Artificial Intelligence Lab Report

Submitted by

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Program 1 - Tic Tac toe

Algorithm

Bafna Gold
Date: 4/10

* Implement TIC TAC TOE Game

→ Pseudocode

```
function minimax (Node, depth, isMaximizingPlayer)
        if node is a terminal state
            return evaluate (node)

if isMaximizingPlayer :
    bestValue = - infinity.
    for each child in node :
            value = minimax (child, depth+1, false)
            bestvalue = max (bestvalue, value)
            return bestValue
else :
    bestvalue = + infinity.
    for each child in node :
            value = minimax (child, depth+1, true
            bestvalue = min (bestvalue, value)
            return bestvalue.
```

10/4/24

CamScanner

Code

```
import random
class TicTacToe:
def __init__(self):
self.board = []
    def create_board(self):
        for i in range(3):
            row = []
            for j in range(3):
                row.append('-')
            self.board.append(row)
    def get_random_first_player(self):
        return random.randint(0, 1)
    def fix_spot(self, row, col, player):
        self.board[row][col] = player
    def is_player_win(self, player):
        win = None
        n = len(self.board)
        for i in range(n):
            win = True
            for j in range(n):
                if self.board[i][j] != player:
                    win = False
                    break



            if win:
                return win
        for i in range(n):
            win = True
            for j in range(n):
                if self.board[j][i] != player:
                    win = False
                    break
            if win:
                return win
        win = True
        for i in range(n):
            if self.board[i][i] != player:
                win = False
                break
        if win:
```

```
        return win
    win = True
        for i in
    range(n):
        if self.board[i][n - 1 - i] != player:
            win = False
            break
    if win:
        return win
    return False
    for row in self.board:
        for item in row:
            if item == '-':
                return False
    return True
def is_board_filled(self):
    for row in self.board:
        for item in row:
            if item == '-':
                return False
    return True
def swap_player_turn(self, player):
    return 'X' if player == 'O' else 'O'
def show_board(self):
    for row in self.board:



        for item in row:
            print(item, end=" ")
        print()
def start(self):
    self.create_board()
    player = 'X' if self.get_random_first_player() == 1 else 'O'
    while True:
        print(f"Player {player} turn")
        self.show_board()
        row, col = list(
            map(int, input("Enter row and column numbers to fix spot: ").split()))
        print()
        self.fix_spot(row - 1, col - 1, player)
        if self.is_player_win(player):
            print(f"Player {player} wins the game!")
            break
```

```
            if self.is_board_filled():
                print("Match Draw!")
                break
            player = self.swap_player_turn(player)
        print()
        self.show_board()
tic_tac_toe = TicTacToe()
tic_tac_toe.start()
```

Output Snapshot

```
Player O turn
- - -
- - -
- - -
Enter row and column numbers to fix spot: 0 3
Player X turn
- - -
- - -
- - O
Enter row and column numbers to fix spot: 1 2
Player O turn
- X - - - -
- - O
Enter row and column numbers to fix spot: 3 0
Player X turn
- X -
- - -
- - O
Enter row and column numbers to fix spot: 3 2
Player O turn
- X -
- - -
- X O
Enter row and column numbers to fix spot: 2 1
Player X turn
- X -
O - -
- X O
Enter row and column numbers to fix spot: 2 2
Player X wins the game!
```

Program 2 - 8 Puzzle

Algorithm

Date 18/1

* Solution to 8 - Puzzle Problem.

-> BFS :-

Algorithm

let fringe be a list containing the initial 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, and add generated nodes to the fringe

End Loop.

-> DFS :

Algorithm

let fringe be a list containing the initial 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 successors.

State space tree

?

CamScanner

Code

```
import sys
import numpy as np
class Node:
    def __init__(self, state, parent, action):
        self.state = state
        self.parent = parent
        self.action = action
class StackFrontier:
    def __init__(self):
        self.frontier = []
    def add(self, node):
        self.frontier.append(node)
    def contains_state(self, state):
        return any((node.state[0] == state[0]).all() for node in self.frontier)
    def empty(self):
        return len(self.frontier) == 0
    def remove(self):
        if self.empty():
            raise Exception("Empty Frontier")
        else:
            node = self.frontier[-1]
            self.frontier = self.frontier[:-1]
            return node



class QueueFrontier(StackFrontier):
    def remove(self):
        if self.empty():
            raise Exception("Empty Frontier")
        else:
            node = self.frontier[0]
            self.frontier = self.frontier[1:]
            return node
class Puzzle:
    def __init__(self, start, startIndex, goal, goalIndex):
        self.start = [start, startIndex]
        self.goal = [goal, goalIndex]
        self.solution = None

    def neighbors(self, state):
        mat, (row, col) = state
```

```
        results = []
        if row > 0:
            mat1 = np.copy(mat)
            mat1[row][col] = mat1[row - 1][col]
            mat1[row - 1][col] = 0
            results.append(('up', [mat1, (row - 1, col)]))
        if col > 0:
            mat1 = np.copy(mat)
            mat1[row][col] = mat1[row][col - 1]
            mat1[row][col - 1] = 0
            results.append(('left', [mat1, (row, col - 1)]))
        if row < 2:
            mat1 = np.copy(mat)
            mat1[row][col] = mat1[row + 1][col]
            mat1[row + 1][col] = 0
            results.append(('down', [mat1, (row + 1, col)]))
        if col < 2:
            mat1 = np.copy(mat)
            mat1[row][col] = mat1[row][col + 1]
            mat1[row][col + 1] = 0
            results.append(('right', [mat1, (row, col + 1)]))
        return results
    def print(self):
        solution = self.solution if self.solution is not None else None



        print("Start State:\n", self.start[0], "\n")
        print("Goal State:\n", self.goal[0], "\n")
        print("\nStates Explored: ", self.num_explored, "\n")
        print("Solution:\n ")
        for action, cell in zip(solution[0], solution[1]):
            print("action: ", action, "\n", cell[0], "\n")
        print("Goal Reached!!")
    def does_not_contain_state(self, state):
        for st in self.explored:
            if (st[0] == state[0]).all():
            return False
        return True
    def solve(self):
        self.num_explored = 0
        start = Node(state=self.start, parent=None, action=None)
```

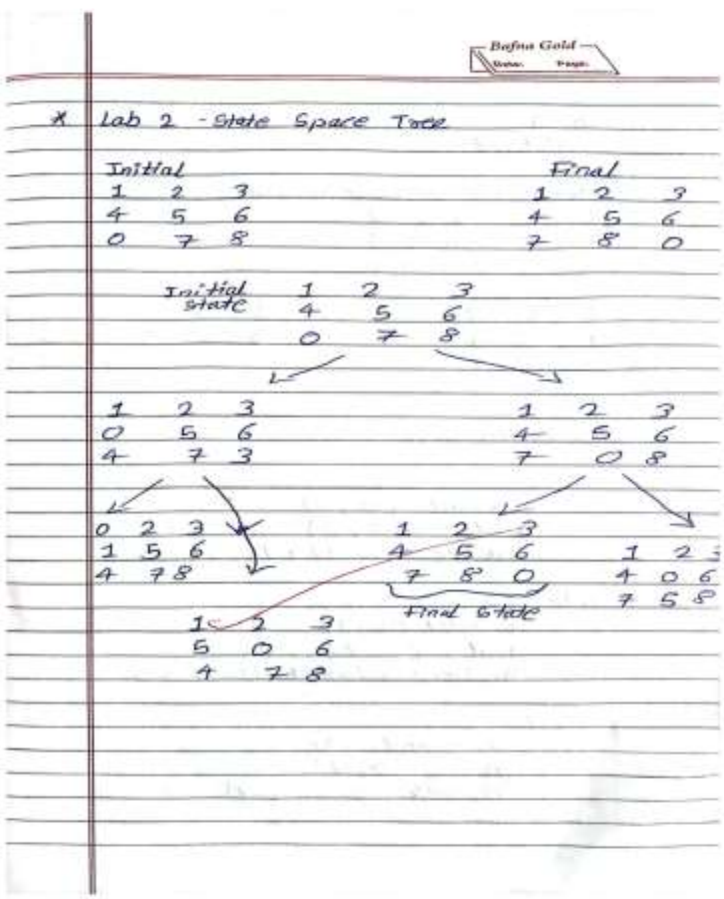
```
        frontier = QueueFrontier()
        frontier.add(start)
        self.explored = []
        while True:
            if frontier.empty():
                raise Exception("No solution")
            node = frontier.remove()
            self.num_explored += 1
            if (node.state[0] == self.goal[0]).all():
                actions = []
                cells = []
                while node.parent is not None:
                    actions.append(node.action)
                    cells.append(node.state)
                    node = node.parent
                actions.reverse()
                cells.reverse()
                self.solution = (actions, cells)
                return
            self.explored.append(node.state)
            for action, state in self.neighbors(node.state):
    if not frontier.contains_state(state) and self.does_not_contain_state(state): child =
                    Node(state=state, parent=node, action=action)
                    frontier.add(child)
start = np.array([[1, 2, 3], [8, 0, 4], [7, 6, 5]])


goal = np.array([[2, 8, 1], [0, 4, 3], [7, 6, 5]])
startIndex = (1, 1)
goalIndex = (1, 0)
p = Puzzle(start, startIndex, goal, goalIndex)
p.solve() p.print()
```

Output Snapshot

```
Start State:
 [[1 2 3]
 [8 0 4]
 [7 6 5]]

Goal State:
 [[2 8 1]
 [0 4 3]
 [7 6 5]]

States Explored:  358

Solution:

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

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

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

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

action:  right
 [[8 1 3]
 [2 4 0]
 [7 6 5]]
```

```
action:  down
 [[8 1 3]
 [0 2 4]
 [7 6 5]]

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

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

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

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

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

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

Goal Reached!!
```

State Space Tree



Program 03 - A* Algorithm

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Lab-03

* A* Algorithm

function A* search (problem) returns a soluti
or failure
node ← a node n with n state:
problem.initial state.

frontier ← a priority queue ordered
by ascending g+h, only element

Loop do
if empty >(frontier) then return
failure.
n← pop (frontier)
if problem.goalTest (n.state) then
return Solution
for each action a in problem
actions (n.state) do
n'← childNode (problem, n, a)
insert (n', g(n) + h(n'),
frontier)

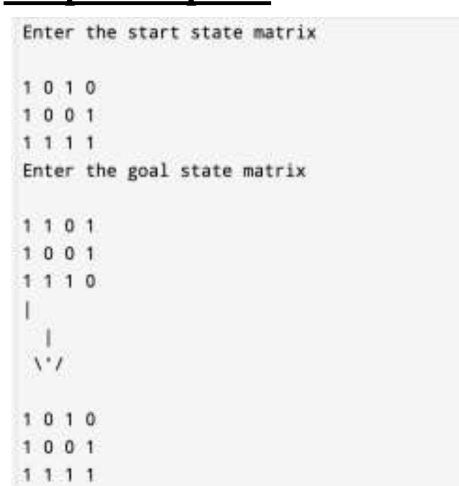
CamScanner

Code

```
def print_b(src):
    state = src.copy()
    state[state.index(-1)] = ' '
    print(
f"""
{state[0]} {state[1]} {state[2]}
{state[3]} {state[4]} {state[5]}
{state[6]} {state[7]} {state[8]}
“””
    )
def h(state, target):
    count = 0
    i = 0
    for j in state:
        if state[i] != target[i]:
            count = count+1
    return count
def astar(state, target):
    states = [src]
    g = 0
    visited_states = []
    while len(states):
        print(f"Level: {g}")
        moves = []
        for state in states:
            visited_states.append(state)
            print_b(state)
            if state == target:
                print("Success")
                return
            moves += [move for move in possible_moves(
                state, visited_states) if move not in moves]
        costs = [g + h(move, target) for move in moves]
        states = [moves[i]
                for i in range(len(moves)) if costs[i] == min(costs)]
        g += 1
    print("Fail")
def possible_moves(state, visited_state):
```

```
    b = state.index(-1)
    d = []
    if b - 3 in range(9):
        d.append('u')
    if b not in [0, 3, 6]:
        d.append('l')
    if b not in [2, 5, 8]:
        d.append('r')
    if b + 3 in range(9):
        d.append('d')
    pos_moves = []
    for m in d:
        pos_moves.append(gen(state, m, b))
    return [move for move in pos_moves if move not in visited_state]
def gen(state, m, b):
    temp = state.copy()
    if m == 'u':
        temp[b - 3], temp[b] = temp[b], temp[b - 3]
    if m == 'l':
        temp[b - 1], temp[b] = temp[b], temp[b - 1]
    if m == 'r':
        temp[b + 1], temp[b] = temp[b], temp[b + 1]
    if m == 'd':
        temp[b + 3], temp[b] = temp[b], temp[b + 3]
    return temp
src = [1, 2, 3, -1, 4, 5, 6, 7, 8]
target = [1, 2, 3, 4, 5,6, 7, 8,-1]
astar(src, target)
```

<u>Output Snapshot</u>



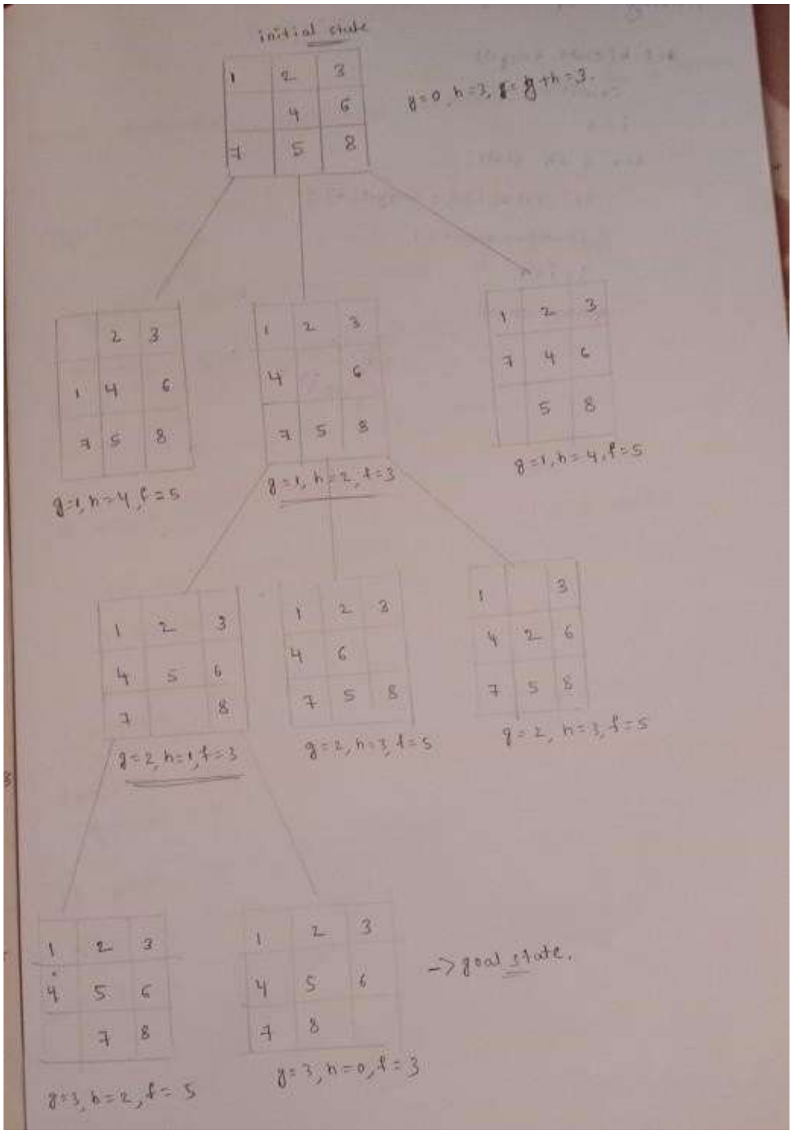
```
Enter the start state matrix

1 0 1 0
1 0 0 1
1 1 1 1
Enter the goal state matrix

1 1 0 1
1 0 0 1
1 1 1 0
|
 |
\'/

1 0 1 0
1 0 0 1
1 1 1 1
```

State Space Tree



Program 4 - Vacuum Cleaner

Algorithm

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× Implementing Vaccum cleaner agent

Algorithm:

1. Initialize the agent's starting (A, B)

2. Loop untill all cells are cleane:
   a. Perceive the current cell
   b. If the cell is dirty
      i. clean the current cell
   c. else:
      i. check surrounding to check if they are dirty.
      ii. move to the next dirty cell
      iii. ~~If~~ no dirty cells are perceive Stop

3. End

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CamScanner

Code

```
def vacuum_world():

    goal_state = {'A': '0', 'B': '0'}
    cost = 0

    location_input = input("Enter Location of Vacuum: ")
    status_input = input("Enter status of " + location_input+ " : ")
    status_input_complement = input("Enter status of other room : ")
    print("Initial Location Condition {A : " + str(status_input_complement) + ", B : " +
str(status_input) + " }" )


    if location_input == 'A':
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            goal_state['A'] = '0'



            cost += 1 #cost for suck
            print("Cost for CLEANING A " + str(cost))
            print("Location A has been Cleaned.")

            if status_input_complement == '1':
                print("Location B is Dirty.")
                print("Moving right to the Location B. ")
                cost += 1
                print("COST for moving RIGHT " + str(cost))
                goal_state['B'] = '0'
                cost += 1
                print("COST for SUCK " + str(cost))
                print("Location B has been Cleaned. ")
            else:
                print("No action" + str(cost))
                print("Location B is already clean.")

        if status_input == '0':
            print("Location A is already clean ")
            if status_input_complement == '1':
                print("Location B is Dirty.")
                print("Moving RIGHT to the Location B. ")
                cost += 1
                print("COST for moving RIGHT " + str(cost))
```

```
        goal_state['B'] = '0'
        cost += 1
        print("Cost for SUCK" + str(cost))
        print("Location B has been Cleaned. ")
    else:
        print("No action " + str(cost))
        print(cost)
        print("Location B is already clean.")

else:
  print("Vacuum is placed in location B")
  if status_input == '1':
    print("Location B is Dirty.")
    goal_state['B'] = '0'
    cost += 1
    print("COST for CLEANING " + str(cost))



    print("Location B has been Cleaned.")

    if status_input_complement == '1':
        print("Location A is Dirty.")
        print("Moving LEFT to the Location A. ")
        cost += 1
        print("COST for moving LEFT " + str(cost))
        goal_state['A'] = '0'
        cost += 1
        print("COST for SUCK " + str(cost))
        print("Location A has been Cleaned.")

  else:
    print(cost)
    print("Location B is already clean.")

    if status_input_complement == '1':
        print("Location A is Dirty.")
        print("Moving LEFT to the Location A. ")
        cost += 1
        print("COST for moving LEFT " + str(cost))
        goal_state['A'] = '0'
        cost += 1
        print("Cost for SUCK " + str(cost))
        print("Location A has been Cleaned. ")
```

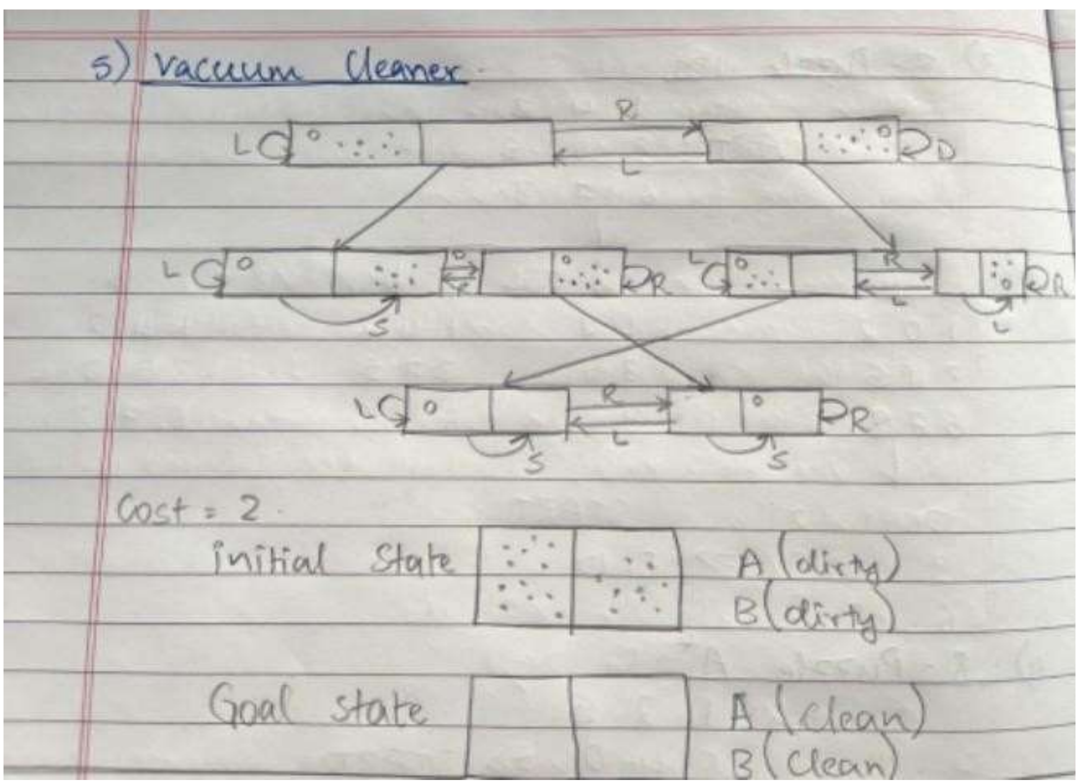
```
        else:
            print("No action " + str(cost))
            print("Location A is already clean.")

    print("GOAL STATE: ")
    print(goal_state)
    print("Performance Measurement: " + str(cost))
vacuum_world()
```

Output Snapshot

```
Enter Location of Vacuum: A
Enter status of A : 0
Enter status of other room : 1
Initial Location Condition {A : 1, B : 0 }
Vacuum is placed in Location A
Location A is already clean
Location B is Dirty.
Moving RIGHT to the Location B.
COST for moving RIGHT 1
Cost for SUCK2
Location B has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 2
```

State Space Tree



Program-05 Hill Climbing

Algorithm

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Lab - 4

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

function HILL-CLIMBING (problem) returns a state
that is a local maximum.

current ← Make-Node (problem. INITIAL-STATE)
loop do
neighbor ← a highest-valued successor of current
if neighbor. Value ≤ current . VALUE
then return current . STATE

Execute current ← neighbor.

Implement :

		Q	
Q			
			Q
	Q		

← Goal.

State	Score.
3 1 2 0	2
1 3 2 0	1
1 2 3 0	1
1 2 0 3	1

Code

```
import random

class NQueensHillClimbing:
    def __init__(self, N):
        self.N = N

    def calculate_heuristic(self, board):
        """Calculate the number of attacking pairs of queens."""
        attacks = 0
        for i in range(self.N):
            for j in range(i + 1, self.N):
                if board[i] == board[j] or abs(board[i] - board[j]) == abs(i - j):
                    attacks += 1
        return attacks

    def get_neighbors(self, board):
        """Generate all possible neighbors by moving each queen to a new row."""
        neighbors = []
        for col in range(self.N):
            for row in range(self.N):
                if board[col] != row:
                    new_board = board[:]
                    new_board[col] = row
                    neighbors.append(new_board)
        return neighbors

    def hill_climbing(self, initial_board):
        """Perform the hill climbing algorithm to solve the N-Queens problem."""
        current_board = initial_board
        current_heuristic = self.calculate_heuristic(current_board)

        while True:
            neighbors = self.get_neighbors(current_board)
            neighbors_heuristics = [self.calculate_heuristic(neighbor) for neighbor in neighbors]
            min_heuristic = min(neighbors_heuristics)

            # If the heuristic cannot be improved, stop
            if min_heuristic >= current_heuristic:
                break
```

```
            # Move to the neighbor with the best heuristic
            best_index = neighbors_heuristics.index(min_heuristic)
            current_board = neighbors[best_index]
            current_heuristic = min_heuristic

        return current_board, current_heuristic

    def solve(self, max_restarts=100):
        """Solve the N-Queens problem using Random Restart Hill Climbing."""
        for restart in range(max_restarts):
            # Start with a random initial state
            initial_board = [random.randint(0, self.N - 1) for _ in range(self.N)]
            solution, heuristic = self.hill_climbing(initial_board)

            if heuristic == 0:
                return solution  # Found a solution

        return None  # No solution found after max_restarts


# Example Usage
if __name__ == "__main__":
    N = 8  # Size of the chessboard
    n_queens = NQueensHillClimbing(N)
    solution = n_queens.solve(max_restarts=1000)  # Try up to 1000 random restarts

    if solution:
        print("Solution found:")
        print(solution)

        # Display the board
        for row in range(N):
            line = ""
            for col in range(N):
                if solution[col] == row:
                    line += "Q "
                else:
                    line += ". "
            print(line)
    else:
        print("No solution found, even after random restarts.")
```

Output Snapshot

```
Solution found:
[7, 3, 0, 2, 5, 1, 6, 4]
. . Q . . . . .
. . . . . Q . .
. . . Q . . . .
. Q . . . . . .
. . . . . . . Q
. . . . Q . . .
. . . . . . Q .
Q . . . . . . .
```

Program 6: Simulated Annealing

<u>Algorithm</u>

LAB-5

Implement Stimulated Annealing algorithm for n-Queen problem

=>

```
current ← initial state
T ← a Large positive value
While T > 0 do
    next ← a random neighbor of current
    ΔE ← current.cost - next.cost.
    if ΔE > 0 then
        current ← next
    else
        current ← next with probability.
    end if
    decrease T
end while.
return current.
```

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Output :-

Final Solution : [1, 3, 0, 2]
Number of conflicts : 0

Code

```
import random
import math

class NQueensSimulatedAnnealing:
    def __init__(self, N):
        self.N = N

    def calculate_heuristic(self, board):
        """Calculate the number of attacking pairs of queens."""
        attacks = 0
        for i in range(self.N):
            for j in range(i + 1, self.N):
                if board[i] == board[j] or abs(board[i] - board[j]) == abs(i - j):
                    attacks += 1
        return attacks

    def get_random_neighbor(self, board):
        """Generate a random neighbor by moving one queen to a different row."""
        neighbor = board[:]
        col = random.randint(0, self.N - 1)  # Pick a random column
        row = random.randint(0, self.N - 1)  # Pick a random row
        while neighbor[col] == row:
            row = random.randint(0, self.N - 1)  # Ensure the new row is different
        neighbor[col] = row
        return neighbor

    def simulated_annealing(self, initial_board, max_steps=1000, initial_temp=100, cooling_rate=0.99):
        """Solve the N-Queens problem using Simulated Annealing."""
        current_board = initial_board
        current_heuristic = self.calculate_heuristic(current_board)
        temperature = initial_temp

        for step in range(max_steps):
            if current_heuristic == 0:
                return current_board  # Solution found

            # Generate a random neighbor
            neighbor = self.get_random_neighbor(current_board)
            neighbor_heuristic = self.calculate_heuristic(neighbor)

            # Calculate the change in heuristic
            delta_heuristic = neighbor_heuristic - current_heuristic

            # Decide whether to accept the neighbor
            if delta_heuristic < 0 or random.uniform(0, 1) < math.exp(-delta_heuristic / temperature):
                current_board = neighbor
                current_heuristic = neighbor_heuristic

            # Cool down the temperature
            temperature *= cooling_rate
```

```
        return None  # No solution found within the maximum steps

    def solve(self):
        """Solve the N-Queens problem using Simulated Annealing."""
        initial_board = [random.randint(0, self.N - 1) for _ in range(self.N)]  # Random initial state
        return self.simulated_annealing(initial_board)


# Example Usage
if __name___== "__main__":
    N = 8  # Size of the chessboard
    n_queens = NQueensSimulatedAnnealing(N)
    solution = n_queens.solve()

    if solution:
        print("Solution found:")
        print(solution)

        # Display the board
        for row in range(N):
            line = ""
            for col in range(N):
                if solution[col] == row:
                    line += "Q "
                else:
                    line += ". "
            print(line)
    else:
        print("No solution found.")



     if ans:
        print("Knowledge Base entails query")
     else:
        print("Knowledge Base does not entail query")
```

OUTPUT

```
Solution found:
[2, 5, 1, 6, 0, 3, 7, 4]
. . . . Q . . .
. . Q . . . . .
Q . . . . . . .
. . . . . Q . .
. . . . . . . Q
. Q . . . . . .
. . . Q . . . .
. . . . . . Q .
```

Program-07- Unification in FOL

Algorithm

22/11

UNIFICATION ALGORITHM

=> Step 1: If Ψ_1 or Ψ_2 is a variable or constant
a) If Ψ_1 or Ψ_2 are identical, return Nil
b) Else if Ψ_2 is a variable,
a. then if Ψ_2 occurs in Ψ_2, then return failure
b. Else return $\{(\Psi_2/\Psi_1)\}$

c) Else if Ψ_2 is a variable,
a) If Ψ_2 occurs in Ψ_1 then return Failure.
b) Else return $\{(\Psi_1, \{\Psi_2\})\}$

d) Else return Failure.

Step 2: If the initial Predicate symbol in Ψ_1 & Ψ_2 are not same, then return failure.

Step 3: If Ψ_1 & Ψ_2 have a different number of arguments, return failure.

Step 4: Set Substitution set (SUBST) to NIL

Step 5: For i=1 to the number of elements
a) Call Unify function with the ith element of Ψ_1 & ith element of Ψ_2
b) If S=failure then return failure.
c) If S≠ NIL then do.

Code

```
def is_variable(term):
    """Check if a term is a variable."""
    return isinstance(term, str) and term.islower()

def is_constant(term):
    """Check if a term is a constant."""
    return isinstance(term, str) and term.isupper()

def unify(term1, term2, subst=None):
    """
    Unify two terms.
    Args:
        term1: The first term (variable, constant, or function).
        term2: The second term (variable, constant, or function).
        subst: Current set of substitutions (dictionary).
    Returns:
        A substitution dictionary if unification is successful, otherwise None.
    """
    if subst is None:
        subst = {}

    if term1 == term2:  # If terms are identical
        return subst

    if is_variable(term1):  # If term1 is a variable
        return unify_variable(term1, term2, subst)

    if is_variable(term2):  # If term2 is a variable
        return unify_variable(term2, term1, subst)

    if isinstance(term1, tuple) and isinstance(term2, tuple):
        # If terms are functions, unify their name and arguments
        if term1[0] != term2[0] or len(term1[1]) != len(term2[1]):
            return None  # Function names or argument lengths differ
        for arg1, arg2 in zip(term1[1], term2[1]):
            subst = unify(arg1, arg2, subst)
            if subst is None:
                return None
        return subst

    return None  # Terms cannot be unified


def unify_variable(var, term, subst):
    """
    Unify a variable with a term.
    Args:
```

```
        var: The variable (string).
        term: The term to unify with (variable, constant, or function).
        subst: Current set of substitutions (dictionary).
    Returns:
        Updated substitution dictionary or None.
    """
    if var in subst:  # Variable already substituted
        return unify(subst[var], term, subst)

    if occurs_check(var, term, subst):  # Prevent infinite loops
        return None

    subst[var] = term
    return subst


def occurs_check(var, term, subst):
    """
    Check if a variable occurs in a term (to prevent infinite loops).
    Args:
        var: The variable (string).
        term: The term to check against.
        subst: Current set of substitutions (dictionary).
    Returns:
        True if var occurs in term, False otherwise.
    """
    if var == term:
        return True
    if isinstance(term, tuple):  # If term is a function, check its arguments
        return any(occurs_check(var, arg, subst) for arg in term[1])
    if var in subst and occurs_check(var, subst[var], subst):
        return True
    return False


def apply_substitution(term, subst):
    """
    Apply a substitution to a term.
    Args:
        term: The term to substitute (variable, constant, or function).
        subst: The substitution dictionary.
    Returns:
        The term after applying the substitution.
    """
    if is_variable(term) and term in subst:
        return apply_substitution(subst[term], subst)
    if isinstance(term, tuple):  # If the term is a function, apply substitution to its arguments
        return (term[0], [apply_substitution(arg, subst) for arg in term[1]])
    return term  # Return the term as-is for constants or unbound variables


# Example Usage
```

```
if __name___== "__main__":
    # Example terms:
    term1 = ("f", ["x", "y"])  # f(x, y)
    term2 = ("f", ["a", "b"])  # f(a, b)

    # Perform unification
    result = unify(term1, term2)
    if result:
        print("Unification successful! Substitution:")
        print(result)

        # Apply substitution to the original terms
        term1_substituted = apply_substitution(term1, result)
        term2_substituted = apply_substitution(term2, result)

        print("\nTerms after substitution:")
        print(f"Term 1: {term1_substituted}")
        print(f"Term 2: {term2_substituted}")
    else:
        print("Unification failed.")
else:
      print("Knowledge Base doesn't entail the query, no empty set produced after resolution") clauses
      = input('Enter the clauses ').split()
      query = input('Enter the query: ')
      checkResolution(clauses, query)
```

Output Snapshot

```
Unification successful! Substitution:
{'x': 'a', 'y': 'b'}

Terms after substitution:
Term 1: ('f', ['a', 'b'])
Term 2: ('f', ['a', 'b'])
```

Program-08 Forward Reasoning

Algorithm

LAB-8

Forward Reasoning Algorithm

⇒

function FOL-FC-ASK (KB, α) returns false
inputs : KB, the Knowledge base, a set of fo
α, the query, an atomic sentence
local variable : new, the new sentences

repeat until new is empty
new ← { }
for each rule in KB do
for each θ such that SUBST
for some $p_1, \ldots, p_n$ in KB
$q' \leftarrow$ SUBST (θ, q)
if q' does not unify with some
sentense already in KB
add q' to new
$\phi \leftarrow$ UNIFY (q', α
if ϕ is not fail then returns

add new to KB
return false.

Code

```
def is_variable(term):
    """Check if a term is a variable."""
    return isinstance(term, str) and term.islower()

def apply_substitution(term, subst):
    """Apply a substitution to a term."""
    if is_variable(term) and term in subst:
        return apply_substitution(subst[term], subst)
    if isinstance(term, tuple):  # If term is a function, apply substitution to arguments
        return (term[0], [apply_substitution(arg, subst) for arg in term[1]])
    return term  # Return the term as-is for constants or unbound variables

def unify(term1, term2, subst=None):
    """Unify two terms."""
    if subst is None:
        subst = {}
    if term1 == term2:
        return subst
    if is_variable(term1):
        return unify_variable(term1, term2, subst)
    if is_variable(term2):
        return unify_variable(term2, term1, subst)
    if isinstance(term1, tuple) and isinstance(term2, tuple):
        if term1[0] != term2[0] or len(term1[1]) != len(term2[1]):
            return None
        for arg1, arg2 in zip(term1[1], term2[1]):
            subst = unify(arg1, arg2, subst)
            if subst is None:
                return None
        return subst
    return None

def unify_variable(var, term, subst):
    """Unify a variable with a term."""
    if var in subst:
```

```
        return unify(subst[var], term, subst)
    if occurs_check(var, term, subst):
        return None
    subst[var] = term
    return subst

def occurs_check(var, term, subst):
    """Check if a variable occurs in a term."""
    if var == term:
        return True
    if isinstance(term, tuple):
        return any(occurs_check(var, arg, subst) for arg in term[1])
    if var in subst and occurs_check(var, subst[var], subst):
        return True
    return False

def forward_reasoning(kb, query):
    """
    Perform forward reasoning on the knowledge base (KB) to prove the query.
    Args:
        kb: The knowledge base, a list of first-order logic rules or facts.
        query: The goal to prove.
    Returns:
        True if the query can be proved, otherwise False.
    """
    known_facts = set()
    new_facts = True

    while new_facts:
        new_facts = False

        for rule in kb:
            if isinstance(rule, tuple) and rule[0] == "implies":  # Implication rule
                conditions, conclusion = rule[1], rule[2]

                substitutions = [{}]
```

```
            for condition in conditions:
                next_substitutions = []
                for fact in known_facts:
                    subst = unify(condition, fact)
                    if subst is not None:
                        next_substitutions.append(subst)
                substitutions = [
                    {**s1, **s2} for s1 in substitutions for s2 in next_substitutions
                ]

            for subst in substitutions:
                derived_fact = apply_substitution(conclusion, subst)
                if derived_fact not in known_facts:
                    known_facts.add(derived_fact)
                    new_facts = True

        else:  # It's a fact
            if rule not in known_facts:
                known_facts.add(rule)
                new_facts = True

    # Check if the query is in the known facts
    for fact in known_facts:
        if unify(fact, query) is not None:
            return True

  return False


# Example Usage
if __name__ == "__main__":
  # Knowledge Base
  kb = [
    ("implies", [("human", ["x"])], ("mortal", ["x"])),  # human(x) -> mortal(x)
    ("human", ["socrates"]),  # human(socrates)
  ]
```

```
# Query
query = ("mortal", ["socrates"])  # Is Socrates mortal?

# Perform forward reasoning
result = forward_reasoning(kb, query)

if result:
    print(f"The query {query} is true based on the knowledge base.")
else:
    print(f"The query {query} cannot be proved from the knowledge base.")
```

Output Snapshot

```
Criminal(Robert) is proven!
Inferred Facts:
Criminal(Robert)
Enemy(A, America)
American(Robert)
Missile(T1)
Weapon(T1)
Sells(Robert, T1, A)
Owns(A, T1)
Hostile(A)
```

Program 09: Resolution

Algorithm

Bafna Gold
Date: Page:

* query using resolution.

=> function: resolution (KB, query): return query is true or false.

input : KB, the Knowledge base, act of propositional

query : o to to proven.

Classes = convert to CNF (KB

negated query = negate (query)

new - class es = set().

apply the resolution rules.

- Select the class contains complementary class.
- resolve the two to form or new clause.
- add the new - classes is empty ()

contradiction is found.

if new = {} print "query if true"

else print 'false'

Output.

KB PVQ

TQVR

TPVS

RVTS

TS

Resolution.

TR TQVR

TQ PVQ

TRVS

P

S

-R -Q

CS Scanned with CamScanner

Code:

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

def knowledge_base_resolution():
    """
    Demonstrate resolution-based proof in propositional logic.
    """
    # Step 1: Define symbols
    P, Q, R = symbols('P Q R')

    # Step 2: Define the Knowledge Base (KB)
    kb = And(
        Implies(P, Q),  # If P, then Q
        Implies(Q, R),  # If Q, then R
        P               # P is true
    )

    # Step 3: Define the query
    query = R

    # Step 4: Negate the query and add it to the KB
    kb_with_negated_query = And(kb, Not(query))

    # Step 5: Convert KB to Conjunctive Normal Form (CNF)
    from sympy.logic.boolalg import to_cnf
    kb_cnf = to_cnf(kb_with_negated_query, simplify=True)

    print("Knowledge Base in CNF:", kb_cnf)

    # Step 6: Apply Resolution
    # Note: Implementing resolution directly requires symbolic manipulation of CNF clauses.
    # For simplicity, we demonstrate by showing the result from the CNF.

    # Check satisfiability
    from sympy.logic.inference import satisfiable
    result = satisfiable(kb_cnf, all_models=False)

    if result:
        print("The query is NOT proved (no contradiction found).")
        print("Satisfying assignment:", result)
    else:
        print("The query is proved (contradiction found).")

# Example usage
if __name__ == "__main__":
    knowledge_base_resolution()
```

OUTPUT SNAPSHOT:

```
Knowledge Base in CNF: False
The query is proved (contradiction found).
```

Program 10: FOL to CNF
Algorithm:

* Convert a given FOL to CNF.

Function FOL to CNF.
Elimate: implication ad. bi conditional.
$A \rightarrow B$: $\neg A \vee B$.
- $A \leftrightarrow B$: $(\neg A \vee B) \wedge (A \vee \neg B)$.
- More negation Inward (If any)
- Standatize variable with. unique variable name.
- Eliminate existial & universal quantifiers.
- Distribute $\vee$ over $\wedge$.
- Simplify the result.

Output
$\forall x (\exists y (P(x, y) \rightarrow Q(y)) \wedge \neg R(x))$

- Eliminate simplication:
$\forall x (\exists y (\neg P(x, y) \vee Q(y) \wedge \neg R(y)))$.

- Eliminate existial quantities
$v((\neg Q(u, f(x)) \vee Q(f(x)) \wedge \neg R(x))$

Drop variable quantifies:- $y = f(x)$
v ~~ff~~
$(\neg P(u, f(u)) \vee (f(x))) \wedge \neg R(u)$

CS Scanned with CamScanner

Code:

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

def convert_to_cnf(statement):
    """
    Convert a given first-order logic statement into Conjunctive Normal Form (CNF).
    """
    from sympy.logic.boolalg import to_cnf
    return to_cnf(statement, simplify=True)

def knowledge_base_resolution():
    """
    Demonstrate resolution-based proof in propositional logic.
    """
    # Step 1: Define symbols
    P, Q, R = symbols('P Q R')

    # Step 2: Define the Knowledge Base (KB)
    kb = And(
        Implies(P, Q),  # If P, then Q
        Implies(Q, R),  # If Q, then R
        P               # P is true
    )

    # Step 3: Define the query
    query = R

    # Step 4: Negate the query and add it to the KB
    kb_with_negated_query = And(kb, Not(query))

    # Step 5: Convert KB to Conjunctive Normal Form (CNF)
    from sympy.logic.boolalg import to_cnf
    kb_cnf = to_cnf(kb_with_negated_query, simplify=True)

    print("Knowledge Base in CNF:", kb_cnf)

    # Step 6: Apply Resolution
    # Note: Implementing resolution directly requires symbolic manipulation of CNF clauses.
    # For simplicity, we demonstrate by showing the result from the CNF.

    # Check satisfiability
    from sympy.logic.inference import satisfiable
    result = satisfiable(kb_cnf, all_models=False)
```

```
 if result:
        print("The query is NOT proved (no contradiction found).")
        print("Satisfying assignment:", result)

 else:
        print("The query is proved (contradiction found).")

# Example usage for converting FOL to CNF
if __name__ == "__main__":
    # Define symbols for FOL example
    A, B, C = symbols('A B C')

    # Example FOL statement: (A -> B) AND (B -> C)
    fol_statement = And(Implies(A, B), Implies(B, C))

    # Convert to CNF
    cnf_statement = convert_to_cnf(fol_statement)
    print("Original FOL Statement:", fol_statement)
    print("Converted CNF Statement:", cnf_statement)

    # Run resolution demonstration
    knowledge_base_resolution()
```

OUTPUT SNAPSHOT:

```
Original FOL Statement: (Implies(A, B)) & (Implies(B, C))
Converted CNF Statement: (B | ~A) & (C | ~B)
Knowledge Base in CNF: False
The query is proved (contradiction found).
```

Program 11: Alpha Beta Pruning

Algorithm:

* Implement alpha-Beta pruning.

function minimax (node, depth, alpha,
beta, maximizingPlayer) is
if depth == 0 or node is a terminal
node.
then
return static evaluation of node.

if Maximize player then.
maxEva = - infinity.
for each child of node do
eva = minimax (child, depth-1,
alpha, beta false)
max Eva = max (MaxEva, eva).
alpha = max (alpha, max Eva.
if beta <= alpha.
break.
return max Eva.

else.
minEva = + infinity.
for each child of node do.
eva = minimax (child, depth-1,
alpha, beta, true)
minEva = min (minEva, eva)
beta = min (beta, eva)
if beta <= alpha
break.
return minEva

CS Scanned with CamScanner

PAGE N
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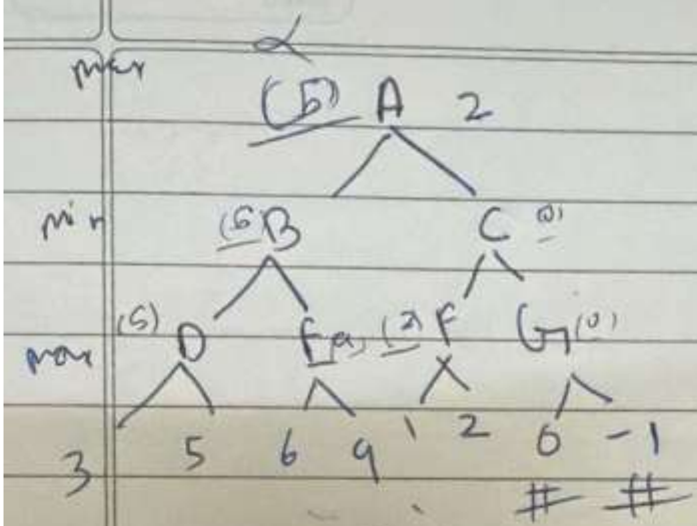

$\alpha \geq \beta$

$5 \geq 2$ prune

20/12/24

Code:

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

def convert_to_cnf(statement):
    """
    Convert a given first-order logic statement into Conjunctive Normal Form (CNF).
    """
    from sympy.logic.boolalg import to_cnf
    return to_cnf(statement, simplify=True)

def alpha_beta_pruning(depth, node_index, maximizing_player, values, alpha, beta):
    """
    Implement the Alpha-Beta Pruning algorithm.

    Parameters:
        depth (int): Current depth in the game tree.
        node_index (int): Index of the current node in the game tree.
        maximizing_player (bool): True if the current player is maximizing, False otherwise.
        values (list): Terminal node values (leaf nodes).
        alpha (float): Alpha value for pruning.
        beta (float): Beta value for pruning.

    Returns:
        int: The optimal value for the current player.
    """
    if depth == 0 or node_index >= len(values):
        return values[node_index]

    if maximizing_player:
        max_eval = float('-inf')
        for i in range(2):  # Assume binary tree
            eval = alpha_beta_pruning(depth - 1, node_index * 2 + i, False, values, alpha, beta)
            max_eval = max(max_eval, eval)
            alpha = max(alpha, eval)
            if beta <= alpha:
                break  # Beta cut-off
        return max_eval
    else:
        min_eval = float('inf')
        for i in range(2):  # Assume binary tree
            eval = alpha_beta_pruning(depth - 1, node_index * 2 + i, True, values, alpha, beta)
            min_eval = min(min_eval, eval)
            beta = min(beta, eval)
            if beta <= alpha:
                break  # Alpha cut-off
        return min_eval

def knowledge_base_resolution():
    """
    Demonstrate resolution-based proof in propositional logic.
```

```
    """
    # Step 1: Define symbols
    P, Q, R = symbols('P Q R')

    # Step 2: Define the Knowledge Base (KB)
    kb = And(
        Implies(P, Q),  # If P, then Q
        Implies(Q, R),  # If Q, then R
        P               # P is true
    )

    # Step 3: Define the query
    query = R

    # Step 4: Negate the query and add it to the KB
    kb_with_negated_query = And(kb, Not(query))

    # Step 5: Convert KB to Conjunctive Normal Form (CNF)
    from sympy.logic.boolalg import to_cnf
    kb_cnf = to_cnf(kb_with_negated_query, simplify=True)

    print("Knowledge Base in CNF:", kb_cnf)

    # Step 6: Apply Resolution
    # Note: Implementing resolution directly requires symbolic manipulation of CNF clauses.
    # For simplicity, we demonstrate by showing the result from the CNF.

    # Check satisfiability
    from sympy.logic.inference import satisfiable
    result = satisfiable(kb_cnf, all_models=False)

    if result:
        print("The query is NOT proved (no contradiction found).")
        print("Satisfying assignment:", result)
    else:
        print("The query is proved (contradiction found).")

# Example usage for converting FOL to CNF
if __name__ == "__main__":
    # Example usage of Alpha-Beta Pruning
    print("Alpha-Beta Pruning Example:")
    values = [3, 5, 6, 9, 1, 2, 0, -1]  # Leaf nodes of the game tree
    depth = 3  # Depth of the tree
    optimal_value = alpha_beta_pruning(depth, 0, True, values, float('-inf'), float('inf'))
    print("Optimal value:", optimal_value)

    # Define symbols for FOL example
    A, B, C = symbols('A B C')

    # Example FOL statement: (A -> B) AND (B -> C)
    fol_statement = And(Implies(A, B), Implies(B, C))
```

```
# Convert to CNF
cnf_statement = convert_to_cnf(fol_statement)
print("Original FOL Statement:", fol_statement)
print("Converted CNF Statement:", cnf_statement)

# Run resolution demonstration
knowledge_base_resolution()
```

OUTPUT SNAPSHOT:

```
Alpha-Beta Pruning Example:
Optimal value: 5
Original FOL Statement: (Implies(A, B)) & (Implies(B, C))
Converted CNF Statement: (B | ~A) & (C | ~B)
Knowledge Base in CNF: False
The query is proved (contradiction found).
```