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A Network Shortest Path Algorithm via Hesitancy Fuzzy Digraph

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Abstaract − Many extension and generalization of fuzzy sets have been studied and introduced in the literature. Hesitancy fuzzy digraph is a generalization of intuitionistic fuzzy set and fuzzy graph. In this paper, we redefine some basic operations of hesitancy fuzzy graph and it is referred as hesitancy fuzzy digraph (in short HFDG). We discuss some arithmetic operations and relations among HFDG. We further proposed a method to solve a shortest path problem through score function.

Keywords − *Digraphs, Hesitancy fuzzy sets, Hesitancy fuzzy digraphs.*

1 Introduction

Several extension of fuzzy set have been proposed, since 1965 [11]. Some of the works among the generalization are remarkable in the history of literature such as intuitionistic fuzzy set [1], type 2 fuzzy set, interval valued fuzzy set, neutrosophic sets [19] and so on. Hesitant fuzzy sets are useful to deal with group decision making problems when experts have a hesitation among several possible memberships for an element to a set.The concept of hesitancy fuzzy set (HFS for short) proposed by Torra [4]. It is a generalization of fuzzy sets and intuitionistic fuzzy sets, that permits us to represent the situation in which different membership functions are considered possible. The concept of hesitancy fuzzy set is characterized by three dependent membership degrees namely truth-membership degree (t), hesitancy membership degree (h), and falsity-membership degree (f). HFSs are motivated to handle the common difficulty

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that appears in fixing the membership degree of an element from some possible values. This situation is rather common in decision making problems too while an expert is asked to assign different degrees of membership to a set of elements $\{x, y, z, ...\}$ in a set A. Often problems arise due to uncertain issues and situations hence one is faced with hesitant moments. The researcher had to find ways and means to take the problems and arrive at a solution. Therefore researchers have taken up the study and application of HFS. HFSs have been extended in [2,3,5,6,13] and Zhu[12] from different perspectives such as, both quantitatively and qualitatively. Since the concept of the hesitant fuzzy set was established,it has gained increasing attention and has been successfully applied to many uncertain decision making problems. hesitancy fuzzy graphs (HFG for short) where introduced and studied by Pathinath and Jon [14] in order to capture the common intricacy that occurs during a selection of membership degree of an element from some possible values that makes one to hesitate. The concept of hesitancy fuzzy graphs are generalizations of fuzzy graphs [7], intuitionistic fuzzy graphs [8,9] and vague graphs [10]. The Table 1, presented a comparative study between all of these kinds of graphs. The shortest path problem is one of the most fundamental problems in graph theory which has many applications diversified field such operation research, computer science, communication network and so on. In a network, the shortest path problem concentrate at finding the path from one source to destination node with minimum weight, where some weight is attached to each edge connecting a pair of nodes. In the literature, many shortest path problems [16-18] have been studied with different types of input data, including fuzzy set, intuitionistic fuzzy sets, trapezoidal intuitionistic fuzzy sets, vague set.

In this paper a new method is proposed for solving shortest path problems in a network which the edges length are characterized by hesitancy fuzzy numbers. We consider a situation that a company wishes to assign a work to service center based on the possible to clear the issue(t) and not possible to clear the issue (f). But if the technician is on leave then the company or else the service center has to approach the near by center. This category is called the hesitancy(h). The paper is organized as follows: In Section 2, definition of Hesitancy fuzzy set is given. In Section 3, we provide the definition of hesitancy fuzzy digraphs (HFDGs), some arithmetic operation and score function of a hesitancy fuzzy number. Section 4 and 5, Network terminology and Algorithm is proposed using the score function and example for the proposed algorithm for network problems to find shortest path and distance from the source node to the destination node. In Section 6, a comparative study between the proposed approach and other existing approaches is summarized and Section 7 conclude the paper.

2 Preliminary

In this paper, we provide the basic definition of hesitancy fuzzy set. This is very useful for the discussions.

Definition 2.1. *Let X be a fixed set, a Hesitant fuzzy set (HFS) on X is in terms of a function that when applied to X returns a subset of* $[0, 1]$. *The HFS is defined by a mathematical symbol as: $A = \{< x, h_A(x) >: x \in X\}$, where $h_A(x)$ is a set of*

Table 1: Comparative study between hesitancy fuzzy graph, fuzzy graphs, intuitionistic fuzzy graphs and vague graphs.

TYPES OF GRAPHS	ADVANTAGEES	DISADVANTAGES
Crisp graph	Graph is a relationship between a set of objects. Each objects is denoted by a vertex and relationship between every object is denoted by an edge	Crisp graph is difficult to apply for uncertainty on vertices and/or edges and the relation among every objects are not precise.
Fuzzy graph[7]	Crisp graph and Fuzzy graph are structurally similar but fuzzy graph can be applied for uncertainty on vertices and/or edges.	It gives less accuracy into problems since the existence of non-zero hesitation.
Intuitionistic fuzzy graph[8,9]	Identify the nature of the arcs. Intuitionistic fuzzy graph assigning degree of membership to each object because there is a fair chance of existence of a hesitation part at each moment of evaluation of anything and also it gives more accuracy into the problem.	Hesitation remains in choosing membership degree of an element from some possible values.
Vague graph[10]	In vague graph, true membership considered as the lower bound for degree of positive membership and false membership is the lower bound for negative of membership.	Error occurs due to choosing lower bound.
Hesitancy fuzzy graph[14]	Hesitant fuzzy graph gives more accuracy than intuitionistic fuzzy graph because it is dependent on membership and non-membership.	We can't apply this technique, if the membership and non-membership are independent.

some values in $[0,1]$, *denoting the possible membership degrees of the element* $x \in X$ *to the set* A *and called* $h = h_A(x)$ *a hesitant fuzzy element (HFE) and* Θ *the set of all HFEs.*

Definition 2.2. *Let* V *be a finite hesitancy fuzzy non-empty set,* $A = \langle V, t_i, h_i, f_i \rangle$ *a hesitancy fuzzy set of* V *and* $B = \langle V \times V, t_{i,j}, h_{i,j}, f_{i,j} \rangle$ *a hesitancy fuzzy relation on* V*. Then the ordered pair* $G = (A, B)$ *is called hesitancy fuzzy directed graph or hesitancy fuzzy digraph (HFDG).*

Where $t_i : V \to [0,1]$, $h_i : V \to [0,1]$ *and* $f_i : V \to [0,1]$ *denote the degree of membership(t), hesitancy(h) and non-membership(f) of the element* $v_i \in V$ *respectively and* $t_i(v_i) + h_i(v_i) + f_i(v_i) = 1$ *for every* $v_i \in V, \forall i \in Z$, $h_i = 1 - (t_i + f_i)$ *and* $B = E \subseteq V \times V$ *where* $t_{i,j} : V \times V \to [0,1]$, $h_{i,j} : V \times V \to [0,1]$ *and* $f_{i,j} : V \times V \to [0,1]$ *are the degrees of membership(t), hesitancy(h) and non-membership(f) of the edge* (v_i, v_j) *respectively such that* $0 \leq t_{i,j} + h_{i,j} + f_{i,j} \leq 1$

and

$$t_{i,j} \leq min\{v_i, v_j\}$$
$$h_{i,j} \leq min\{v_i, v_j\}$$
$$f_{i,j} \leq max\{v_i, v_j\}$$

Note 1: In hesitancy fuzzy graph, the graph is symmetric relation on V but HFDG is not symmetric relation on V

Notation

1. Hereafter, $\langle t(v_i), h(v_i), f(v_i)\rangle$ or simply $\langle t_i, h_i, f_i\rangle$ denotes the degrees of membership, hesitancy and non-membership of the vertex $v_i \in V$, such that $t_i(v_i) + h_i(v_i) + f_i(v_i) = 1$.

2. $\langle t(v_{i,j}), h(v_{i,j}), f(v_{i,j})\rangle$ or simply $\langle t_{i,j}, h_{i,j}, f_{i,j}\rangle$ denotes the degrees of membership, hesitancy and non-membership of the edge $(v_i, v_j) \in V \times V$, such that $0 \leq t_{i,j} + h_{i,j} + f_{i,j} \leq 1$.

Note 2:

1. If $t_{i,j} = 0$, for some i and j , then there is no edge between v_i and v_j and it is indexed by $\langle 0, 1, 0\rangle$ or $\langle 0, 0, 1\rangle$ or $\langle 0, 0, 0\rangle$. Otherwise there exists edge between v_i and v_j.

2. In this paper, we are interested in hesitancy fuzzy zero, given by: $0 = \langle 0, 0, 1\rangle$

Example 2.3. *Let $G = (V, E)$ be a HFDG, where the vertex set is $V = \{v_1, v_2, v_3, v_4, v_5, v_6\}$ shown in Figure 1*

The index matrix of G is $G = \{V, V, \langle t_{i,j}, h_{i,j}, f_{i,j}\rangle\}$, where $V = \{v_1, v_2, v_3, v_4, v_5, v_6\}$ is given in the Table 2.

Table 2: Index matrix

	v_1	v_2	v_3	v_4	v_5	v_6
v_1	$\langle 0,0,1\rangle$	$\langle 0.3,0.2,0.5\rangle$	$\langle 0,0,1\rangle$	$\langle 0.1,0.2,0.5\rangle$	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$
v_2	$\langle 0,0,1\rangle$	$\langle 0.6,0.3,0.1\rangle$	$\langle 0,0,1\rangle$	$\langle 0.5,0.3,0.2\rangle$	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$
v_3	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$	$\langle 0.1,0.2,0.7\rangle$	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$	$\langle 0.1,0.2,0.6\rangle$
v_4	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$	$\langle 0.1,0.2,0.7\rangle$	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$
v_5	$\langle 0.3,0.1,0.5\rangle$	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$	$\langle 0.4,0.1,0.3\rangle$
v_6	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$	$\langle 0.3,0.1,0.5\rangle$	$\langle 0,0,1\rangle$	$\langle 0,0,1\rangle$

Definition 2.4. *Let $A_1 = \langle t_1, h_1, f_1\rangle$ and $A_2 = \langle t_2, h_2, f_2\rangle$ be two hesitancy fuzzy numbers. Then, the operations for HFNs are defined as below;*

1. $A_1 \oplus A_2 = \langle t_1 + t_2 - t_1t_2, h_1 + h_2 - h_1h_2, f_1f_2\rangle$

2. $A_1 \otimes A_2 = \langle t_1t_2, h_1h_2, f_1 + f_2 - f_1f_2\rangle$

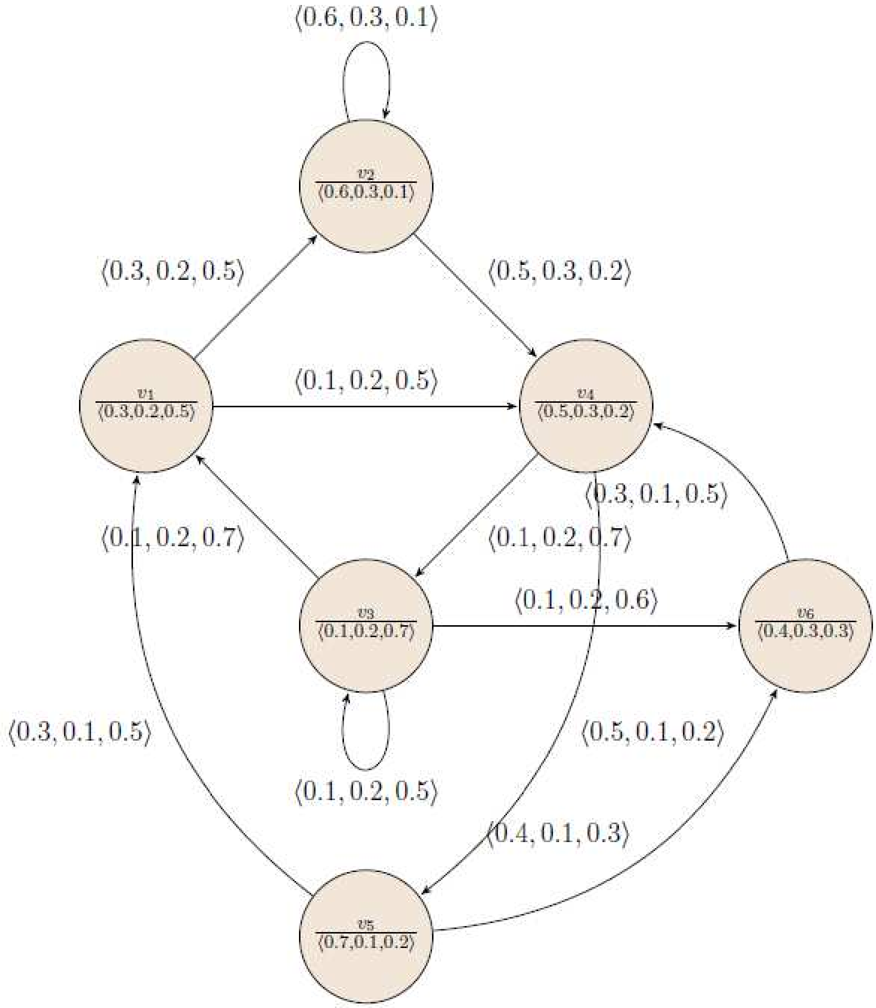

Figure 1: G: Hesitancy fuzzy digraph

3. $\lambda A_1 = \langle (1-(1-t_1)^\lambda), (1-(1-h_1)^\lambda), f_1^\lambda \rangle$

4. $A_1^\lambda = \langle t_1^\lambda, h_1^\lambda, (1-(1-f_1)^\lambda), \rangle$

Definition 2.5. *Let $A = \langle t, h, f \rangle$ be a hesitancy fuzzy number. Then, the score function $s(A)$ is defined by* $s(A) = \frac{1+(t+2h-f)(2-t-f)}{2}$

Comparison of two hesitancy fuzzy numbers.

Let $A_1 = \langle t_1, h_1, f_1 \rangle$ and $A_2 = \langle t_2, h_2, f_2 \rangle$ be two hesitancy fuzzy numbers then

1. $A_1 \prec A_2$ if $s(A_1) \prec s(A_2)$

2. $A_1 \succ A_2$ if $s(A_1) \succ s(A_2)$

3. $A_1 = A_2$ if $s(A_1) = s(A_2)$

3 Network Terminology and the Proposed Algorithm

Consider a directed network $G(V, E)$ consisting of a finite set of nodes $V = \{1, 2, ..., n\}$ and a set of m directed edges $E \subseteq V \times V$. Each edge is denoted by an ordered pair (i, j) where $i, j \in V$ and $i \neq j$. In this network, we specify two nodes, denoted by 1 and n, which are the source node and the destination node, respectively. We define a path $p_{ij} = \{i = i_1, (i, j), i_3, i_4, .., i_{l-1}, (i_{l-1}, i_l), i_l\}$ of alternating nodes and edges. The existence of atleast one path P_{1i} in $G(V, E)$ is assumed for every $i \in V - \{1\}$. d_{ij} denotes hesitancy fuzzy number associated with the edge (i, j), corresponding to the length necessary to traverse (i, j) from i to j. The hesitancy fuzzy distance along the path P is denoted as $d(P)$ is defined as $d(P) = \sum_{\{i,j \in P\}} d_{ij}$

Remark: A node i is said to be predecessor node of node j if

1. Node i is directly connected to node j.
2. The direction of path connecting node i and j from i to j.

In this paper, the edge length in a network is considered to be a hesitancy fuzzy number , also in this section, an algorithm is being proposed to find the hesitancy fuzzy minimum arc length and the shortest distance in a network of each node from source node. The algorithm is a labeling technique which can be applied for solving shortest path problems occurring in real life problem.

Algorithm:

1. Assume $d_1 = \langle 0, 0, 1\rangle$ and label the source node as d_1.
2. Find $d_j = min\{d_i \oplus d_{ij}\}$, where $j = 2, 3, ..., n$.
3. If minimum occurs corresponding to unique value of i i.e., $i = p$ then label node j as $[d_j, p]$. If minimum occurs corresponding to more than one values of i then it represents that there are more than one hesitancy fuzzy path between source node i and node j but hesitancy fuzzy distance along the path is d_j, so choose any value of i.
4. Let the destination node (node n) be labeled as $[d_n, l]$, then the hesitancy fuzzy shortest distance between source node is d_n.
5. Since destination node is labeled as $[d_n, l]$, so, to find the hesitancy fuzzy shortest path between source node and destination node, check the label of node l. Let it be $[d_l, r]$, now check the label of node r and so on. Repeat the same procedure until node l is attained.
6. Now the hesitancy fuzzy shortest path can be obtained by combining all the nodes obtained by the step 5.

4 Illustrative Network Example

A DTH company, say a wish to provide a best service to the customers. A customer, say f have problem in the DTH. He approaches the customer care of the DTH company to get recover from the issue. The company has private service center in different cities. Those service centers are associated with the other service centers because if the issue is big, they will approaches the other. Here the truth membership represents that possibe to clear the issue by the service center, non-membership represents that not possible to clear the issue and hesitancy represents technicians availability. The company wish to find best service center through the proposed algorithm.

Let us consider a hesitancy fuzzy digraph for the given network problem shown in figure 2. b, c, d, e represents the private service centers and a, b, c, d, e, f are called nodes.

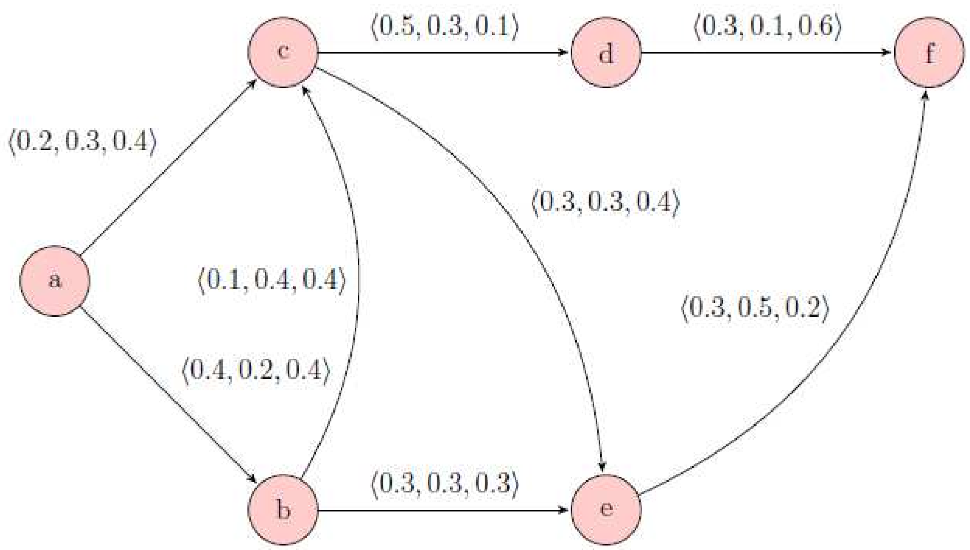

Figure 2: Network with hesitancy fuzzy distance

Using the algorithm described in section 4, the following computational results are obtained. Let us consider the source node = a and the destination node = f, so $n = f$.

Let $d_a = \langle 0, 0, 1\rangle$ and label the source node distance as $d_a = [\langle 0, 0, 1\rangle, a]$, the value of $d_j; j = b, c, d, e, f$ can be obtained as follows:

Iteration 1: Since a is the only one the predecessor node of node b , put $i = a$ and $j = b$ in step 2 of the proposed algorithm, the value of d_b is $d_b = min\{d_a \oplus d_{ab}\}=min\{\langle 0, 0, 1\rangle \oplus \langle 0.4, 0.2, 0.4\rangle\}=\langle 0.4, 0.2, 0.4\rangle$

The minimum node value corresponds to the node $i = a$. Therefore label the distance of node b as $d_b = [\langle 0.4, 0.2, 0.4\rangle, a]$

Iteration 2 : Nodes a and b are the two predecessor nodes of node c, put $i = a, b$ and $j = c$ in step 2 of the proposed algorithm, the value of d_c is

$$\begin{aligned}
d_c &= min\{d_a \oplus d_{ac}, d_b \oplus d_{bc}\}\\
&= min\{\langle 0,0,1\rangle \oplus \langle 0.4,0.2,0.4\rangle, \langle 0.4,0.2,0.4\rangle \oplus \langle 0.1,0.4,0.4\rangle\}\\
&= \langle 0.2,0.3,0.4\rangle, \langle 0.46,0.52,0.16\rangle \ s\langle 0.2,0.3,0.4\rangle\\
&= \tfrac{1+(t+2h-f)(2-t-f)}{2}\\
&= 0.78 \ s\langle 0.46,0.52,0.16\rangle\\
&= \tfrac{1+(t+2h-f)(2-t-f)}{2}\\
&= 1.4246\\
&\Rightarrow s\langle 0.2,0.3,0.4\rangle \leq s\langle 0.46,0.52,0.16\rangle.
\end{aligned}$$

The minimum node value corresponds to the node $i = a$. Therefore label the distance of node c as $d_c = [\langle 0.2, 0.3, 0.4\rangle, a]$

Iteration 3 : Node c is the predecessor node of node d , put $i = c$ and $j = d$ in step 2 of the proposed algorithm, the value of d_d is

$$d_4 = min\{d_c \oplus d_{cd}\} = min\{\langle 0.2,0.3,0.4\rangle \oplus \langle 0.5,0.3,0.1\rangle\} = \langle 0.6,0.51,0.04\rangle$$

The minimum node value corresponds to the node $i = c$. Therefore label the distance of node d as $d_d = [\langle 0.6, 0.51, 0.04\rangle, c]$

Iteration 4: b and c are the two predecessor nodes of node e, put $i = b, c$ and $j = e$ in step 2 of the proposed algorithm, the value of d_e is

$$\begin{aligned}
d_e &= min\{d_b \oplus d_{be}, d_c \oplus d_{ce}\}\\
&= min\{\langle 0.4,0.2,0.4\rangle \oplus \langle 0.3,0.3,0.3\rangle, \langle 0.2,0.3,0.4\rangle \oplus \langle 0.3,0.3,0.4\rangle\}\\
&= \langle 0.58,0.44,0.12\rangle, \langle 0.44,0.51,0.64\rangle \ s\langle 0.58,0.44,0.12\rangle\\
&= \tfrac{1+(t+2h-f)(2-t-f)}{2}\\
&= 1.371 \ s\langle 0.44,0.51,0.64\rangle\\
&= \tfrac{1+(t+2h-f)(2-t-f)}{2} = 0.8772\\
&\Rightarrow s\langle 0.44,0.51,0.64\rangle \leq s\langle 0.58,0.44,0.12\rangle.
\end{aligned}$$

The minimum node value corresponds to the node $i = c$. Therefore label the distance of node c as $d_e = [\langle 0.44, 0.51, 0.64\rangle, c]$.

Iteration 5 :d and e are the two predecessor nodes of node f , put $i = d, e$ and $j = f$ in step 2 of the proposed algorithm, the value of d_f is

$$\begin{aligned}
d_e &= min\{d_d \oplus d_{df}, d_e \oplus d_{ef}\}\\
&= min\{\langle 0.6,0.51,0.04\rangle \oplus \langle 0.3,0.1,0.6\rangle, \langle 0.44,0.51,0.64\rangle \oplus \langle 0.3,0.5,0.2\rangle\}
\end{aligned}$$

$= \langle 0.72, 0.559, 0.24\rangle, \langle 0.608, 0.755, 0.128\rangle$ $s\langle 0.72, 0.559, 0.24\rangle$
$= \frac{1+(t+2h-f)(2-t-f)}{2}$
$= 1.33096$ $s\langle 0.608, 0.755, 0.128\rangle$
$= \frac{1+(t+2h-f)(2-t-f)}{2}$
$= 1.75768$
$\Rightarrow s\langle 0.72, 0.559, 0.24\rangle \leq s\langle 0.608, 0.755, 0.128\rangle.$

The minimum node value corresponds to the node $i = d$. Therefore label the distance of node d as $d_f = [\langle 0.72, 0.559, 0.24\rangle, d]$.

Now the hesitancy fuzzy shortest path between node a and node f can be obtained by using the following procedure: Since node f is labeled by $d_f = [\langle 0.72, 0.559, 0.24\rangle, d]$, which represents that we are coming from node d. Node d is labeled by $d_d = [\langle 0.6, 0.51, 0.04\rangle, c]$ which represents that we are coming from node c. Node c is labeled by $d_c = [\langle 0.2, 0.3, 0.4\rangle, a]$, which represents that we are coming from node a. Now the hesitancy fuzzy shortest path between the company a and customer f is obtaining by joining all the obtained nodes. Hence the hesitancy fuzzy shortest path is $a \to c \to d \to f$ with the hesitancy fuzzy value $\langle 0.72, 0.559, 0.24\rangle$. In figure 3, the dark lines indicate the shortest path from the source node (company) to the destination node (customer).

The hesitancy fuzzy shortest distance and the hesitancy fuzzy shortest path of all nodes from node a is shown in the table 2 and the labeling of each node is shown in Figure 3.

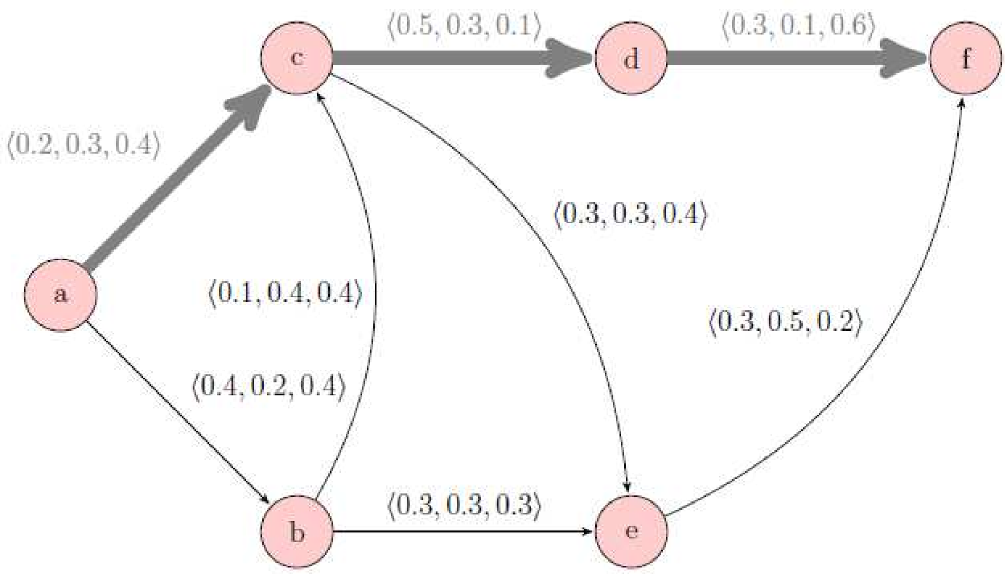

Figure 3: Network with Hesitancy fuzzy shortest distance

Since there is no other work on shortest path problem using hesitancy fuzzy parameters for the edges (arcs), numerical comparison of this work with others work could not be done.

In this paper we find the shortest path from company to customer using the hesitancy fuzzy shortest path algorithm. The idea of this algorithm is to carry the distance function which works as a tool to identify the successor node from company at the beginning till it reaches the customer with a shortest path. Hence our hesitancy fuzzy shortest path algorithm is much efficient providing the fuzziness between the intervals classified with true, hesitancy and false membership values. This concept is ultimately differing with intuitionistic membership values as the case of intuitionistic considers only the true and the false membership values. Hence in hesitancy fuzzy, all the cases of fuzziness is discussed and so the algorithm is effective in finding the shortest path.

5 Comparison table

In this section, a comparative study of various existing path problem such as crisp shortest path problem, fuzzy shortest path problem, intuitionistic fuzzy shortest path problem and hesitancy fuzzy shortest path problem is presented in Table 3.

Shortest path problems	Advantages	Disadvantages
Crisp shortest path problem	It deals with exact information based on its computed distance and weight.	It is unable to deal with uncertainty and inconsistencies exist in the weights or distance of given information.
fuzzy shortest path problem [7]	The weights of the edges are normalized or computed with fuzzy membership-values to deal with uncertainty in distance or weight of given information.	It provides a fuzzy shortest path length is found, but it does not correspond to an actual path in the network
intuitionistic fuzzy shortest path [9]	1. Intuitionistic fuzzy numbers are the more generalized form of fuzzy numbers involving two independently estimated degrees: degree of acceptance and degree of rejection. 2. Weights of the arc(edges) are intuitionistic fuzzy numbers.	It produces some marginal error which is beyond acceptation and rejection membership-values.
hesitancy fuzzy shortest path problem	Its reduces the marginal or uncertain error which may arises due to inconsistency in shortest path problem	Output differs slightly due to algorithm, and score function of hesitancy fuzzy number adopted by the researchers.

Table 3: Comparison table

6 Conclusion

In this paper we proposed an algorithm for finding shortest path and shortest arc length for a real life problem. we found shortest path and shortest arc length from company to customer on a network where the edges weights are assigned by hesitancy fuzzy number. The procedure of finding shortest path has been well explained and suitably discussed. Further, the implementation of the proposed algorithm is successfully illustrated with the help of a network example. The algorithm is easy to understand and can be used for all types of shortest path problems with arc length as triangular hesitancy fuzzy, trapezoidal hesitancy fuzzy and interval valued hesitancy fuzzy numbers. As a future work, we plan to implement this approach practically in the area of soft computing such as neural networks, decision-making, and geographical information systems.

References

[1] K. Atanassov, *Intuitionistic fuzzy sets*, Fuzzy Sets and Systems vol. 20 (1986) 87-96.

[2] N. X. Thao, F. Smarandache, N. V. Dinh. *Support-Neutrosophic Set: A New Concept in Soft Computing*, Neutrosophic Sets and Systems 16 (2017) 93-98.

[3] L. Zadeh, *Fuzzy sets*, Inform and Control 8 (1965) 338-353

[4] F. Smarandache, *A Unifying Field in Logics. Neutrosophic Logic: Neutrosophy, Neutrosophic Set, Neutrosophic Probability*, Rehoboth: American Research Press (1999).

[5] M. Parimala, M. Karthika, S. Jafari, F. Smarandache, and R. Udhayakumar, *Decision-Making via Neutrosophic Support Soft Topological Spaces*, Symmetry 10(6) (2017) 1-10.

[6] A. Kauffman, *Introduction a la Theorie des Sous-emsembles Flous*, Masson et Cie 1 1973.

[7] S. Broumi, M. Talea, A. Bakali, and F. Smarandache, *Single-valued neutrosophic graphs* ,Journal of New Theory 10 (2016) 86-101.

[8] M. Akram and S. Shahzadi, *Neutrosophic soft graphs with application*, Journal of Intelligent and Fuzzy Systems 32 (2017) 841-858.

[9] M. Akram, S. Shahzadi, and S. Broumi, *Single-valued neutrosophic hypergraphs*, TWMS Journal of Applied and Engineering Mathematics 2016.