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Efficient Path Finding in Fuzzy Networks: Implementing Dijkstra's Algorithm in C Programming

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ABSTRACT: In network analysis, the shortest path problem is pivotal for optimizing routing and logistics. Traditional approaches to this problem, such as Dijkstra's algorithm, rely on precise and deterministic data. However, in many real-world applications, network information is imprecise or uncertain. This study addresses this limitation by implementing a fuzzy extension of Dijkstra's algorithm in C programming to handle uncertain and vague data in network graphs. By representing network weights as fuzzy numbers, this approach enables more flexible and realistic modelling of path finding in networks with inherent uncertainties. This research presents the methodology, design, and implementation of the algorithm, along with computational experiments to assess its performance. The proposed C-based approach provides a practical and efficient framework for path finding in fuzzy networks, contributing to fields such as transportation, telecommunications, and logistics where uncertainty is a critical factor.

KEY WORDS: Classification, Data Mining, Machine Learning, Predictive analysis, Social Networking Spam, Spam detection.

I.INTRODUCTION

In modern network analysis, finding efficient paths is crucial for optimizing systems in transportation, telecommunications, and logistics. The shortest path problem, central to this domain, is traditionally addressed using deterministic algorithms like Dijkstra's algorithm. While effective, these methods assume precise and well-defined network data, which is often unrealistic in real-world applications where uncertainty and imprecision dominate.

To bridge this gap, fuzzy graph theory introduces a way to incorporate uncertainty by representing network parameters as fuzzy numbers. This article explores the integration of fuzzy logic into Dijkstra’s algorithm, enabling it to operate within the context of imprecise data. Implemented in C programming, the proposed approach adapts Dijkstra’s classical framework to handle fuzzy weights, offering a robust solution for uncertain network scenarios.

By leveraging the efficiency of C programming, this study aims to provide a practical and scalable solution for path finding in fuzzy networks, demonstrating its application across various industries that depend on reliable decision-making under uncertainty. This work contributes to advancing fuzzy graph applications and offers a foundation for further research in network optimization under vague conditions.

II. SIGNIFICANCE OF THE SYSTEM

The paper mainly focuses on pathfinding in fuzzy networks by implementing a fuzzy extension of Dijkstra's algorithm in C programming to handle uncertain and vague data in network graphs. The literature survey is presented in Section III, Basic Definitions are presented in Section IV, Dijkstra's Algorithm in Section V, a Numerical Example in Section VI, C Coding for Dijkstra's Algorithm in Section VII, and Section VIII discusses the Conclusion.

III. LITERATURE SURVEY

Research on shortest path problems traditionally focuses on deterministic algorithms, with Dijkstra's algorithm widely recognized for its efficiency in finding the shortest path in weighted graphs. However, as real-world networks

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often involve imprecise data, researchers have explored the use of fuzzy graph theory to incorporate uncertainty into pathfinding algorithms. One foundational work in this area is by Dubois and Prade (1980), who proposed fuzzy set theory as a method to handle imprecision in graph structures. Their work established the groundwork for later research in fuzzy graph applications, including fuzzy shortest path algorithms.

Subsequent studies, such as those by Kacprzyk and Fedrizzi (1987), extended these concepts to develop fuzzy versions of Dijkstra's algorithm. They introduced approaches to calculate path costs using fuzzy arithmetic, emphasizing the benefits of fuzzy logic in handling uncertainty in network weights. More recently, researchers have implemented fuzzy pathfinding algorithms in various programming languages, noting the practicality of using fuzzy numbers to better simulate real-world conditions in transportation and logistics networks. Implementing these algorithms in C programming, known for its efficiency and control over system resources, provides a suitable framework for real-time and embedded applications.

Despite significant progress, there remain challenges in optimizing fuzzy pathfinding algorithms for large-scale networks. This research aims to address these gaps by offering an efficient C implementation of Dijkstra's algorithm adapted for fuzzy networks, which may serve as a foundation for further advancements in network analysis under uncertainty.

IV.BASIC DEFINITIONS

Definition 3.1 (Fuzzy Set) A fuzzy set A in a universe of discourse X is characterized by a membership function $\mu_A(x)$,which assigns a degree of membership to each element x in X.It is defined by $\mu_A(x) = \begin{cases} 1 \ if & x \in A \\ 0 \ if & x \notin A \end{cases}$

Definition 3.2 A fuzzy number is a generalization of the real numbers, in the sense that it does not refer to one single value but rather to a connected set of possible values with weights. This weight is called the membership function.

Definition 3.3 A triangular fuzzy number is a specific type of fuzzy number characterized by a triangular-shaped membership function. It is represented with three points as follows: A = (a,b,c).

Definition 3.4 The **shortest path** in a graph is the path between two nodes that has the smallest sum of weights.

V.DIJKSTRA'S ALGORITHM

Step 1: Initialize Distances
- Set the distance of the starting node to 0 and all other nodes to infinity.
- Mark all nodes as unvisited.

Step 2: Select the Current Node
- Choose the unvisited node with the smallest distance as the current node.
- Start with the starting node in the first iteration.

Step 3: Update Distances
- For each neighbor of the current node, calculate the tentative distance from the starting node.
- If the calculated distance to a neighbor is smaller than the currently known distance, update it with this new distance.

Step 4: Mark as Visited
- Once all neighbors of the current node are evaluated, mark the current node as visited.
- A visited node will not be checked again.

Step 5: Repeat or End
- Repeat Steps 2 to 4 until all nodes have been visited.

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- The algorithm ends when all nodes have been marked as visited. The shortest path distances to all nodes from the starting node are now determined.

VI. Numerical Example

In this example, we have five towns connected by roads with uncertain distances. The goal is to find the shortest path from **A** to **E** using fuzzy graph theory concepts, where distances between towns are represented by triangular fuzzy numbers to account for uncertainties.

Towns with Fuzzy Distances

(Represented as triangular fuzzy numbers (a,b,c))

- Distance between **A** and **B**: $d_{AB} = (4,5,6)$
- Distance between **A** and **C**: $d_{AC} = (3,4,5)$
- Distance between **B** and **D**: $d_{BD} = (2,3,4)$
- Distance between **C** and **D**: $d_{CD} = (5,6,7)$
- Distance between **C** and **E**: $d_{CE} = (3,4,5)$
- Distance between **D** and **E**: $d_{DE} = (1,2,3)$

SOLUTION:

STEP 1: Defuzzification of Fuzzy Distances

Each fuzzy distance is represented by a triangular fuzzy number (a,b,c).

We defuzzify these fuzzy distances by calculating the centroid of each triangular fuzzy number, given by:

$$\text{Centroid} = \frac{a+b+c}{3}$$

Using this formula, we get the following defuzzified distances:

A to B: $d_{AB} = \frac{4+5+6}{3} = 5$

A to C: $d_{AC} = \frac{3+4+5}{3} = 4$

B to D: $d_{BD} = \frac{2+3+4}{3} = 3$

C to D: $d_{CD} = \frac{5+6+7}{3} = 6$

C to E: $d_{CE} = \frac{3+4+5}{3} = 4$

D to E: $d_{DE} = \frac{3+4+5}{3} = 4$

Now we have towns A, B, C,D and E, connected by roads with the following defuzzified distances:

A → B: 5

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A → C: 4

B → D: 3

C → D: 6

C → E: 4

D → E: 2

Step 2: Solution Using Dijkstra's Algorithm

Initialize

1. Set the starting distance to A as 0 .ie) dist (A) = 0.

2. Set the distance for all other towns (B, C, D, E) as infinity:

dist (B) = dist (C) = dist (D) = dist (E) = ∞.

Start at Town A:

Visit **A** and update the distances to the neighboring towns

A → B: 5 ⟹ dist (B) = 5

A → C: 4 ⟹ dist (C) = 4

Now, the updated distances are:

dist (A) = 0 ; dist (B) = 5 ; dist (C) = 4 ; dist (D) = ∞; dist (E) = ∞

Choose the Next Town with the Smallest Distance

C has the smallest distance 4 , so we visit C next.

Update Distances from C

From C, update the distances to its neighboring towns:

C → D: 4 + 6 = 10 ⟹ dist (D) = 10

C → E: 4 + 4 = 8 ⟹ dist (E) = 8

Now, the updated distances are:

dist (A) = 0 ; dist (B) = 5 ; dist (C) = 4 ; dist (D) = 10; dist (E) = 8

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Choose the Next Town with the Smallest Distance

B has the next smallest distance 5, so we visit B.

Update Distances from B

From B, update the distance to its neighboring town D:

B → D: 5 + 3 = 8 $\Rightarrow$ dist (D) = 8

which is less than the current dist(D) = 10, so we update: dist(D) = 8

Now, the updated distances are:

dist (A) = 0 ; dist (B) = 5 ; dist (C) = 4 ; dist (D) = 8; dist (E) = 8

Choose the Next Town with the Smallest Distance

E has the next smallest distance 8, so we visit E.

Update Distances from E

From E, we would update distances to its neighboring towns, but E has no additional neighbors, so no updates are needed.

Choose the Next Town with the Smallest Distance

Finally, we visit D with a distance of 8, which has already been covered by other paths.

Final Distances

After running Dijkstra's algorithm, the shortest distances from A to each town are:

dist (A) = 0 ; dist (B) = 5 ; dist (C) = 4 ; dist (D) = 8; dist (E) = 8

Shortest Path from A to E

From our calculations, the shortest path from **A** to **E** is: **A → C → E**

Distance Calculation: 4 (from A to C) + 4 (from C to E) = 8

So, the total shortest distance from **A** to **E** is **8 units**.

RESULT:

The shortest path from **A** to **E** is: **A → C → E** with a total distance of **8 units**.

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VII. C CODING FOR DIJKSTRA'S ALGORITHM

Here's a C programming solution for solving the shortest path problem using **Dijkstra's Algorithm**:

```
#include <stdio.h>
#include <limits.h>
#define V 5 // Number of towns (nodes)
// Function to find the node with the minimum distance value
int minDistance(int dist[], int visited[]) {
    int min = INT_MAX, minIndex;
    for (int v = 0; v < V; v++)
        if (visited[v] == 0 && dist[v] <= min) {
            min = dist[v];
            minIndex = v;
        }
    return minIndex;
}
// Dijkstra's algorithm to find the shortest path from source (0) to destination (4)
void dijkstra(int graph[V][V], int src) {
    int dist[V];      // Shortest distance from src to each town
    int visited[V];   // visited[i] will be 1 if the shortest path to town i is found
    // Initialize distances with infinity and visited with false (0)
    for (int i = 0; i < V; i++) {
        dist[i] = INT_MAX;
        visited[i] = 0;
    }
    // Distance from src to itself is always 0
    dist[src] = 0;
    // Find shortest path for all towns
    for (int count = 0; count < V - 1; count++) {
        int u = minDistance(dist, visited);
        visited[u] = 1;
        // Update distance values for adjacent towns of the selected town
        for (int v = 0; v < V; v++)
            if (!visited[v] && graph[u][v] && dist[u] != INT_MAX && dist[u] + graph[u][v] < dist[v])
                dist[v] = dist[u] + graph[u][v];
    }
    // Print the result for the path from A (src) to E (destination)
    printf("Shortest distance from town A to town E: %d\n", dist[4]);
}
int main() {
    /* Adjacency matrix representing the distances between towns:
       A - B - C - D - E
       Where:
        - graph[i][j] = 0 if there is no direct path between towns i and j.
        - graph[i][j] = distance between town i and town j if there is a path.
    int graph[V][V] = {
        {0, 5, 4, 0, 0}, // A to B (5), A to C (4)
        {5, 0, 0, 3, 0}, // B to D (3)
        {4, 0, 0, 6, 4}, // C to D (6), C to E (4)
        {0, 3, 6, 0, 2}, // D to E (2)
        {0, 0, 4, 2, 0}  // Connections to E
    };
    // Run Dijkstra's algorithm from source town A (index 0)
```

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```
    dijkstra(graph, 0);
    return 0;
}
```

OUTPUT:

Shortest distance from town A to town E: 8

VIII. CONCLUSION

In this problem, Dijkstra's algorithm has been effectively applied to find the shortest path in a network of towns represented as nodes connected by weighted edges, where each weight signifies the distance between towns. By constructing an adjacency matrix and implementing Dijkstra's algorithm, we successfully identified the shortest distance from Town A to Town E, which was found to be 8 units. This solution demonstrates the efficiency of Dijkstra's algorithm in handling shortest path problems for connected, weighted graphs, especially when optimizing routes in transportation networks or similar applications in construction management and logistics. The approach provides a reliable way to navigate through complex networks, minimizing travel costs and improving efficiency in planning and operations.

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