited:
new_g = g + 1
new_f = new_g + manhattan_distance(new_state) heapq.heappush(open_set, (new_f, new_g,
new_state, path + [direction]))
return None, visited_count # Main
start = input("Enter start state (e.g., 724506831): ")

if len(start) == 9 and set(start) == set('012345678'): print("Start state:")
print_state(start)

result, visited_states = a_star(start) print(f"Total states visited: {visited_states}")
if result is not None:
print("Solution found!") print("Moves:", ' '.join(result)) print("Number of moves:", len(result))
print("1BM23CS345 Suhas B P\n")

current_state = start
g = 0 # initialize cost so far
for i, move in enumerate(result, 1):
new_state = move_tile(current_state, move)
g += 1
h = manhattan_distance(new_state) f = g + h
print(f"Move {i}: {move}") print_state(new_state)
print(f"g(n) = {g}, h(n) = {h}, f(n) = g(n) + h(n) = {f}\n") current_state = new_state
else:
print("No solution exists for the given start state.")
else:
```

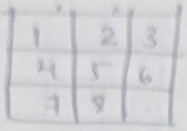
print("Invalid input! Please enter a 9-digit string using digits 0-8 without repetition.")



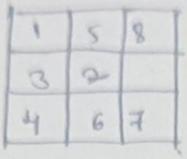
Misplaced



Initial



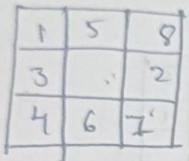
Final.



m = 13

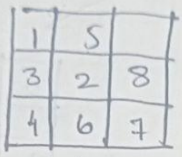
1+3+1+1+2 g=1

L D



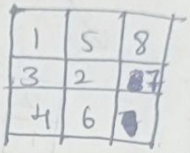
m = 14

2+3+1+1+2+2+3+2



1+3+1+1+2+2+2

m = 12

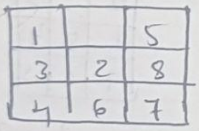


g=1

1+3+1+1+2+3+3

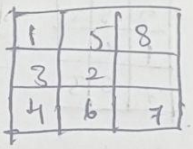
14.

L D



1+3+1+2+2+2+2

m = 13



g=2

1+3+1+1+2+2+3

m=13

Algorithm for misplace & Manhattan Distance

S1: Start

S2: Evaluate nodes by combining g(n), the cost to reach the node, and h(n), the cost to get from the node to goal node.

S3: calculate f(n) = g(n) + h(n)

S4: f(n) is evaluation function which gives the cheapest solution cost.

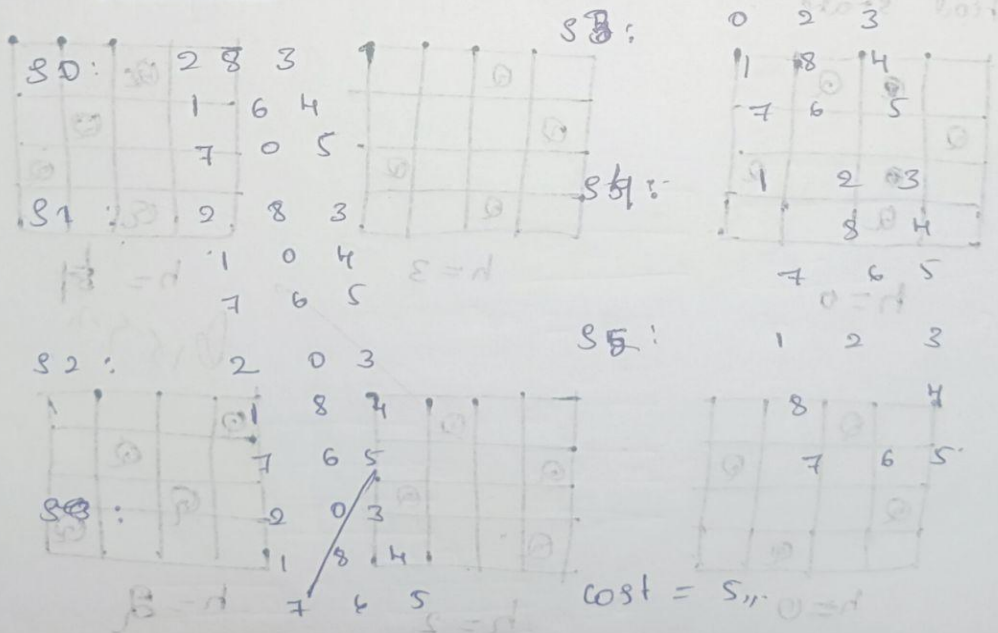
S5: g(n) is exact cost to reach node n from the initial state.

S6: h(n) is an estimation of the assured cost from current state (n) to reach the goal.

S7: End.

Output

1) For Misplace and Manhattan.



Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:

```
import random
import time

def print_board(state):
"""Prints the chessboard for a given state.""" n = len(state)
for row in range(n): line = ""
for col in range(n):
if state[col] == row: line += "Q "
else:
line += ". " print(line)
print()

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

def get_neighbors(state):
"""Generates all possible neighbors by moving one queen in its column.""" neighbors = []
n = len(state)
for col in range(n): for row in range(n):
if row != state[col]: neighbor = list(state) neighbor[col] = row
neighbors.append(neighbor) return neighbors

def hill_climb_verbose(initial_state, step_delay=0.5):
"""Hill climbing algorithm with verbose output at each step.""" current = initial_state
current_h = compute_heuristic(current)

step = 0

print(f"Initial state (heuristic: {current_h}):") print_board(current)
time.sleep(step_delay)

while True:
```

```
neighbors = get_neighbors(current) next_state = None
next_h = current_h

for neighbor in neighbors:
h = compute_heuristic(neighbor) if h < next_h:
next_state = neighbor next_h = h

if next_h >= current_h:
print(f"Reached local minimum at step {step}, heuristic: {current_h}") return current, current_h

current = next_state current_h = next_h step += 1
print(f"Step {step}: (heuristic: {current_h})") print_board(current)
time.sleep(step_delay)

def solve_n_queens_verbose(n, max_restarts=1000):
"""Solves N-Queens problem using hill climbing with restarts and verbose output.""" for attempt in
range(max_restarts):
print(f"\n=== Restart {attempt + 1} ===\n")
initial_state = [random.randint(0, n - 1) for _ in range(n)] solution, h = hill_climb_verbose(initial_state)
if h == 0:
print(f" ■  Solution found after {attempt + 1} restart(s):") print_board(solution)
return solution else:
print(f"+ No solution in this attempt (local minimum).\n") print("Failed to find a solution after max
restarts.")

return None

# --- Run the algorithm ---
if   name                    == "  main  ":
N = int(input("Enter the number of queens (N): ")) solve_n_queens_verbose(N)
print("1BM23CS339 SRINIDHI  B V")
```

Output:

```
Enter the number of queens (N): 4

=== Restart 1 ===

Initial state (heuristic: 3):
Q . Q .
. Q . .
. . . Q
. . . .

Step 1: (heuristic: 1)
. . Q .
```

. Q . .
. . . Q
Q . . .

Reached local minimum at step 1, heuristic: 1
+ No solution in this attempt (local minimum).

=== Restart 2 ===

Initial state (heuristic: 3):
. Q . .
. . Q .
. . . . Q . . Q

Step 1: (heuristic: 1)
. Q . .
. . Q .
Q . . .
. . . Q

Reached local minimum at step 1, heuristic: 1
+ No solution in this attempt (local minimum).

=== Restart 3 ===

Initial state (heuristic: 2):
. . . .
. Q . Q
. . . . Q . Q .

Step 1: (heuristic: 1)
. Q . .
. . . Q
. . . . Q . Q .

Step 2: (heuristic: 0)
. Q . .
. . . Q
Q . . .
. . Q .

Reached local minimum at step 2, heuristic: 0
Solution found after 3 restart(s):

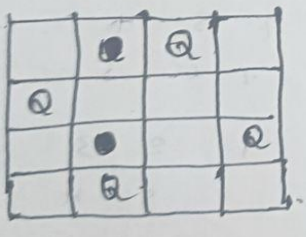
. Q . .
. . . Q
Q . . .
. . Q .
1BM23CS339 SRINIDHI B V

Lab-5 Hill climbing

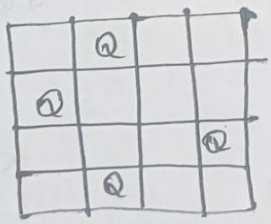
1) Define current state as initial state.
2) Loop until goal state is reached, or no more operation is applied.
3) Apply on operand
4) compare new state with goal state
5) Quit
6) Evaluate newstate with its heuristics
7) compare.
8) if newstate is close to goal state then update current state.
9) display.
10) End.

4-Queens problem.

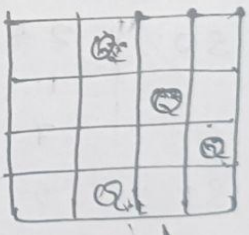
Initial state.



h = 0



h = 3



h = 1

Display

Program 5

Simulated Annealing to Solve 8-Queens problem

Code:

```
import random import math

def compute_heuristic(state): """Number of attacking pairs.""" h = 0
n = len(state) for i in range(n):
for j in range(i + 1, n):
if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):

h += 1
return h

def random_neighbor(state):
"""Returns a neighbor by randomly changing one queen's row.""" n = len(state)
neighbor = state[:]
col = random.randint(0, n - 1) old_row = neighbor[col]
new_row = random.choice([r for r in range(n) if r != old_row]) neighbor[col] = new_row
return neighbor

def dual_simulated_annealing(n, max_iter=10000, initial_temp=100.0, cooling_rate=0.99):
"""Simulated Annealing with dual acceptance strategy."""
current = [random.randint(0, n - 1) for _ in range(n)] current_h = compute_heuristic(current)
temperature = initial_temp

for step in range(max_iter): if current_h == 0:
print(f" Solution found at step {step}") return current

neighbor = random_neighbor(current) neighbor_h = compute_heuristic(neighbor) delta = neighbor_h
- current_h

if delta < 0:
current = neighbor current_h = neighbor_h
else:
# Dual acceptance: standard + small chance of higher uphill move probability = math.exp(-delta /
temperature)
if random.random() < probability: current = neighbor
current_h = neighbor_h

temperature *= cooling_rate
if temperature < 1e-5: # Restart if stuck temperature = initial_temp
```

```
current = [random.randint(0, n - 1) for _ in range(n)] current_h = compute_heuristic(current)

print("+ Failed to find solution within max iterations.") return None

# --- Run the algorithm ---
if   name                    == "  main  ":
N = int(input("Enter number of queens (N): ")) solution = dual_simulated_annealing(N)

if solution:
print("Position format:")
print("[", " ".join(str(x) for x in solution), "]") print("Heuristic:", compute_heuristic(solution))
print("1BM23CS339 SRINIDHI B V ")
```

Output:

```
Enter number of queens (N): 8
   Solution found at step 675 Position format:
[ 3 0 4 7 5 2 6 1 ]
Heuristic: 0
1BM23CS3339 SRINIDHI
B V
```

Simulated Annealing

1. current ← initial state.
2. T ← a large positive value.
3. while T > 0 do
4. next ← a random neighbour of current
5. ΔE ← current.cost − next.cost
6. if ΔE > 0 then
7. current ← next
8. else current ← next with probability $p = e^{\frac{\Delta E}{T}}$
9. end if decrease T.
10. end while.
13. return current.

Output

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

15/9/25

Program 6

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

Code:

```
from itertools import product

# ---------- Propositional Logic Symbols ---------- class Symbol:
def  init (self, name): self.name = name

def  invert (self): # ~P return Not(self)

def  and (self, other): # P & Q return And(self, other)

def  or (self, other): # P | Q return Or(self, other)

def  rshift (self, other): # P >> Q (implication) return Or(Not(self), other)

def  eq  (self, other): # P == Q (biconditional) return And(Or(Not(self), other), Or(Not(other), self))

def eval(self, model): return model[self.name]

def symbols(self): return {self.name}

def  repr (self): return self.name

class Not:
def  init (self, operand): self.operand = operand

def eval(self, model):
return not self.operand.eval(model)

def symbols(self):
return self.operand.symbols()
```

```
    def  repr  (self):
    return f"~{self.operand}"

    def  invert (self): # allow ~~A return Not(self)


class And:
    def _init_(self, left, right):
        self.left, self.right = left, right

    def eval(self, model):
        return self.left.eval(model) and self.right.eval(model)

    def symbols(self):
        return self.left.symbols() | self.right.symbols()

    def __repr__(self):
        return f"({self.left} & {self.right})"

    def _invert_(self): # allow ~(A & B) return
        Not(self)


class Or:
    def _init_(self, left, right):
        self.left, self.right = left, right

    def eval(self, model):
        return self.left.eval(model) or self.right.eval(model)

    def symbols(self):
        return self.left.symbols() | self.right.symbols()

    def __repr__(self):
        return f"({self.left} | {self.right})"

    def _invert_(self): # allow ~(A | B) return
        Not(self)
```

```
tt_entails(kb, alpha, show_table=False):
    symbols = sorted(list(kb.symbols() | alpha.symbols()))
    if show_table:
        print_truth_table(kb, alpha, symbols)
    return tt_check_all(kb, alpha, symbols, {})


def tt_check_all(kb, alpha, symbols, model):
    if not symbols: # all symbols assigned
        if kb.eval(model): # KB is true
            return alpha.eval(model)
        else:
            return True # if KB is false, entailment holds
    else:
        P, rest = symbols[0], symbols[1:]

        model_true = model.copy()
        model_true[P] = True
        result_true = tt_check_all(kb, alpha, rest, model_true)

        model_false = model.copy()
        model_false[P] = False
        result_false = tt_check_all(kb, alpha, rest, model_false)

        return result_true and result_false


# ---------------------- Truth Table Printer ----------------------
def print_truth_table(kb, alpha, symbols):
    header = symbols + ["KB", "Query"]
    print(" | ".join(f"{h:^5}" for h in header))
    print("-" * (7 * len(header)))

    for values in product([False, True], repeat=len(symbols)):
        model = dict(zip(symbols, values))
        kb_val = kb.eval(model)
        alpha_val = alpha.eval(model)
```

```
            row = [str(model[s]) for s in symbols] + [str(kb_val), str(alpha_val)]
            print(" | ".join(f"{r:^5}" for r in row))

print(“Srinidhi B V “)
```

```
    print()
C = Symbol("C")
T = Symbol("T")


c = T | ~T

# KB: P → Q
kb1 = ~(S|T)
# Query: Q
alpha1 = S & T


print("Knowledge Base:", kb1)
print("Query:", alpha1)
print()
result = tt_entails(kb1, alpha1, show_table=True)
print("Does KB entail Query?", result)
```

Output:

```
Knowledge Base: (P | (Q & P))
Query: (Q | P)

  P  |  Q  | KB  | Query
-------------------------------------
False | False | False | False
False | True | False | True
True | False | True | True
True | True | True | True

Does KB entail Query? True
```

Srinidhi B V

2) Try every possibility

* Each symbol can be true / false
* So use test all combination.

3) Create KB.

For each combination, see if KB is true

4) Check α

* if, KB is true, then α must also true, then α must also be true
* If KB is false, we don't care about α in that row.

5) Final decision.

* If in all cases, where KB is true, α is also true → KB entails α
* If in any case KB is true but false → KB does not entail.

Output

KB: Not

Enter Query (alpha): t

Truth table

Not	T	KB	alpha
True	True	True	True
True	False	True	False
False	True	False	True
False	False	False	False

Result: False.

6) Create a knowledge base using propositional logic & show that the given query entails the knowledge base / not

Truth table for connectives

P	Q	¬P	P∧Q	P∨Q	P⇒Q
false	false	true	false	false	true
false	true	true	false	true	false
false	false	false	false	true	true
true	true	false	true	true	true

propositional inference: Enumeration method,

$\alpha = A \vee B$ $KB = (A \vee C) \wedge (B \vee \neg C)$

A	B	C	A∨C	B∨¬C	KB	α
F	F	F	F	T	F	F
F	F	T	T	F	F	F
F	T	F	F	T	F	T
F	T	T	T	T	T	T
T	F	F	T	T	T	T
T	F	T	T	F	F	T
T	T	F	T	T	T	T
T	T	T	T	T	T	T

$KB \models \alpha$ holds (KB entails α)

Algorithm

1) List all variables
   - Find all the symbols that appear in KB & α

Ex: A, B, C

Program 7

Implement unification in first order logic

Code:

```
class
   UnificationError(
   Exception): pass

def occurs_check(var, term):

   """Check if a variable occurs in a term (to prevent infinite
   recursion)""" if var == term:
      return True
   if isinstance(term, tuple): # Term is a compound
      (function term) return any(occurs_check(var,
      subterm) for subterm in term)
   return False

def unify(term1, term2, substitutions=None):
   """Try to unify two terms, return the MGU (Most
   General Unifier)""" if substitutions is None:
      substitutions = {}

   # If both terms are equal, no further
   substitution is needed if term1 == term2:
      return substitutions

   # If term1 is a variable, we substitute
   it with term2 elif isinstance(term1,
   str) and term1.isupper():
      # If term1 is already
      substituted, recurse if
      term1 in substitutions:
         return unify(substitutions[term1], term2,
      substitutions) elif occurs_check(term1,
      term2):
         raise UnificationError(f"Occurs check fails: {term1}
      in {term2}") else:
```

substitutions[term

```
        1] = term2 return
        substitutions

    # If term2 is a variable, we substitute
    it with term1 elif isinstance(term2,
    str) and term2.isupper():
        # If term2 is already
        substituted, recurse if
        term2 in substitutions:
            return unify(term1, substitutions[term2],
        substitutions) elif occurs_check(term2,
        term1):
            raise UnificationError(f"Occurs check fails: {term2}
        in {term1}") else:
            substitutions[term
            2] = term1 return
            substitutions

    # If both terms are compound (i.e., functions), unify their
    parts recursively elif isinstance(term1, tuple) and
    isinstance(term2, tuple):
        # Ensure that both terms have the same "functor" and number of arguments

        # if len(term1) != len(term2):
        #     raise UnificationError(f"Function arity mismatch: {term1} vs {term2}")

        for subterm1, subterm2 in zip(term1, term2):
            substitutions = unify(subterm1, subterm2,

        substitutions) return substitutions

    else:
        raise UnificationError(f"Cannot unify: {term1} with {term2}")

# Define the terms
as tuples term1 =
('p', 'b', 'X', ('f',
('g', 'Z')))
term2 = ('p', 'Z', ('f', 'Y'), ('f', 'Y'))

try:
```

```
    # Find the MGU
    result = unify(term1,
    term2) print("Most
    General Unifier
    (MGU):") print(result)
except
    UnificationError
    as e:
    print(f"Unification
    failed: {e}")
finally:
Print(“Srinidhi B V “)
```

Output:

```
Most General Unifier (MGU):
{'Z': 'b', 'X': ('f', 'Y'),
'Y': ('g', 'Z')}
Srinidhi B V
```

Lab - 4

Unification Algorithm

Unification :- It is process to find substitution make different FOL (first order logic).

1) unify (knows (John, x), knows (John, Jane))

θ = x / Jane

x / Jane

unify (knows (John, Jane), know (John, Jane)).

2) unify (knows (John, x), know (y, Bill))

θ = y / John

knows (John, x), know (John, Bill)

θ = x / Bill

knows (John, Bill), knows (John, Bell).

3) Find MGU of { P(b, x, f(g(z)) }

{ P (z, f(y), f(y)) }

θ = b / z

~~knows { P(z / x~~

θ = z / f(y)

θ = g(z) / y.

4) Find MGU of {Q(a, g(x,a), f(y)), Q(a, g(f(b), a), x)}

$\theta = x / f(b)$

Unify {Q(a, g(f(b), a), f(y)), Q(a, g(f(b), a), x)}

$\theta = f(y) / x$

Unify {Q(a, g(f(b), a), x), Q(a, g(f(b), a), x)}

5) Find MGU of {P(f(a), g(y)), P(x, x)}

$\theta = f(a) / x$

{P(x, g(y)), P(x, x)}

Unification fails.

6) Unify {prime(11) & prime(y)}

$\theta = 11 / y$

Unify {prime(y) & prime(y)}.

Algorithm

Unify(Ψ_1, Ψ_2)

Step 1: If Ψ_1 / Ψ_2 is a variable or constant, then

a) If Ψ_1 occurs then return NIL.

b) Else if Ψ_1 is variable.

a. then if Ψ_1 occurs in Ψ_2, then return Failure.

c) Else if ψ_2 is a variable
   a. If ψ_2 occure in ψ_1 then return Failure.
   b. Else return $\{(\psi_1 / \psi_2)\}$.
d) Else return $\{(\psi_1/\psi_2)\}$ Failure.

Step 2: If initial predicate symbol in ψ_1 & ψ_2 are same, then return failure.

Step 3: If ψ_1 & ψ_2 have different number of arguments then return failure.

Step 4: Set substitution set (SUBST) to NIL.

Step 5: For i = 1 to number of elements in ψ_1
   a) If S = failure then return Failure.
   b) If S ≠ NIL then do,
      a. Apply S to the remainder of both ψ_1 & ψ_2
      b. SUBST = APPEND(S, SUBST).

Step 6: Return SUBT.

Output,

Input: P(b, x, f(g(z))) & P(z, f(y), f(y))

Trace;

unify b with z

unify x with f(y)

unify f(g(z)) with f(y)

unify g(z) with y

Final MGU:

z → b

x → f(g(z))

y → g(z)

Program 8

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

```
facts = {
    "American(Robert)",
    "Enemy(A, America)",
    "Missile(T1)",
    "Owns(A, T1)"
}


rules = [
    ("Enemy(x, America)", "Hostile(x)"),
    ("Missile(x)", "Weapon(x)"),
    ("Missile(x) ⋀ Owns(A, x)", "Sells(Robert, x, A)"),
    ("American(p) ⋀ Weapon(q) ⋀ Sells(p, q, r) ⋀ Hostile(r)", "Criminal(p)")
]

def apply_rules(facts):
    new_facts = set()


    if "Enemy(A, America)" in facts and "Hostile(A)" not in facts:
        print("Step 1: Enemy(A, America) → Hostile(A)")
        new_facts.add("Hostile(A)")


    if "Missile(T1)" in facts and "Weapon(T1)" not in facts:
        print("Step 2: Missile(T1) → Weapon(T1)")
        new_facts.add("Weapon(T1)")


    if "Missile(T1)" in facts and "Owns(A, T1)" in facts and "Sells(Robert, T1, A)"
not in facts:
        print("Step 3: Missile(T1) ⋀ Owns(A, T1) → Sells(Robert, T1, A)")
        new_facts.add("Sells(Robert, T1, A)")

    if {"American(Robert)", "Weapon(T1)", "Sells(Robert, T1, A)", "Hostile(A)"} <=
facts and "Criminal(Robert)" not in facts:
        print("Step 4: American(Robert) ⋀ Weapon(T1) ⋀ Sells(Robert, T1, A) ⋀
Hostile(A) → Criminal(Robert)")
        new_facts.add("Criminal(Robert)")

    return new_facts
```

```
step = 1
while True:
    new_facts = apply_rules(facts)
    if not new_facts:
        break
    facts |= new_facts
    step += 1
```

```
print("\n☑ Final
Facts:") for fact in
facts:
    print(fact)
```

```
Step 1: Enemy(A, America) → Hostile(A)
Step 2: Missile(T1) → Weapon(T1)
Step 3: Missile(T1) ∧ Owns(A, T1) → Sells(Robert, T1, A)
Step 4: American(Robert) ∧ Weapon(T1) ∧ Sells(Robert, T1, A) ∧ Hostile(A) →
Criminal(Robert)

☑ Final Facts:
Weapon(T1)
Criminal(Robert)
Hostile(A)
Sells(Robert, T1, A)
Missile(T1)
Enemy(A, America)
Owns(A, T1)
American(Robert)
```

Srinidhi B V

First order logic

Create knowledge base consisting of first order logic statements & the given query using forward reasoning

Rules

$P \Rightarrow Q$

$L \wedge M \Rightarrow P$

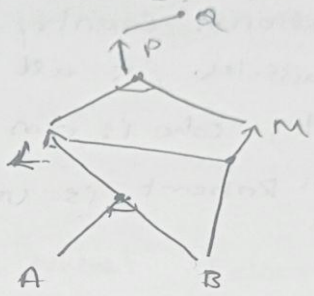
$B \wedge L \Rightarrow M$

$A \wedge P \Rightarrow L$

$A \wedge B \Rightarrow L$

fact $\{A, B\}$

prove Q



Algorithm

function FOL-FC-ASK (KB, α) returns a substitution/fo

inputs : KB, the knowledge base, a set of FOD cla

α, the query, an atomic sentence

Local variable : new, the new sentence inferred of each

repeat until new is empty

new $\leftarrow \{\}$

for each rule in KB do

$(P_1 \wedge \dots \wedge P_n \Rightarrow q) \leftarrow$ STANDARDIZE-VARIAB

for each θ such that SUBST($\theta, P_1 \wedge \dots \wedge P_n$) = SUBST($\theta, P'_1 \wedge \dots$

for some $P'_1 \dots P'_n$ in KB.

$q' \leftarrow$ SUBST(θ, q)

If q' does not unify with some sentence alread

in KB / new then.

Add q to KB
θ ← UNIFY(ψ(q), α)
If θ is not fail then return θ
Add new to KB
Return false.

Problem

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

Prove that "Robert is criminal"

Representation in FOL.

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

Lets say P, q & r are variables

American(P) ∧ weapon(q) ∧ sells(P, q, r) ∧ Hostile(r) => Criminal(P)

Country A has some missiles.

∃x owns(A, x) ∧ Missile(x)

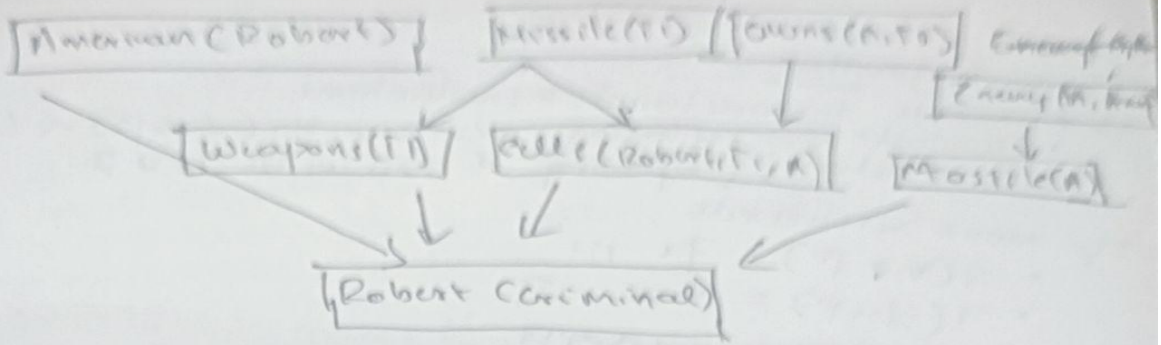
Existential Instantiation, introducing a new constant T1

owns(A, T1)

Missile(T1)

All of the missiles were sold to country A by Robert

∀x Missile(x) ∧ owns(A, x) => sells(Robert, x, A)



. American(p) ∧ weapon(a) ∧ sells(p,a,r) ∧ Hostile(r)

=> Criminal(p).

output →

All condition are meet Robert is criminal.

Final Facts :

Enemy(A, America)

American(Robert)

Hostile(A)

Criminal(Robert).

13/10/25

Program 9

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

```
class Literal:
    def __init__(self, name, negated=False):
        self.name = name
        self.negated = negated

    def __repr__(self):
        return f"¬{self.name}" if self.negated else self.name

    def __eq__(self, other):
        return isinstance(other, Literal) and self.name == other.name and
self.negated == other.negated

    def __hash__(self):
        return hash((self.name, self.negated))
print('Suhas B P (1BM23CS345)')
def convert_to_cnf(sentence):
    return sentence  # Placeholder for CNF conversion logic

def negate_literal(literal):
    return Literal(literal.name, not literal.negated)

def resolve(clause1, clause2):
    resolvents = []
    for literal1 in clause1:
        for literal2 in clause2:
            if literal1.name == literal2.name and literal1.negated !=
literal2.negated:
                new_clause = (set(clause1) - {literal1}) | (set(clause2) -
{literal2})
                resolvents.append(frozenset(new_clause))
    return resolvents

def prove_conclusion(premises, conclusion):
    cnf_premises = [convert_to_cnf(p) for p in premises]
    cnf_conclusion = convert_to_cnf(conclusion)
    negated_conclusion = frozenset({negate_literal(lit) for lit in cnf_conclusion})

    clauses = set(frozenset(p) for p in cnf_premises)
    clause_list = list(clauses)
```

```
id_map = {}
parents = {}
clause_id = 1
```

```
    for c in clause_list:
        id_map[c] = f"C{clause_id}"
        clause_id += 1

    id_map[negated_conclusion] = f"C{clause_id} (¬Conclusion)"
    clauses.add(negated_conclusion)
    clause_list.append(negated_conclusion)
    clause_id += 1

    print("\n--- Initial Clauses ---")
    for c in clause_list:
        print(f"{id_map[c]}: {set(c)}")

    print("\n--- Resolution Steps ---")

    while True:
        new_clauses = set()
        for i in range(len(clause_list)):
            for j in range(i + 1, len(clause_list)):
                resolvents = resolve(clause_list[i], clause_list[j])
                for r in resolvents:
                    if r not in id_map:
                        id_map[r] = f"C{clause_id}"
                        parents[r] = (id_map[clause_list[i]],
id_map[clause_list[j]])
                        clause_id += 1

                    print(f"{id_map[r]} = RESOLVE({id_map[clause_list[i]]},
{id_map[clause_list[j]]}) -> {set(r)}")

                    if not r:
                        print(f"\nEmpty clause derived! ({id_map[r]})")
                        print("\n--- Resolution Tree ---")
                        print_resolution_tree(parents, id_map, r)
                        return True

                    new_clauses.add(r)

        if new_clauses.issubset(clauses):
            print("\nNo new clauses can be derived.")
            return False

        clauses |= new_clauses
        clause_list = list(clauses)

def print_resolution_tree(parents, id_map, empty_clause):
    """Recursively print resolution tree leading to the empty clause."""
    def recurse(clause):
        if clause not in parents:
```

```
    print(f" {id_map[clause]}: {set(clause)}")
```

```
            return
        left, right = parents[clause]
        print(f" {id_map[clause]} derived from {left} and {right}")
        for parent_clause, parent_name in zip([k for k, v in id_map.items() if v in
[left, right]], [left, right]):
            recurse(parent_clause)

def parse_literal(lit_str):
    lit_str = lit_str.strip()
    if lit_str.startswith("¬") or lit_str.startswith("~"):
        return Literal(lit_str[1:], True)
    return Literal(lit_str, False)

def get_user_input():
    premises = []
    num_premises = int(input("Enter number of premises: "))
    for i in range(num_premises):
        clause_str = input(f"Enter clause {i+1} (e.g., A, ¬B, C): ")
        literals = {parse_literal(l) for l in clause_str.split(",")}
        premises.append(literals)

    conclusion_str = input("Enter conclusion (e.g., C or ¬C): ")
    conclusion = {parse_literal(l) for l in conclusion_str.split(",")}
    return premises, conclusion

if __name__ == "__main__":
    premises, conclusion = get_user_input()

    if prove_conclusion(premises, conclusion):
        print("\n Conclusion can be proven from the premises.")
    else:
        print("\n Conclusion cannot be proven from the premises.")
```

```
Suhas B P (1BM23CS345)
Enter number of premises: 4
Enter clause 1 (e.g., A, ¬B, C): A
Enter clause 2 (e.g., A, ¬B, C): -A
Enter clause 3 (e.g., A, ¬B, C): -B
Enter clause 4 (e.g., A, ¬B, C): c
Enter conclusion (e.g., C or ¬C): c

--- Initial Clauses ---
C1: {A}
C2: {-B}
C3: {c}
C4: {-A}
```

C5 (¬Conclusion): {¬c}

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```
--- Resolution Steps ---
C6 = RESOLVE(C3, C5 (¬Conclusion)) -> set()

Empty clause derived! (C6)

--- Resolution Tree ---

 Conclusion can be proven from the premises.
```

Algorithem

1) Eliminate biconditionals & implications
   - Eliminate $\Leftrightarrow$ replacing $\alpha \Leftrightarrow \beta$ with $(\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)$
   - Eliminate $\Rightarrow$, replacing $\alpha \Rightarrow \beta$ with $\neg\alpha \vee \beta$

2) Move $\neg$ inwards
   - $\neg(\forall x\, p) \equiv \exists x\, \neg p$
   - $\neg(\exists x\, p) \equiv \forall x\, \neg p$,
   - $\neg(\alpha \vee \beta) \equiv \neg\alpha \wedge \neg\beta$,
   - $\neg(\alpha \wedge \beta) \equiv \neg\alpha \vee \neg\beta$,

3) Standardize variables apart by renaming them

4) skolemize: each existential variable is replace by skolem constant / skolem function.
   - For instance, $\exists x$ Rich(x) becomes Rich(G1) where G1 is a new skolem constant.
   - "Everyone has a heart" $\forall x$ person(x) $\Rightarrow \exists y$ Heart(y) $\wedge$ Has(x,y) becomes $\forall x$ person(x) $\Rightarrow$ Heart(H(x)) $\wedge$ Has(x, H(x))

5) Drop universal qualifiers
   - for instance, $\forall x$ person(x) becomes person(x).

6) Distribute $\wedge$ over $\vee$:
   - $(\alpha \wedge \beta) \vee \gamma \equiv (\alpha \vee \gamma) \wedge (\beta \vee \gamma)$.

Proof by Resolution:

Given Premises: John likes all kind of food. Apples & vegetables are food. Anything anyone eats & not killed is food. Harry eats everything that Anil eats. Anil eats peanuts & still alive. Imp not killed anyone who is not killed implies all

prove by resolution: John likes peanuts.

Representation in FOL:

a) $\forall x$: food(x) $\rightarrow$ likes(John, x)
b) food(Apple) $\wedge$ food(vegetables)
c) $\forall x\, \forall y$: eats(x, y) $\wedge$ $\neg$ killed(x) $\rightarrow$ food(y)
d) eats(Anil, peanuts) $\wedge$ alive(Anil)
e) $\forall x$: eats(Anil, x) $\rightarrow$ eats(Harry, x)
f) $\forall x$: alive(x) $\rightarrow$ $\neg$ killed(x)
g) $\forall x$: $\neg$ killed(x) $\rightarrow$ alive(x)

backspace

prove : h) likes (John, Peanuts)

Proof by Resolution:

a) ¬food (x) V likes (John, x)
b) food (Apple)
c) food (Vegetable)
d) ¬eats (y, z) V killed (y) V food (z)
e) eats (Anil, Peanuts)
f) alive (Anil)
g) ¬eats (Anil, w) V eats (Harry, w)
h) killed (g) V alive (g)
i) ¬killed (k) V ¬alive (k)
j) likes (John, Peanuts).

Output

Goal Prove likes (John, Peanuts),
Negated Goal : { 'Not likes (John, Peanuts)' }
Step 1: Resolving Negated Goal with clause a
{'Not likes (John, Peanuts)'} Result 1: {Not food(Peanuts)}

Step 2: Resolving Result 1 with clause d
Result 2: {'killed(y)', 'Not eats(y, Peanuts)'}
Step 3: Resolving Result 2 with clause e
Result 3: {'killed(Anil)'}
Step 4: Resolving Result 3 with clause i
Result 4: {Not alive(Anil)'}
Step 5: Resolving Result 4 with clause f
{Not alive(Anil)'} => {alive(Anil)'} Result 5: set()

Resion: The original goal likes (John, Peanuts) is True

¬likes(John, Peanuts)
¬food(x) V likes(John, x)
{Peanuts/x}
¬food(Peanuts)
¬eats(y, z) V killed(y) V food(z)
{Peanuts/z}
¬eats(y, Peanuts) V killed(y)
eats (Anil, Peanuts)

Hence proved.

Program 10

Implement Alpha-Beta Pruning.

```
import math

def alpha_beta(node, depth, alpha, beta, maximizingPlayer, game_tree):


    if depth == 0 or isinstance(game_tree[node], int):
        return game_tree[node]

    if maximizingPlayer:
        maxEval = -math.inf

        for child in game_tree[node]:
            eval = alpha_beta(child, depth - 1, alpha, beta, False,
game_tree)

            maxEval = max(maxEval, eval)

            alpha = max(alpha, eval)

            if beta <= alpha:
                break

        return maxEval

    else:
        minEval = math.inf

        for child in game_tree[node]:
            eval = alpha_beta(child, depth - 1, alpha, beta, True, game_tree)

            minEval = min(minEval, eval)

            beta = min(beta, eval)
```

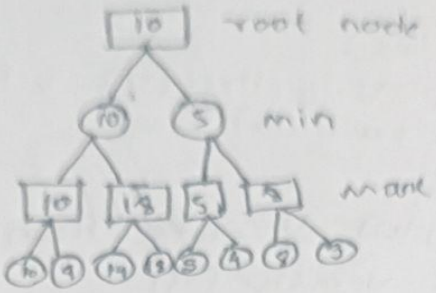
```
if beta <= alpha:
    break
```

```
            return minEval


    game_tree = {
        'A': ['B', 'C'],
        'B': ['D', 'E'],
        'C': ['F', 'G'],
        'D': 3,
        'E': 5,
        'F': 2,
        'G': 9
    }

    best_value = alpha_beta(
        'A', depth=3, alpha=-math.inf, beta=math.inf,
        maximizingPlayer=True, game_tree=game_tree
    )

    print("Best value for maximizer:", best_value)


     output:

    Best value for maximizer: 3
```

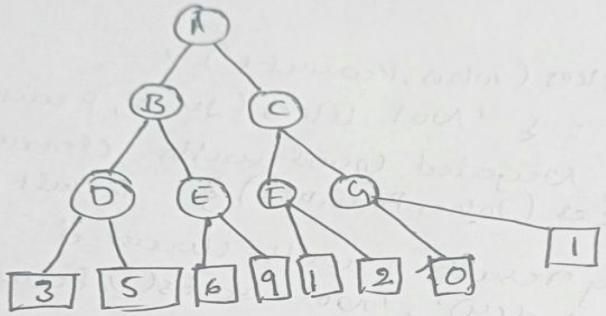
Srinidhi B V

Feb 15-18

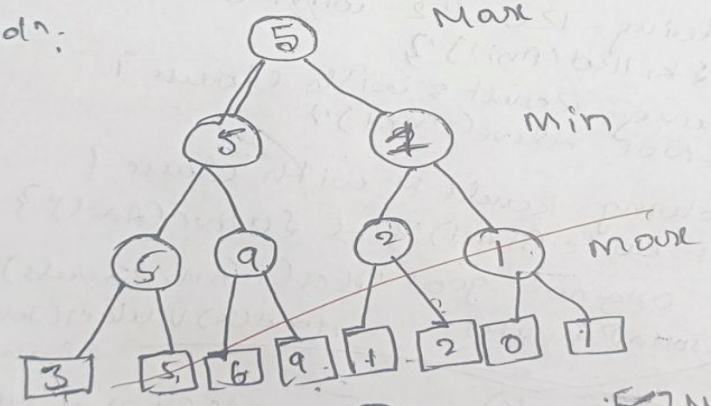
Min-Max Algorithm



Solve using min-max & Alpha-Beta



Soln:



$\alpha \geq \beta$