Title: Implement and Demonstrate Depth First Search Algorithm on Water Jug Problem

Introduction to Water jug problem:

Problem Statement:

- Given two jugs with capacities of X liters and Y liters, and an unlimited supply of water, the objective is to measure exactly Z liters using a sequence ofoperations.
- The allowed operations are:
  - Fill either jug completely.
  - Empty either jug.
  - Pour water from one jug into the other until either the first jug is empty or the second jug is full.
- The problem is to determine whether it is possible to obtain exactly Z liters inone of the jugs, and if so, to find the sequence of operations that achieves this.

Constraints:

- All jugs are unmarked (no intermediate measurements).
- The capacities X, Y, and the target Z are positive integers.
- The solution must use only the allowed operations.

Existence of Solution:

- A solution exists if and only if:
- $Z \le \max(X, Y)$, and
- Z is a multiple of the greatest common divisor (GCD) of X and Y

DFS Pseudocode:

```
function DEPTH-FIRST-SEARCH(problem) returns a solution, or failure
  node ← a node with STATE = problem.INITIAL-STATE, PATH-COST = 0
  if problem.GOAL-TEST(node.STATE) then return SOLUTION(node)
  frontier ← a LIFO stack with node as the only element
  explored ← an empty set
  loop do
    if EMPTY?(frontier) then return failure
    node ← POP(frontier)  /* chooses the deepest node in frontier */
    add node.STATE to explored
    for each action in problem.ACTIONS(node.STATE) do
      child ← CHILD-NODE(problem, node, action)
      if child.STATE is not in explored or frontier then
        if problem.GOAL-TEST(child.STATE) then return SOLUTION(child)
```

Python Code:

```python
# Generate all the possible states and transitions for the water jug problem
def generate_graph(jug1, jug2):
    graph = {}
    for x in range(jug1 + 1):
        for y in range(jug2 + 1):
            state = (x, y)
            graph[state] = []
            # Fill jug1
            graph[state].append((jug1, y))
            # Fill jug2
            graph[state].append((x, jug2))
            # Empty jug1
            graph[state].append((0, y))
            # Empty jug2
            graph[state].append((x, 0))
            # Pour jug1 to jug2
            pour_to_jug2 = min(x, jug2 - y)
            graph[state].append((x - pour_to_jug2, y + pour_to_jug2))
            # Pour jug2 to jug1
            pour_to_jug1 = min(y, jug1 - x)
            graph[state].append((x + pour_to_jug1, y - pour_to_jug1))
    return graph

# For the given input generate graph consisting of all the possible states and
transitions
jug1 = 5
jug2 = 3
target = 4
graph = generate_graph(jug1, jug2)

# Implementation of Depth First Search (DFS) to find a path to the target
state
def dfs_graph(graph, start, target):
    stack = [(start, [start])]
    visited = set()
    while stack:
        current, path = stack.pop()
        if current in visited:
            continue
        visited.add(current)
        if target in current:
            return path
        for neighbor in graph[current]:
            if neighbor not in visited:
                stack.append((neighbor, path + [neighbor]))
    return None
```

```python
# Solution path from initial state (0,0) to target state

solution = dfs_graph(graph, (0, 0), target)

print("Solution path:")
for step in solution:
    print(step)
```

Result

```
Solution path:
(0, 0)
(0, 3)
(3, 0)
(3, 3)
(5, 1)
(5, 0)
(2, 3)
(2, 0)
(0, 2)
(5, 2)
(4, 3)
```

Title: Implement and Demonstrate Best First Search Algorithm on Missionaries-Cannibals Problems using Python

Introduction to Missionaries-Cannibals Problem

Problem Statement

- Three missionaries and three cannibals are on one side of a river. They all need to cross to the other side using a boat that can carry at most two people at a time.

Constraints:

- At no point should cannibals outnumber missionaries on either side of the river (or the missionaries will be eaten!).
- The boat cannot cross the river by itself — it needs at least one person to operate it.
- Only missionaries and cannibals are available to row the boat.

BFS Pseudocode:

```
function BREADTH-FIRST-SEARCH(problem) returns a solution, or failure
  node ← a node with STATE = problem.INITIAL-STATE, PATH-COST = 0
  if problem.GOAL-TEST(node.STATE) then return SOLUTIO N(node)
  frontier ← a FIFO queue with node as the only element
  explored ← an empty set
  loop do
    if EMPTY?(frontier) then return failure
    node ← POP(frontier)  /* chooses the shallowest node in frontier */
    add node.STATE to explored
    for each action in problem.ACTIONS(node.STATE) do
      child ← CHILD-NODE(problem, node, action)
      if child.STATE is not in explored or frontier then
        if problem.GOAL-TEST(child.STATE) then return SOLUTION(child)
        INSERT(child, frontier)
```

Python Code:

```
from collections import deque

# Function to check if a state is valid
# A state is valid if the number of missionaries is not less than the number
of cannibals on both sides of the river.
# m = missionaries, c = cannibals, b = boat position (0 for left bank, 1 for
right bank)

def is_valid(state):
    m, c, b = state
    return (m == 0 or m >= c) and (3 - m == 0 or 3 - m >= 3 - c)

# Generate all possible next states from the current state by moving 1 or 2
people (either missionaries or cannibals) across the river.

def get_next_states(state):
    m, c, b = state
    next_states = []
    if b == 1: # Boat on the starting side
        if m > 0:
            next_states.append((m - 1, c, 0)) # Move 1 missionary
        if m > 1:
            next_states.append((m - 2, c, 0)) # Move 2 missionaries
        if c > 0:
            next_states.append((m, c - 1, 0)) # Move 1 cannibal
        if c > 1:
            next_states.append((m, c - 2, 0)) # Move 2 cannibals
        if m > 0 and c > 0:
            next_states.append((m - 1, c - 1, 0)) # Move 1 missionary and 1
cannibal
    else:  # Boat on the other side
        if m < 3:
            next_states.append((m + 1, c, 1)) # Move 1 missionary
        if m < 2:
            next_states.append((m + 2, c, 1)) # Move 2 missionaries
        if c < 3:
            next_states.append((m, c + 1, 1)) # Move 1 cannibal
        if c < 2:
            next_states.append((m, c + 2, 1)) # Move 2 cannibals
        if m < 3 and c < 3:
            next_states.append((m + 1, c + 1, 1)) # Move 1 missionary and 1
cannibal
    return [state for state in next_states if is_valid(state)]
```

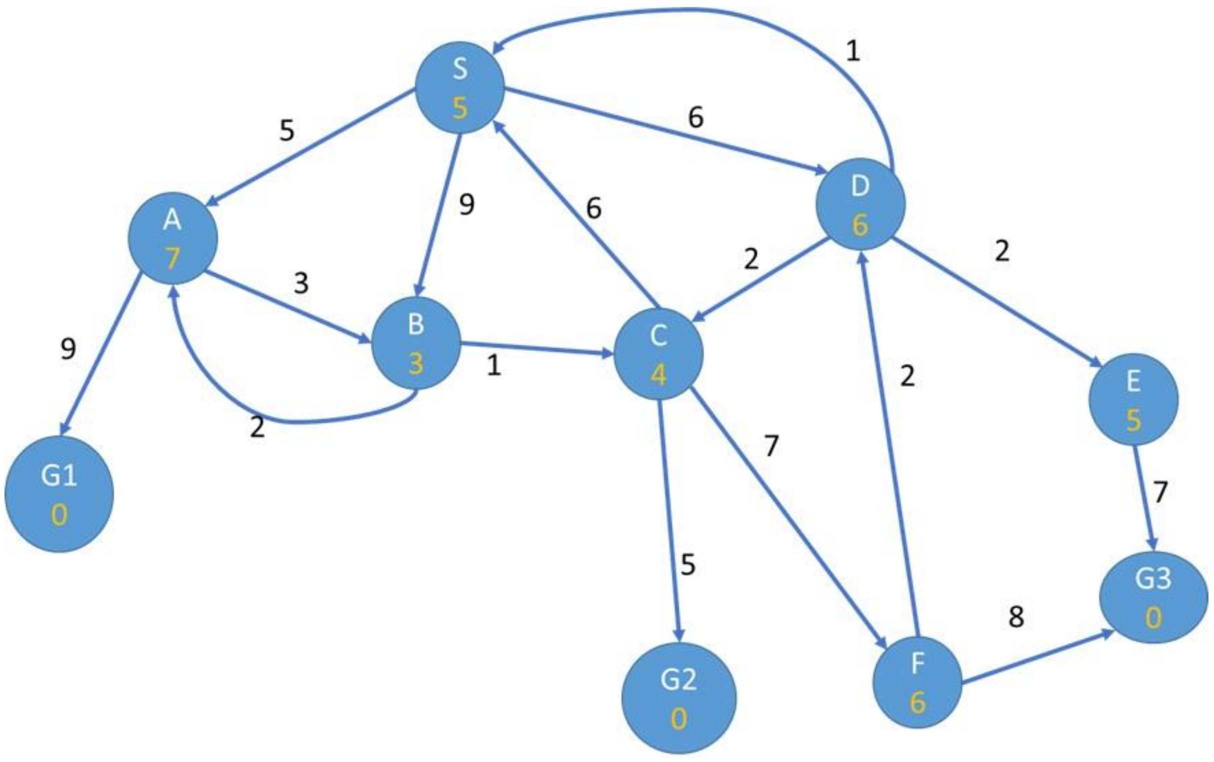
```python
# BFS algorithm to solve the problem
def bfs(initial_state, goal_state):
    queue = deque([(initial_state, [])])
    visited = set()
    while queue:
        state, path = queue.popleft()
        if state == goal_state:
            return path + [state]
        if state not in visited:
            visited.add(state)
            for next_state in get_next_states(state):
                queue.append((next_state, path + [state]))
    return None

# Define the initial state and goal state
# The initial state is (3, 3, 1) representing 3 missionaries, 3 cannibals, and
the boat on the starting side.
# The goal state is (0, 0, 0) representing all missionaries and cannibals on
the other side.

initial_state = (3, 3, 1)
goal_state = (0, 0, 0)

# Find the solution
solution = bfs(initial_state, goal_state)
if solution:
    for step in solution:
        print(step)
else:
    print("No solution found")
```

Result:

```
(3, 3, 1)
(3, 1, 0)
(3, 2, 1)
(3, 0, 0)
(3, 1, 1)
(1, 1, 0)
(2, 2, 1)
(0, 2, 0)
(0, 3, 1)
(0, 1, 0)
(1, 1, 1)
(0, 0, 0)
```

Title: Implement A* Search algorithm

Example Graph with multiple goals:



A* Pseudocode:

```
function A-STAR-SEARCH(problem) returns a solution, or failure
    node ← a node with STATE = problem.INITIAL-STATE, PATH-COST = 0
    frontier ← a priority queue ordered by f(n) = g(n) + h(n)
    INSERT node into frontier
    explored ← an empty set
    loop do
        if EMPTY?(frontier) then return failure
        node ← POP(frontier)  /* node with lowest f(n) */
        if problem.GOAL-TEST(node.STATE) then return SOLUTION(node)
        add node.STATE to explored
        for each action in problem.ACTIONS(node.STATE) do
            child ← CHILD-NODE(problem, node, action)
            if child.STATE is not in explored or frontier then
                INSERT(child, frontier)
            else if child.STATE is in frontier with higher f(child) then
                REPLACE the existing node in frontier with child
```

Python Code:

```
import heapq
import networkx as nx
import matplotlib.pyplot as plt

# A* algorithm for multiple goals
def a_star_multiple_goals(graph, start, goals, heuristic):
    open_list = []
    heapq.heappush(open_list, (heuristic[start], 0, start, [start]))
    closed_set = set()
    best_path = None
    best_cost = float('inf')

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

        if current in goals and g < best_cost:
            best_path = path
            best_cost = g
            continue
        if current in closed_set:
            continue
        closed_set.add(current)

        for neighbor, cost in graph.get(current, []):
            if neighbor not in closed_set:
                new_g = g + cost
                new_f = new_g + heuristic.get(neighbor, float('inf'))
                heapq.heappush(open_list, (new_f, new_g, neighbor, path +
[neighbor]))

    return best_path

# Graph with weights and heuristic values
graph = {
    'S': [('A',5), ('B',9), ('D',6)],
    'A': [('G1',9), ('B',3)],
    'B': [('A',2), ('C',1)],
    'C': [('S',6), ('G2',5), ('F',7)],
    'D': [('S',1), ('E',2), ('C',2)],
    'E': [('G3',7)],
    'F': [('G3',8)],
    'G1': [],
    'G2': [],
    'G3': []
}
```

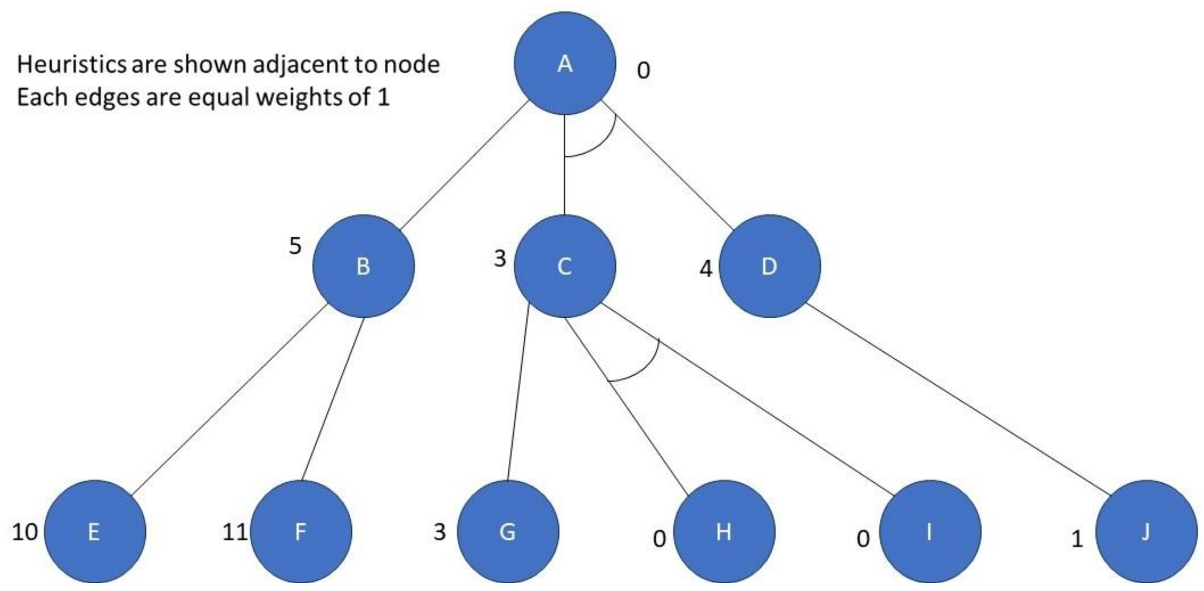
```python
heuristic = {
    'A': 7,
    'B': 3,
    'C': 4,
    'D': 6,
    'E': 5,
    'F': 6,
    'S': 5,
    'G1': 0,
    'G2': 0,
    'G3': 0
}

start_node = 'S'
goal_nodes = {'G1', 'G2', 'G3' }

# Find shortest path using A* algorithm
shortest_path = a_star_multiple_goals(graph, start_node, goal_nodes,
heuristic)
print("Shortest path from", start_node, "to one of the goals", goal_nodes,
"is:", shortest_path)
```

Result:

```
Shortest path from S to one of the goals {'G1', 'G3', 'G2'} is: ['S', 'D',
'C', 'G2']
```

Title: Implement AO* Search algorithm

Example Graph


Heuristics are shown adjacent to node
Each edges are equal weights of 1
A
0
5
B
3
C
4
D
10
E
11
F
3
G
0
H
0
I
1
J

A* Pseudocode:

```
function AND-OR-SEARCH(problem) returns a conditional plan, or failure
    return OR-SEARCH(problem, problem.INITIAL, [ ])

function OR-SEARCH(problem, state, path) returns a conditional plan, or failure
    if problem.IS-GOAL(state) then return the empty plan
    if IS-CYCLE(path) then return failure
    for each action in problem.ACTIONS(state) do
        plan ←AND-SEARCH(problem, RESULTS(state, action), [state] + path])
        if plan 6= failure then return [action] + plan]
    return failure

function AND-SEARCH(problem, states, path) returns a conditional plan, or failure
    for each $s_i$ in states do
        $plan_i$←OR-SEARCH(problem, $s_i$, path)
        if $plan_i$ = failure then return failure
    return [if $s_1$ then $plan_1$ else if $s_2$ then $plan_2$ else . . . if $s_{n-1}$ then $plan_{n-1}$ else $plan_n$]
```

Python Code:

```
import networkx as nx
import matplotlib.pyplot as plt

# AO* algorithm function
def ao_star(node, graph, heuristic, solved):
    if node in solved:
        return heuristic[node], [node]

    if not graph[node]:  # Goal node
        solved.add(node)
        return heuristic[node], [node]

    min_cost = float('inf')
    best_path = []

    for child, relation in graph[node]:
        if relation == 'OR':
            cost, path = ao_star(child, graph, heuristic, solved)
            if cost < min_cost:
                min_cost = cost
                best_path = [node] + path
        elif relation == 'AND':
            cost1, path1 = ao_star(child, graph, heuristic, solved)
            siblings = [s for s, r in graph[node] if r == 'AND' and s != 
child]
            total_cost = cost1
            total_path = [node] + path1
            for sib in siblings:
                cost2, path2 = ao_star(sib, graph, heuristic, solved)
                total_cost += cost2
                total_path += path2
            if total_cost < min_cost:
                min_cost = total_cost
                best_path = total_path

    heuristic[node] = min_cost
    solved.add(node)
    return min_cost, best_path

graph = {
    'A' : [('B', 'OR'), ('C', 'AND'), ('D', 'AND')],
    'B' : [('E', 'OR'), ('F', 'OR')],
    'C' : [('G', 'OR'), ('H', 'AND'), ('I', 'AND')],
    'D' : [('J', 'OR')],
    'E' : [],
    'F' : [],
    'G' : [],
    'H' : [],
    'I' : [],
    'J' : []
}


heuristic = {
    'A': 0,
    'B': 5,
    'C': 3,
    'D': 4,
    'E': 10,
    'F': 11,
    'G': 3,
    'H': 0,
    'I': 0,
    'J': 1
}

# Run AO* from the Start node
solved_nodes = set()
cost, optimal_path = ao_star('A', graph, heuristic, solved_nodes)

# Output the optimal path and cost
print("Optimal Path:", " -> ".join(optimal_path))
```

Result:

```
Optimal Path: A -> C -> H -> I -> D -> J
```

Title: Solve 8-Queens Problem with suitable assumptions

Discussion

8-Queens Problem

The eight queens problem was first proposed by Max Bezzel in the Berliner Schachzeitung (1848) and first fully solved by Franz Nauck in Leipziger Illustrierte Zeitung (1850). It asks in how many ways eight queens can be placed on a chess board so that no two attack each other. Each of the twelve solutions shown on this page represents an equivalence class of solutions resulting from each other by rotating the chessboard and/or flipping it along one of its axes of symmetry. The eight queens puzzle is the problem of placing eight chess queens on an 8×8 chessboard such that none of them is able to capture any other using the standard chess queen's moves. The queens must be placed in such a way that no two queens would be able to attack each other. Consequently, a solution requires that no two queens share the same row, column, or diagonal. The eight queens puzzle is an example of the more general n queens puzzle of placing n queens on an n×n chessboard for n ≥ 4.

Python Code:

```python
def solve_n_queens(n):
    def is_safe(row, col, queens):
        for r, c in queens:
            if c == col or abs(r - row) == abs(c - col):
                return False
        return True

    def backtrack(row, queens):
        if row == n:
            solutions.append(queens[:])
            return
        for col in range(n):
            if is_safe(row, col, queens):
                queens.append((row, col))
                backtrack(row + 1, queens)
                queens.pop()

    solutions = []
    backtrack(0, [])
    return solutions
```

```
def print_board(solution, n):
    board = [['.' for _ in range(n)] for _ in range(n)]
    for row, col in solution:
        board[row][col] = 'Q'
    for row in board:
        print(' '.join(row))



# Set the board size
n = 8

# Solve the N Queens problem
solutions = solve_n_queens(n)

# Display one solution
if solutions:
    path_cost = len(solutions[0])  # Each queen placement counts as 1
    print("Total path cost:", path_cost)
    print("One solution to the N Queens problem:")
    print_board(solutions[0], n)
else:
    print("No solution found.")
```

Result:

```
Total path cost: 8
One solution to the N Queens problem:
Q . . . . . . .
. . . . Q . . .
. . . . . . . Q
. . . . . Q . .
. . Q . . . . .
. . . . . . Q .
. Q . . . . . .
. . . Q . . . .
```

Title: Implementation of TSP using heuristic approach

The Travelling Salesman Problem (TSP) is a classic optimization problem in computer science and operations research. It involves finding the shortest possible route for a salesman to visit a set of cities exactly once and return to the starting city. The goal is to minimize the total travel cost or distance.

A* search algorithm for TSP

The A* search algorithm is a heuristic based approach to solving the Travelling Salesman Problem (TSP). It starts with the start node and uses a heuristic function to find the best path to the goal node. The algorithm maintains a priority queue for nodes, sorted by distance and heuristic value, and adds the closest node to the path. If the closest node cannot be reached from the previous closest node, the algorithm may need to backtrack to find a different path. The A* algorithm is particularly useful when the number of nodes is high, as it can improve the search process by using a graph search method that creates a list of visited cities and unvisited cities. This approach can give optimal or very near-optimal solutions in reasonable computation time and usage space.

Python Code:

```python
import heapq

# Sample graph represented as a distance matrix
graph = [
    [0, 10, 15, 20],
    [10, 0, 35, 25],
    [15, 35, 0, 30],
    [20, 25, 30, 0]
]

# Prim's algorithm to compute MST cost for a set of nodes
def mst_cost(graph, nodes):
    if not nodes:
        return 0
    visited = set()
    start = nodes[0]
    visited.add(start)
    edges = [(graph[start][j], start, j) for j in nodes if j != start]
    heapq.heapify(edges)
    total_cost = 0

    while edges and len(visited) < len(nodes):
        cost, u, v = heapq.heappop(edges)
        if v not in visited:
            visited.add(v)
            total_cost += cost
            for k in nodes:
                if k not in visited:
                    heapq.heappush(edges, (graph[v][k], v, k))
    return total_cost

# Heuristic using MST cost of unvisited cities
def heuristic(graph, current, visited, start):
    n = len(graph)
    unvisited = [i for i in range(n) if i not in visited]
    if not unvisited:
        return graph[current][start]
    mst = mst_cost(graph, unvisited)
    min_to_unvisited = min(graph[current][u] for u in unvisited)
    min_return = min(graph[u][start] for u in unvisited)
    return mst + min_to_unvisited + min_return
# A* algorithm for TSP
def tsp_a_star(graph, start):
    n = len(graph)
    pq = []
    heapq.heappush(pq, (0, start, [start], 0))  # (f, current_city, path, g)

    while pq:
        f, current, path, g = heapq.heappop(pq)
        if len(path) == n:
            return path + [start], g + graph[current][start]

        for neighbor in range(n):
            if neighbor not in path:
                new_path = path + [neighbor]
                new_g = g + graph[current][neighbor]
                h = heuristic(graph, neighbor, new_path, start)
                heapq.heappush(pq, (new_g + h, neighbor, new_path, new_g))

# Run the algorithm
start_city = 0
optimal_path, total_cost = tsp_a_star(graph, start_city)

# Display results
print("Optimal TSP path using A* with MST heuristic:", optimal_path)
print("Total cost:", total_cost)
```

Result:

```
Optimal TSP path using A* with MST heuristic: [0, 1, 3, 2, 0]
```