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

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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 **Sidhvin Vidyadhar Burli(1BM21CS211) ,**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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Tic Tac - Toe

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

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

def spaceFree (pos):
    if (board[pos] == ' '):
        return True
    else:
        return False

def checkwin () :
    if (board[1] == board[2] and board[1] == board[3] and
            board[1] != ' '):
        return True
    elif (board[4] == board[5] and board[4] == board[6] and
            board[4] != ' '):
        return True
    elif ( board[7] == board[8] and board[7] == board[9]
            and board[7] != ' ') :
        return True
```

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

    if isMax
        bestScore = -1000
        for key in board.keys():
            if board[key] == ' ' :
                board[key] = bot
                score = minimax (board, false)
                board [key] = ' '
                if ( score > bestscore ):
                    bestscore = score
        return bestScore
    else:
        bestScore = 1000

        for key in board.keys():
            if board[key] == ' ' :
                board[key] = player
                score = minimax (board, True)
                board[key] = ' '
                if ( score < bestScore ):
                    bestScore = score
        return bestScore

while not checkWin():
    compMove()
    playerMove()
```

Code:

```
def print_board(board):
    print("\n")
    for row in board:
        print("|".join(row))
        print("-" * 5)
    print("\n")


def check_winner(board, player):
    for row in board:
        if all([cell == player for cell in row]):
            return True
    for col in range(3):
        if all([board[row][col] == player for row in range(3)]):
            return True
    if board[0][0] == player and board[1][1] == player and board[2][2] == player:
        return True
    if board[0][2] == player and board[1][1] == player and board[2][0] == player:
        return True
    return False


def is_board_full(board):
    return all([cell != ' ' for row in board for cell in row])
```

```
def player_move(board, player):
    while True:
        try:
            move = int(input(f"Player {player}, enter your move (1-9): ")) - 1
            if move < 0 or move >= 9:
                raise ValueError
            row, col = divmod(move, 3)
            if board[row][col] == ' ':
                board[row][col] = player
                break
            else:
                print("This spot is already taken. Try again.")
        except ValueError:
            print("Invalid input. Enter a number between 1 and 9.")


def play_game():
    board = [[' ' for _ in range(3)] for _ in range(3)]
    current_player = 'X'
    game_over = False
    print("Welcome to Tic Tac Toe!")
    print("Player X goes first.")
    print("Enter a number between 1-9 to make your move (1 is top-left and 9 is bottom-right).")
```

```
    print_board(board)
    while not game_over:
        player_move(board, current_player)
        print_board(board)
        if check_winner(board, current_player):
            print(f"Player {current_player} wins!")
            game_over = True
        elif is_board_full(board):
            print("It's a tie!")
            game_over = True
        else
  current_player = 'O' if current_player == 'X' else 'X'
if _name___== "_main_":
    play_game()
```

Implement Vaccum Cleaner Agent

18/10/21

Vacuum Cleaner

State:
State is determined by both agent and dirty location. Agent is in one of the two locations, each may or may not contain any dirt

Initial state:
Any state can be ~~designed~~ assigned as initial state

Actions:
Right: the agent moves to the right to find any dirt present
Left: the agent moves to left to find ~~any~~ dirt present
Suck: If dirt is present, the agent suck the operation dirt.

Repeats untill all the dirt is sucked

Ends when all the squares are cleaned

18.10

18/10/24

Vacuum Cleaner

State:
State is determined by both agent and dirty location. Agent is in one of the two locations, each may or may not contain any dirt

Initial State:
Any state can be ~~designed~~ assigned as initial state

Actions:
Right: the agent moves to the right to find any dirt present
Left: the agent moves to left to find ~~any~~ dirt present
Suck: If dirt is present, the agent suck the operation dirt.

Repeats untill all the dirt is sucked

Ends when all the squares are cleaned

18.10

Code:

```
if state['A'] == 0 and state['B'] == 0:

print("Turning vacuum off") return

     if state[loc] == 1:
        state[loc] = 0
        count += 1
        print(f"Cleaned {loc}.")
        next_loc = 'B' if loc == 'A' else 'A'
        state[loc] = int(input(f"Is {loc} clean now? (0 if clean, 1 if dirty): "))
        if(state[next_loc]!=1):
          state[next_loc]=int(input(f"Is {next_loc} dirty? (0 if clean, 1 if dirty): "))
     if(state[loc]==1):
       rec(state,loc)
     else:
       next_loc = 'B' if loc == 'A' else 'A'
       dire="left" if loc=="B" else "right"
       print(loc,"is clean")
       print(f"Moving vacuum {dire}")
       if state[next_loc] == 1:
           rec(state, next_loc)

  state = {}
```

```python
state['A'] = int(input("Enter state of A (0 for clean, 1 for dirty): "))

state['B'] = int(input("Enter state of B (0 for clean, 1 for dirty): "))

loc = input("Enter location (A or B): ")

rec(state, loc)

print("Cost:",count)

print(state)
```

```
Enter state of A (0 for clean, 1 for dirty): 0
Enter state of B (0 for clean, 1 for dirty): 0
Enter location (A or B): A
Turning vacuum off
Cost: 0
{'A': 0, 'B': 0}
```

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)

Algorithm

Let Fringe be a list containing state

loop
    if Fringe is empty return failure
    Node ← remove-first (Fringe)
    if Node is a goal
        then return the path from initial state to node
    else generate all successor of Node, and
        add generated node back to the fringe
End loop

DFS Algorithm

Let fringe be a list containing state

loop
    if fringe is empty return Failure
    Node ← remove-first (fringe)
    if Node is a goal
        then return the path from initial state to no
    else generate all successor of Node, and
        add generated node ~~back~~ front to the fringe

End loop

```
goal_state=[
[1,2,3],

[4,5,6],
 [7, 8, 0]]



    def is_goal(state):

        return state == goal_state

    def find_blank(state):

        for i in range(3):

            for j in range(3):

                if state[i][j] == 0:

                    return i, j

    def swap(state, i1, j1, i2, j2):

        new_state = [row[:] for row in state]

        new_state[i1][j1], new_state[i2][j2] = new_state[i2][j2], new_state[i1][j1]

        return new_state

    def get_neighbors(state):

        neighbors = []

        i, j = find_blank(state)

        if i > 0:

            neighbors.append(swap(state, i, j, i - 1, j))

        if i < 2:

            neighbors.append(swap(state, i, j, i + 1, j))

        if j > 0:

            neighbors.append(swap(state, i, j, i, j - 1))

        if j < 2:
```

```
        neighbors.append(swap(state, i, j, i, j + 1))
    return neighbors
def dfs(state, visited, path):
    state_tuple = tuple(tuple(row) for row in state)
    if state_tuple in visited:
        return None
    visited.add(state_tuple)
    if is_goal(state):
        return path
    for neighbor in get_neighbors(state):
        result = dfs(neighbor, visited, path + [neighbor])
        if result is not None:
            return result

    return None

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

visited = set()
solution = dfs(initial_state, visited, [])
```

```
if solution:
    print("Solution found in", len(solution), "steps:")
    for step in solution:
        for row in step:
            print(row)
        print()
else:
    print("No solution found.")
```

```
Solution found in 2 steps:
[1, 2, 3]
[4, 5, 6]
[7, 0, 8]

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

Implement BFS algorithm

BFS Algorithm

Let Fringe be a list containing state

loop

if fringe is empty return failure

Node ← remove-first (fringe)

if Node is a goal

then return the path from initial state to node

else generate all successor of Node, and

add generated node back to the fringe

End loop

class PuzzleState:

def __init__(self, board, moves=0):

```
        self.board = board
        self.blank_index = board.index(0)  # Find the index of the blank space (0)
        self.moves = moves

    def get_possible_moves(self):
        possible_moves = []
        row, col = divmod(self.blank_index, 3)

        # Define possible movements: up, down, left, right
        directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]  # (row_change, col_change)

        for dr, dc in directions:
            new_row, new_col = row + dr, col + dc
            if 0 <= new_row < 3 and 0 <= new_col < 3:
                new_blank_index = new_row * 3 + new_col
                new_board = self.board[:]
                # Swap the blank with the adjacent tile
                new_board[self.blank_index], new_board[new_blank_index] =
new_board[new_blank_index], new_board[self.blank_index]
                possible_moves.append(PuzzleState(new_board, self.moves + 1))

        return possible_moves

    def is_goal(self, goal_state):
```

```
        return self.board == goal_state


def depth_limited_search(state, depth, goal_state):
    if state.is_goal(goal_state):
        return state
    if depth == 0:
        return None

    for next_state in state.get_possible_moves():
        result = depth_limited_search(next_state, depth - 1, goal_state)
        if result is not None:
            return result

    return None


def iterative_deepening_search(initial_state, goal_state):
    depth = 0
    while True:
        result = depth_limited_search(initial_state, depth, goal_state)
        if result is not None:
            return result
        depth += 1
```

```python
# Example Usage
if __name__ == "__main__":
    initial_board = [2, 8, 3, 1, 6, 4, 7, 0, 5]  # Initial state
    goal_state = [2, 0, 3, 1, 8, 4, 7, 6, 5]  # Final state
    initial_state = PuzzleState(initial_board)

    solution = iterative_deepening_search(initial_state, goal_state)

    if solution:
        print("Solution found!")
        print("Moves:", solution.moves)
        print("Final Board State:", solution.board)
    else:
        print("No solution found.")
```

```
Solution found!
Moves: 2
Final Board State: [2, 0, 3, 1, 8, 4, 7, 6, 5]
```

Program 3

Implement A* Search Algorithm

Misplaced Tiles:

Knowledge base using PL

Procedure Prove (Query):

a. If Query matches the fact
return true

b. If Query matches head of Rule
i Prove each subgoal in Body:
for each element in Body.
If prove(subgoal) fails:
return false

if all are true:
return true

else:
false

Output
KB = ["A", "B", "A & B => C", "C => D"]
query = 'D'

Query is entailed by KB

```
import heapq
    def manhattan_distance(state, goal):
    distance = 0

    for i in range(3):

        for j in range(3):

            tile = state[i][j]

            if tile != 0:

                for r in range(3):

                    for c in range(3):

                        if goal[r][c] == tile:

                            target_row, target_col = r, c

                            break

                distance += abs(target_row - i) + abs(target_col - j)

    return distance


  def findmin(open_list, goal):

    minv = float('inf')

    best_state = None

    for state in open_list:

        h = manhattan_distance(state['state'], goal)

        f = state['g'] + h

        if f < minv:

            minv = f

            best_state = state

    open_list.remove(best_state)
```

```python
    return best_state


def operation(state):
    next_states = []
    blank_pos = find_blank_position(state['state'])
    for move in ['up', 'down', 'left', 'right']:
        new_state = apply_move(state['state'], blank_pos, move)
        if new_state:
            next_states.append({
                'state': new_state,
                'parent': state,
                'move': move,
                'g': state['g'] + 1
            })
    return next_states


def find_blank_position(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
    return None
```

```
def apply_move(state, blank_pos, move):
    i, j = blank_pos
    new_state = [row[:] for row in state]
    if move == 'up' and i > 0:
        new_state[i][j], new_state[i - 1][j] = new_state[i - 1][j], new_state[i][j]
    elif move == 'down' and i < 2:
        new_state[i][j], new_state[i + 1][j] = new_state[i + 1][j], new_state[i][j]
    elif move == 'left' and j > 0:
        new_state[i][j], new_state[i][j - 1] = new_state[i][j - 1], new_state[i][j]
    elif move == 'right' and j < 2:
        new_state[i][j], new_state[i][j + 1] = new_state[i][j + 1], new_state[i][j]
    else:
        return None
    return new_state


def print_state(state):
    for row in state:
        print(' '.join(map(str, row)))
initial_state = [[2, 8, 3], [1, 6, 4], [7, 0, 5]]
goal_state = [[1, 2, 3], [8, 0, 4], [7, 6, 5]]


open_list = [{'state': initial_state, 'parent': None, 'move': None, 'g': 0}]
visited_states = []
```

```
while open_list:
    best_state = findmin(open_list, goal_state)

    h = manhattan_distance(best_state['state'], goal_state)
    f = best_state['g'] + h

    print(f"g(n) = {best_state['g']}, h(n) = {h}, f(n) = {f}")
    print_state(best_state['state'])
    print()

    if h == 0:
        print("Goal state reached!")
        break

    visited_states.append(best_state['state'])
    next_states = operation(best_state)

    for state in next_states:
        if state['state'] not in visited_states:
            open_list.append(state)

if h == 0:
```

```
    moves = []
    goal_state_reached = best_state
    while goal_state_reached['move'] is not None:
        moves.append(goal_state_reached['move'])
        goal_state_reached = goal_state_reached['parent']
    moves.reverse()
    print("\nMoves to reach the goal state:", moves)
else:
    print("No solution found.")
```

```
g(n) = 0, h(n) = 5, f(n) = 5
2 8 3
1 6 4
7 0 5

g(n) = 1, h(n) = 4, f(n) = 5
2 8 3
1 0 4
7 6 5

g(n) = 2, h(n) = 3, f(n) = 5
2 0 3
1 8 4
7 6 5

g(n) = 3, h(n) = 2, f(n) = 5
0 2 3
1 8 4
7 6 5

g(n) = 4, h(n) = 1, f(n) = 5
1 2 3
0 8 4
7 6 5

g(n) = 5, h(n) = 0, f(n) = 5
1 2 3
8 0 4
7 6 5

Goal state reached!

Moves to reach the goal state: ['up', 'up', 'left', 'down', 'right']
```

Misplaced Tiles:

```
import heapq

defind_blank_tile(st
    ate):
for i in range(3):
    for j in range(3):
if state[i][j] == 0:
    return i, j
  return None


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


def generate_moves(state):
  moves = []
  x, y = find_blank_tile(state)
  directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]


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

```python
            moves.append(new_state)
    return moves


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


def a_star_8_puzzle(start, goal):

    open_list = []

    heapq.heappush(open_list, (count_misplaced_tiles(start, goal), 0, start, None))

    visited = set()

    while open_list:

        f_n, g_n, current_state, previous_state = heapq.heappop(open_list)

        print(f"g(n) = {g_n}, h(n) = {f_n - g_n}, f(n) = {f_n}")
        print_state(current_state)
```

```
        if current_state == goal:
            print("Goal state reached!")
            return

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

        for move in generate_moves(current_state):
            move_tuple = tuple(map(tuple, move))
            if move_tuple not in visited:

                g_move = g_n + 1
                h_move = count_misplaced_tiles(move, goal)
                f_move = g_move + h_move
                heapq.heappush(open_list, (f_move, g_move, move, current_state))

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

a_star_8_puzzle(start_state, goal_state)
```

```
g(n) = 0, h(n) = 4, f(n) = 4
[2, 8, 3]
[1, 6, 4]
[7, 0, 5]

g(n) = 1, h(n) = 3, f(n) = 4
[2, 8, 3]
[1, 0, 4]
[7, 6, 5]

g(n) = 2, h(n) = 3, f(n) = 5
[2, 0, 3]
[1, 8, 4]
[7, 6, 5]

g(n) = 2, h(n) = 3, f(n) = 5
[2, 8, 3]
[0, 1, 4]
[7, 6, 5]

g(n) = 3, h(n) = 2, f(n) = 5
[0, 2, 3]
[1, 8, 4]
[7, 6, 5]

g(n) = 4, h(n) = 1, f(n) = 5
[1, 2, 3]
[0, 8, 4]
[7, 6, 5]

g(n) = 5, h(n) = 0, f(n) = 5
[1, 2, 3]
[8, 0, 4]
[7, 6, 5]

Goal state reached!
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem.

Hill climbing search algorithm

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

current ← make-node(problem.initial-state)

loop do

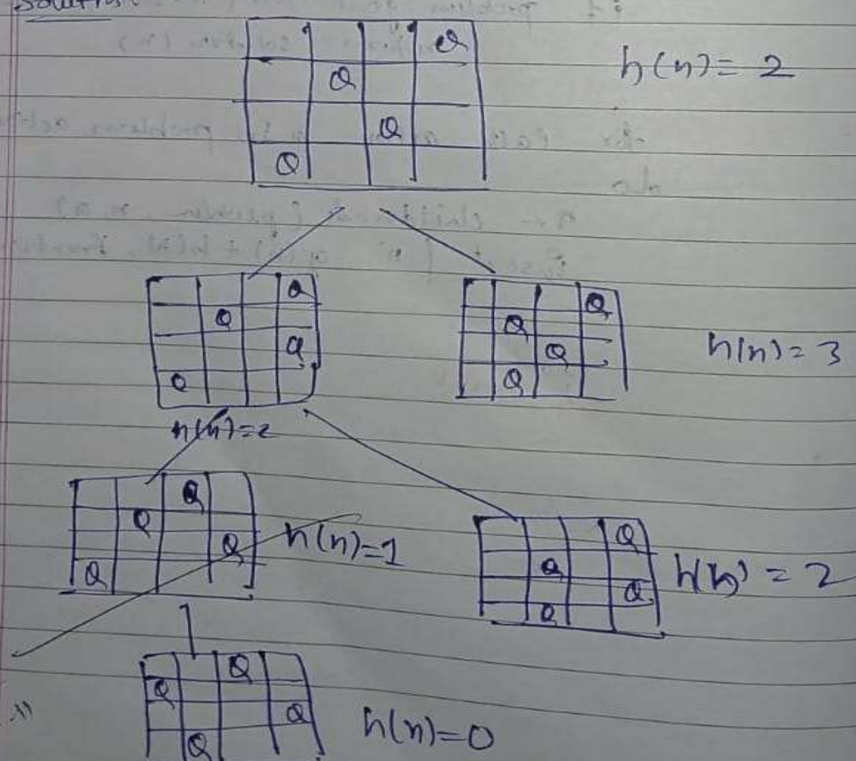
neighbour ← a highest-valued successor of current

if neighbour.value ≤ current.value

then return current.state

current ← neighbour

Solution:



08.11

```
import random

class NQueens:

    def _init_(self, n):

        self.n = n

        self.board = self.init_board()

    def init_board(self):

        # Randomly place one queen in each column

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



    def fitness(self, board):

        # Count the number of pairs of queens attacking each other

        conflicts = 0

        for col in range(self.n):

            for other_col in range(col + 1, self.n):

                if board[col] == board[other_col] or abs(board[col] - board[other_col]) == abs(col - 
other_col):

                    conflicts += 1

        return conflicts

    def get_neighbors(self, board):

        neighbors = []

        for col in range(self.n):

            for row in range(self.n):

                if row != board[col]:  # Move queen to a different row in the same column

                    new_board = board[:]
```

```
            new_board[col] = row
            neighbors.append(new_board)
    return neighbors
def hill_climbing(self):
    current_board = self.board
    current_fitness = self.fitness(current_board)

    while current_fitness > 0:
        neighbors = self.get_neighbors(current_board)
        next_board = None
        next_fitness = current_fitness
        for neighbor in neighbors:
            neighbor_fitness = self.fitness(neighbor)
            if neighbor_fitness < next_fitness:
                next_fitness = neighbor_fitness
                next_board = neighbor
        if next_board is None:
            # Stuck at local maximum, can either return or restart
            print("Stuck at local maximum. Restarting...")
            self.board = self.init_board()
            current_board = self.board
            current_fitness = self.fitness(current_board)
        else:
```

```
            current_board = next_board
            current_fitness = next_fitness
        return current_board

# Example usage
if __name__ == "__main__":
    n = 4  # Size of the board (N)
    n_queens_solver = NQueens(n)
    solution = n_queens_solver.hill_climbing()

    print("Solution:")
    for row in solution:
        line = ['Q' if i == row else '.' for i in range(n)]
        print(' '.join(line))
```

```
Solution:
. Q . .
. . . Q
Q . . .
. . Q .
```

Program 5

Simulated Annealing to Solve 8-Queens problem.

Simulated Annealing - Basic Algorithm

current ← initial state
T ← a large positive value
while T > 0 do
    next ← a random neighbour for current
    ΔE ← current.cost - next.cost
    if ΔE > 0 then
        current ← next
    else
        current ← next with probability $p = e^{\Delta E / T}$
    end if
    decrease T
end while
return current

Algorithm :

current ← randomly generated initial state
current_cost ← cost (current)
T ← a large positive value
While T > 0 and current_cost > 0
    neighbour ← generated neighbours of current state
    neighbour_cost = cost (neighbour)
    cost_diff = current_cost - neighbour_cost
    if cost_diff > 0 :
        current ← neighbour
        current_cost ← neighbour_cost
    T = T - 1
end while
return current, current_state

```
import random
import math


def print_board(state):
    size = len(state)
    for i in range(size):
        row = ['.'] * size
        row[state[i]] = 'Q'
        print(' '.join(row))
    print()


def calculate_conflicts(state):
    conflicts = 0
    size = len(state)
    for i in range(size):
        for j in range(i + 1, size):
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                conflicts += 1
    return conflicts


def random_state(size):
    return [random.randint(0, size - 1) for _ in range(size)]
```

```
def neighbor(state):
    new_state = state[:]
    idx = random.randint(0, len(state) - 1)
    new_state[idx] = random.randint(0, len(state) - 1)
    return new_state


def simulated_annealing(size, initial_temp, cooling_rate):
    current_state = random_state(size)
    current_conflicts = calculate_conflicts(current_state)
    temperature = initial_temp

    while temperature > 1:
        new_state = neighbor(current_state)
        new_conflicts = calculate_conflicts(new_state)

        # If new state is better, accept it
        if new_conflicts < current_conflicts:
            current_state, current_conflicts = new_state, new_conflicts
        else:
            # Accept with a probability based on temperature
            acceptance_probability = math.exp((current_conflicts - new_conflicts) / temperature)
            if random.random() < acceptance_probability:
                current_state, current_conflicts = new_state, new_conflicts
```

```
        temperature *= cooling_rate

    return current_state

def main():
    size = 8
    initial_temp = 1000
    cooling_rate = 0.995

    solution = simulated_annealing(size, initial_temp, cooling_rate)
    print("Solution found:")
    print_board(solution)
    print("Conflicts:", calculate_conflicts(solution))

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

```
Solution found:
. . . . . . Q .
. . Q . . . . .
. . . . . . . Q
Q . . . . . . .
. . . . Q . . .
. . . Q . . . .
. . . . Q . . .
. . . . . Q . .

Conflicts: 6
```

```
def truth_table_entailment():
    print(f"{'A':<7}{'B':<7}{'C':<7}{'A or C':<12}{'B or not C':<15}{'KB':<8}{'alpha':<10}")
    print("-" * 65)
    all_entail = True
    for A in [False, True]:
        for B in [False, True]:
            for C in [False, True]:
                # Calculate individual components
                A_or_C = A or C                    # A or C
                B_or_not_C = B or (not C)          # B or not C
                KB = A_or_C and B_or_not_C         # KB = (A or C) and (B or not C)
                alpha = A or B                     # alpha = A or B

                # Determine if KB entails alpha for this row
                kb_entails_alpha = (not KB) or alpha  # True if KB implies alpha

                # If in any row KB does not entail alpha, set flag to False
                if not kb_entails_alpha:
                    all_entail = False

                # Print the results for this row
print(f"{str(A):<7}{str(B):<7}{str(C):<7}{str(A_or_C):<12}{str(B_or_not_C):<15}{str(KB):<8
}{str(alpha):<10}")
```

```
    # Final result based on all rows
    if all_entail:
        print("\nKB entails alpha for all cases.")
    else:
        print("\nKB does not entail alpha for all cases.")


# Run the function to display the truth table and final result
truth_table_entailment()
```

```
A      B      C      A or C      B or not C     KB      alpha
-----------------------------------------------------------------
False  False  False  False       True           False   False
False  False  True   True        False          False   False
False  True   False  False       True           False   True
False  True   True   True        True           True    True
True   False  False  True        True           True    True
True   False  True   True        False          False   True
True   True   False  True        True           True    True
True   True   True   True        True           True    True

KB entails alpha for all cases.
```

Program 7

Implement unification in first order logic.

22/11/24

Unification Algorithm

Algorithm : Unify (Ψ_1, Ψ_2)

Step 1: if Ψ_1 or Ψ_2 is variable or constant then:

if Ψ_1 or Ψ_2 are identical, then,
return NIL.

else if Ψ_1 is variable,
then
if Ψ_1 occurs in Ψ_2 then
return failure
else
return { (Ψ_2/Ψ_1) }

else if Ψ_2 is a variable:
if Ψ_2 occurs in Ψ_1 then
return failure
else
return { (Ψ_1/Ψ_2) }

else:
return failure

Step 2: if the initial predicate symbol in Ψ_1 and Ψ_2 are not same, then
return failure

Step 3: if Ψ_1 and Ψ_2 have different no. of arguments, then
return failure

Step 4: Set substitution set (SUBST) to NIL

Step 5:
for i=1 to no. of element in Ψ_1
call unify function with ith element of Ψ_1 & ith element of Ψ_2 and put the result to S
if S = failure ; return failure
else if S ≠ NIL then do
apply S to remainder of both L1 and L2
SUBST = APPEND (S, SUBST)

return SUBST

```
"""
    Perform unification on two expressions in first-order logic.

    Args:
        expr1: The first expression (can be a variable, constant, or list representing a function).
        expr2: The second expression.
        substitution: The current substitution (dictionary).

    Returns:
        A dictionary representing the most general unifier (MGU), or None if unification fails.
    """
    if substitution is None:
        substitution = {}

    # Debug: Print inputs and current substitution
    print(f"Unifying {expr1} and {expr2} with substitution {substitution}")

    # Apply existing substitutions to both expressions
    expr1 = apply_substitution(expr1, substitution)
    expr2 = apply_substitution(expr2, substitution)

    # Debug: Print expressions after applying substitution
    print(f"After substitution: {expr1} and {expr2}")
```

```
# Case 1: If expressions are identical, no substitution is needed
if expr1 == expr2:
    return substitution


# Case 2: If expr1 is a variable
if is_variable(expr1):
    return unify_variable(expr1, expr2, substitution)


# Case 3: If expr2 is a variable
if is_variable(expr2):
    return unify_variable(expr2, expr1, substitution)


# Case 4: If both are compound expressions (e.g., functions or predicates)
if is_compound(expr1) and is_compound(expr2):
    if expr1[0] != expr2[0] or len(expr1) != len(expr2):
        print(f"Failure: Predicate names or arity mismatch {expr1[0]} != {expr2[0]}")
        return None  # Function names or arity mismatch
    for arg1, arg2 in zip(expr1[1:], expr2[1:]):
        substitution = unify(arg1, arg2, substitution)
        if substitution is None:
            print(f"Failure: Could not unify arguments {arg1} and {arg2}")
            return None
```

```
        return substitution

    # Case 5: Otherwise, unification fails
    print(f"Failure: Could not unify {expr1} and {expr2}")
    return None

def unify_variable(var, expr, substitution):
    """
    Handles the unification of a variable with an expression.

    Args:
        var: The variable.
        expr: The expression to unify with.
        substitution: The current substitution.

    Returns:
        The updated substitution, or None if unification fails.
    """
    if var in substitution:
        # Apply substitution recursively
        return unify(substitution[var], expr, substitution)
    elif occurs_check(var, expr):
        # Occurs check fails if the variable appears in the term it's being unified with
```

```
        print(f"Occurs check failed: {var} in {expr}")
        return None
    else:
        substitution[var] = expr
        print(f"Substitution added: {var} -> {expr}")
        return substitution


def occurs_check(var, expr):
    """
    Checks if a variable occurs in an expression (to prevent cyclic substitutions).


    Args:
        var: The variable to check.
        expr: The expression to check against.


    Returns:
        True if the variable occurs in the expression, otherwise False.
    """
    if var == expr:
        return True
    elif is_compound(expr):
        return any(occurs_check(var, arg) for arg in expr[1:])
    return False
```

```python
def is_variable(expr):
    """Checks if the expression is a variable."""
    return isinstance(expr, str) and expr[0].islower()


def is_compound(expr):
    """Checks if the expression is compound (e.g., function or predicate)."""
    return isinstance(expr, list) and len(expr) > 0


def apply_substitution(expr, substitution):
    """
    Applies a substitution to an expression.


    Args:
        expr: The expression to apply the substitution to.
        substitution: The current substitution.


    Returns:
        The updated expression with substitutions applied.
    """
    if is_variable(expr) and expr in substitution:
        return apply_substitution(substitution[expr], substitution)
    elif is_compound(expr):
```

```
        return [apply_substitution(arg, substitution) for arg in expr]
    return expr


# Example Usage:
expr1 = ['P', 'X', 'Y']
expr2 = ['P', 'a', 'Z']
result = unify(expr1, expr2)
print("Unification Result:", result)
```

```
Unifying ['P', 'X', 'Y'] and ['P', 'a', 'Z'] with substitution {}
After substitution: ['P', 'X', 'Y'] and ['P', 'a', 'Z']
Unifying X and a with substitution {}
After substitution: X and a
Substitution added: a -> X
Unifying Y and Z with substitution {'a': 'X'}
After substitution: Y and Z
Failure: Could not unify Y and Z
Failure: Could not unify arguments Y and Z
Unification Result: None
```

Program 8

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

22/11/24

Forward Reasoning Algorithm

function FOL-FC-ASK (KB, α) returns a subs or false
  inputs: KB, the knowledge base, a set of FOL clauses α,
    the query, an atomic sentence

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

repeat until new is empty
  new ← { }
  for each rule in KB do
    ($p_1 \wedge \ldots \wedge p_n \Rightarrow q$) ← S-V (rule)
    for each θ such that subset(θ, $p_1 \wedge \ldots p_n$)
      = subset (θ, $p_1' \wedge \ldots \wedge p_n'$)
      for some $p_1' \ldots p_n'$ in KB
    q' ← subset (θ, q)
    if q' does not unify with some sentence already in KB or new then
      add q' to new
      ϕ ← unify (q', α)
      if ϕ is not fail then
      return ϕ
  add new to KB
return false

Class Forward_reasoninig:

self.rules = rules # List of rules (condition -> result)

self.facts = set(facts) # Known facts

```python
    def infer(self):
        applied_rules = True

        while applied_rules:
            applied_rules = False
            for rule in self.rules:
                condition, result = rule
                if condition.issubset(self.facts) and result not in self.facts:
                    self.facts.add(result)
                    applied_rules = True
                    print(f"Applied rule: {condition} -> {result}")
        return self.facts


# Define rules as (condition, result) where condition is a set
rules = [
    ({"A"}, "B"),
    ({"B"}, "C"),
    ({"C", "D"}, "E"),
    ({"E"}, "F")
]

# Define initial facts
facts = {"A", "D"}

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

print("\nFinal facts:")
print(final_facts)
```

```
Applied rule: {'A'} -> B
Applied rule: {'B'} -> C
Applied rule: {'C', 'D'} -> E
Applied rule: {'E'} -> F

Final facts:
{'C', 'E', 'B', 'F', 'A', 'D'}
```

Program 9

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

KB using PL and proving query using Resolution

Procedure Res (KB, Query)
  Negate (Query)
  convert KB → CNF
  Add (¬Q) to set of clause

Initialise set of clauses
  clauses = KB ∪ {¬Q}

while true:
  select 2 clauses from set
  Not found, move to next pair

  If ¬Literals found:
    resolve two clauses

  if clause are empty
    return True.

If clauses ≠ { }
  return False

```
# Define the knowledge base (KB) as a set of facts KB =
set()
    # Premises based on the provided FOL problem
    KB.add('American(Robert)')
    KB.add('Enemy(America, A)')
    KB.add('Missile(T1)')
    KB.add('Owns(A, T1)')
    # Define inference rules
    def modus_ponens(fact1, fact2, conclusion):
    """ Apply modus ponens inference rule: if fact1 and fact2 are true, then conclude conclusion
    """
    if fact1 in KB and fact2 in KB:
    KB.add(conclusion)
    print(f"Inferred: {conclusion}")
    def forward_chaining():
    """ Perform forward chaining to infer new facts until no more inferences can be made """
    # 1. Apply: Missile(x) → Weapon(x)
    if 'Missile(T1)' in KB:
    KB.add('Weapon(T1)')
    print(f"Inferred: Weapon(T1)")
    1
    # 2. Apply: Sells(Robert, T1, A) from Owns(A, T1) and Weapon(T1)
    if 'Owns(A, T1)' in KB and 'Weapon(T1)' in KB:
    KB.add('Sells(Robert, T1, A)')
    print(f"Inferred: Sells(Robert, T1, A)")
    # 3. Apply: Hostile(A) from Enemy(A, America)
    if 'Enemy(America, A)' in KB:
    KB.add('Hostile(A)')
    print(f"Inferred: Hostile(A)")
    # 4. Now, check if the goal is reached (i.e., if 'Criminal(Robert)' can be inferred)
    if 'American(Robert)' in KB and 'Weapon(T1)' in KB and 'Sells(Robert, T1, A)' in KB and
    'Hostile(A)' in KB:
```

```
KB.add('Criminal(Robert)')
print("Inferred: Criminal(Robert)")
# Check if we've reached our goal
if 'Criminal(Robert)' in KB:
print("Robert is a criminal!")
else:
print("No more inferences can be made.")
# Run forward chaining to attempt to derive the conclusion
forward_chaining()
```

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

Program 10

Implement Alpha-Beta Pruning.

Alpha-beta pruning

```
Alphabeta(node, depth, α, β, max):

    if depth = 0 or terminal node:
        return h(n)

    if max:
        initialize maxEval to -∞
        for each child in node:
            Evaluate Alpha(child, depth-1,
                           α, β, False)
            maxEval = max(EvalChild, maxEval)

            if α ≥ β ; break (prune)

        return maxEval

    else (min-player)
        eval → +∞
        for each child in +∞
            evaluate AlphaBeta(child, depth,
                               α, β, true)
            update β to min of β & minval
            if β ≤ α , break

        return minEval
```

```
# Alpha-Beta Pruning Implementation
def alpha_beta_pruning(node, alpha, beta, maximizing_player):
# Base case: If it's a leaf node, return its value (simulating evaluation of the node)
if type(node) is int:
return node
# If not a leaf node, explore the children
if maximizing_player:
max_eval = -float('inf')
for child in node: # Iterate over children of the maximizer node
eval = alpha_beta_pruning(child, alpha, beta, False)
max_eval = max(max_eval, eval)
alpha = max(alpha, eval) # Maximize alpha
if beta <= alpha: # Prune the branch
break
return max_eval
else:
min_eval = float('inf')
for child in node: # Iterate over children of the minimizer node
eval = alpha_beta_pruning(child, alpha, beta, True)
min_eval = min(min_eval, eval)
beta = min(beta, eval) # Minimize beta
if beta <= alpha: # Prune the branch
1
break
return min_eval
# Function to build the tree from a list of numbers
def build_tree(numbers):
# We need to build a tree with alternating levels of maximizers and minimizers
# Start from the leaf nodes and work up
current_level = [[n] for n in numbers]
while len(current_level) > 1:
next_level = []
for i in range(0, len(current_level), 2):
if i + 1 < len(current_level):
next_level.append(current_level[i] + current_level[i + 1]) # Combine two nodes
else:
```

```
next_level.append(current_level[i]) # Odd number of elements, just carry forward
current_level = next_level
return current_level[0] # Return the root node, which is a maximizer
# Main function to run alpha-beta pruning
def main():
# Input: User provides a list of numbers
numbers = list(map(int, input("Enter numbers for the game tree (space-separated): ").split()))
2
# Build the tree with the given numbers
tree = build_tree(numbers)
# Parameters: Tree, initial alpha, beta, and the root node is a maximizing player
alpha = -float('inf')
beta = float('inf')
maximizing_player = True # The root node is a maximizing player
# Perform alpha-beta pruning and get the final result
result = alpha_beta_pruning(tree, alpha, beta, maximizing_player)
print("Final Result of Alpha-Beta Pruning:", result)
if _name___== "_main_":
main()
```

```
Enter numbers for the game tree (space-separated): 10 9 14 18 5 4 50 3
Final Result of Alpha-Beta Pruning: 50
```