Application of Dijkstra Algorithm for Solving Interval Valued Neutrosophic Shortest Path Problem

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Abstract— **In this paper, the authors propose an extended version of Dijkstra' algorithm for finding the shortest path on a network where the edge weights are characterized by an interval valued neutrosophic numbers. Finally, a numerical example is given to explain the proposed algorithm.**

Keywords—Dijkstra algorithm; interval valued neutrosophic number; Shortest path problem; Network;

I. INTRODUCTION

Smarandache [1] originally proposed the concept of a neutrosophic set from a philosophical point of view. The concept of the neutrosophic set (NS for short) has the ability to handle uncertain, incomplete, inconsistent, the indeterminate in a more accurate way. The theory of neutrosophic sets are a generalization of the theory of fuzzy sets [3], intuitionistic fuzzy sets [4] and interval- valued intuitionistic fuzzy sets [6]. The concept of the neutrosophic sets is expressed by a truth-membership degree (T), an indeterminacy-membership degree (I) and a falsity-membreship degree (F) independently, which are within the real standard or nonstandard unit interval $]^{-}0,1^{+}[$. The concept of neutrosophic set is difficult to apply it real scientific and engineering areas. For this purpose. Smarandache [1] introduced the concept of SVNS, an instance of neutrosophic set, whose functions of truth, indeterminacy and falsity are within [0, 1]. In fact sometimes the degree of truth-membership, indeterminacy-membership and falsity-membership about a certain statement can not be defined exactly in the real situations, but expressed by several possible interval values. So the interval valued neutrosophic set (IVNS) was required. For this purpose, Wang et al.[8] introduced the concept of interval valued neutrosophic set (IVNS for short), which is more precise and more flexible than the single valued neutrosophic set. The interval valued neutrosophic sets (IVNS) is a generalization of the concept of single valued neutrosophic set, in which three membership functions are independent, and their values belong to the unite interval [0 , 1].

Some more literature about neutrosophic sets, interval valued neutrosophic sets and their applications in divers fields can be found in [9]. In addition, the operations on interval valued neutrosophic sets and their ranking methods are presented in [10-11]

The selection of shortest path problem (SPP) is one of classic problems in graph theory. Several algorithms have been proposed for solving the shortest path problem in a network. The shortest path problem appears in various disciplines such as transportation, road networks and other applications. The shortest path problems could be classified into three types [12]:

1) Problem of finding shortest path from a single source in which the aim is to find shortest path from source node to all other nodes around the graph.
2) Problem of finding shortest path to a single source in which the aim is to find the shortest path between each connected pair in the graph.
3) Problem of finding shortest path between each two nodes in which the aim is to find shortest path between connected pair in the graph.

In a network, the shortest path problem concentrates at finding the path from one source node to destination node with minimum weight. The edge length of the network may represent the real life quantities such as, cost, time, etc. In classical shortest path problem, it is assumed that decision maker is certain about the parameters (time, distance, etc)

978-1-5090-4240-1/16/$31.00 ©2016 IEEE

between different nodes. But in real life situations, there always exist uncertainty about the parameters between different nodes. For this purpose, several algorithms have been developed the shortest path under different types of input data, including, fuzzy sets, interval valued fuzzy sets, interval valued intuitionistic fuzzy sets and vague sets [13-18]. One of the well- known algorithms in solving shortest path problem is Dijikstra algorithm [19]. Dijikstra 'algorithm finds the shortest path from source node to other nodes in a graph, the so-called single source shortest path problem.

Recently, several articles have been published on neutrosophic graph theory [20-28]. In addition, Broumi et al. [29-32] proposed some algorithms dealt with shortest path problem in a network where the edge weights are characterized by a neutrosophic numbers including single valued neutrosophic number, bipolar neutrosophic numbers and interval valued neutrosophic numbers.

The main purpose of this article is to introduce an extended version of Dijkstra algorithm for solving shortest path problem on a network where the edge weights are characterized by an interval valued neutrosophic numbers. The decision maker can determine the shortest path and the shortest distance of each node from source node by using the proposed method. This method is more efficient due to the fact that the summing operation and the ranking of IVNNs can be done in an easy and straight manner.

The article is organized as follows. Some basic concepts of neutrosophic sets, single valued neutrosophic set and interval valued neutrosophic sets are introduced in section 2. In section 3, a network terminology is introduced. The extended version of Dijkstra'algorithm for solving the shortest path with connected edges in neutrosophic data is proposed in section 4. Section 5 illustrates a numerical example which is solved by the proposed method. Conclusions and further research are given in section 6.

II. Preliminaries

In this section, we introduced some basic concepts and definitions of single valued neutrosophic sets and interval valued neutrosophic sets from the literature [1, 7, 8, 10, 11]

Definition 2.1 [1]. Let X be an universe of discourse of points with generic elements in X denoted by x. Hence, the neutrosophic set A (NS A) is an object having the form A = {< x: $T_A(x)$, $I_A(x)$, $F_A(x)$>, x ∈ X}, where the functions T, I, F: X→$]^-0,1^+[$ define respectively the truth-membership function, the indeterminacy- membership and the falsity-membership function of the element x ∈ X to the set A with the condition:

$$^-0 \le T_A(x) + I_A(x) + F_A(x) \le 3^+. \qquad (1)$$

The functions $T_A(x)$, $I_A(x)$ and $F_A(x)$ are real standard or non-standard subset of $]^-0,1^+[$.

Since it is difficult to apply NSs to practical problems, Wang et al. [7] introduced the concept of a SVNS, which is an instance of Neutrosophic set and can be utilized in real scientific and engineering applications.

Definition 2. 2[7] Let X be an universe of discourse of points (objects) with generic elements in X denoted by x. the single valued neutrosophic set A (SVNS A) is characterized by truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$, and a falsity-membership function $F_A(x)$. For each point x in X, $T_A(x)$, $I_A(x)$, $F_A(x)$ ∈ [0, 1]. A SVNS A can be expressed as

$$A = \{< x: T_A(x), I_A(x), F_A(x)>, x \in X\} \qquad (2)$$

Definition 2.3 [8]. Let X be an universe of discourse of points (object) with generic elements in X denoted by x. An interval valued valued neutrosophic set A (IVNS A) is characterized by an interval truth-membership function $T_A(x) = \left[T_A^L, T_A^U\right]$,an interval indeterminacy-membership function $I_A(x) = \left[I_A^L, I_A^U\right]$, and an interval falsity membership function $F_A(x) = \left[F_A^L, F_A^U\right]$. For each point x in X $T_A(x)$, $I_A(x)$, $F_A(x)$ ∈ [0, 1]. An IVNS A can be expressed as

$$A= \{< x: T_A(x), I_A(x), F_A(x)>, x \in X\} \qquad (3)$$

Definition 2.4[11]. Let $\tilde{A}_1 =<\left[T_1^L, T_1^U\right],\left[I_1^L, I_1^U\right],\left[F_1^L, F_1^U\right]>$ and $\tilde{A}_2 =<\left[T_2^L, T_2^U\right],\left[I_2^L, I_2^U\right],\left[F_2^L, F_2^U\right]>$ be two interval valued neutrosophic numbers. Then, the operations for IVNNs are defined as below:

(i)

$$\tilde{A}_1 \oplus \tilde{A}_2 =<\left[T_1^L + T_2^L - T_1^L T_2^L, T_1^U + T_2^U - T_1^U T_2^U\right],\left[I_1^L I_2^L, I_1^U I_2^U\right],\left[F_1^L F_2^L, F_1^U F_2^U\right]> \qquad (4)$$

(ii)

$$\tilde{A}_1 \otimes \tilde{A}_2 =<\left[T_1^L T_2^L, T_1^U T_2^U\right],\left[I_1^L + I_2^L - I_1^L I_2^L, I_1^U + I_2^U - I_1^U I_2^U\right], \left[F_1^L + F_2^L - F_1^L F_2^L, F_1^U + F_2^U - F_1^U F_2^U\right]> \qquad (5)$$

(iii)

$$\lambda\tilde{A} =<\left[1-(1-T_1^L)^\lambda, 1-(1-T_1^U)^\lambda\right],\left[(I_1^L)^\lambda,(I_1^U)^\lambda\right],\left[(F_1^L)^\lambda,(F_1^U)^\lambda\right]> \qquad (6)$$

(iv)

$$\tilde{A}_1^\lambda =<\left[(T_1^L)^\lambda,(T_1^U)^\lambda\right],\left[1-(1-I_1^L)^\lambda, 1-(1-I_1^U)^\lambda\right],\left[1-(1-F_1^L)^\lambda, 1-(1-F_1^U)^\lambda\right]>$$

where $\lambda > 0$

(7)

Definition 2.5 [8]. An interval valued neutrosophic number $\tilde{A}_1 =<\left[T_1^L, T_1^U\right],\left[I_1^L, I_1^U\right],\left[F_1^L, F_1^U\right]>$ is said to be empty if and only if

$T_1^L = 0, T_1^U = 0, I_1^L = 1, I_1^U = 1$, and $F_1^L = 1, F_1^U = 1$ and is denoted by

$$0_n = \{<\text{x}, <[0,\ 0],\ [1,\ 1],\ [1,\ 1]>: \text{x} \in \text{X}\} \qquad (7)$$

A convenient method for comparing two interval valued neutrosophic numbers is by use of score function.

Definition 2.6 [10]. Let $\tilde{A}_1 = <\left[T_1^L, T_1^U\right], \left[I_1^L, I_1^U\right], \left[F_1^L, F_1^U\right]>$ be an interval valued neutrosophic number. Then, the score function $s(\tilde{A}_1)$ and accuracy function $\text{H}(\tilde{A}_1)$ of an IVNN are defined as follows:

(i) $s(\tilde{A}_1) = \left(\dfrac{1}{4}\right) \times \left[2 + T_1^L + T_1^U - 2I_1^L - 2I_1^U - F_1^L - F_1^U\right]$ (8)

(ii) $\text{H}(\tilde{A}_1) = \dfrac{T_1^L + T_1^U - I_1^U(1-T_1^U) - I_1^L(1-T_1^L) - F_1^U(1-I_1^U) - F_1^L(1-I_1^L)}{2}$

(9)

Definition 2.7 [10]. Let $\tilde{A}_1 = <\left[T_1^L, T_1^U\right], \left[I_1^L, I_1^U\right], \left[F_1^L, F_1^U\right]>$ and $\tilde{A}_2 = <\left[T_2^L, T_2^U\right], \left[I_2^L, I_2^U\right], \left[F_2^L, F_2^U\right]>$ are two interval valued neutrosophic numbers. Then, we define a ranking method as follows:

i. If $s(\tilde{A}_1) \succ s(\tilde{A}_2)$,then $\tilde{A}_1$ is greater than $\tilde{A}_2$,that is, $\tilde{A}_1$ is superior to $\tilde{A}_2$, denoted by $\tilde{A}_1 \succ \tilde{A}_2$

ii. If $s(\tilde{A}_1) = s(\tilde{A}_2)$, and $H(\tilde{A}_1) \succ H(\tilde{A}_2)$ then $\tilde{A}_1$ is greater then $\tilde{A}_2$, that is , $\tilde{A}_1$ is superior to $\tilde{A}_2$, denoted by $\tilde{A}_1 \succ \tilde{A}_2$.

III. NETWORK TERMINOLOGY

In this subsection we consider a directed network G= (V, E) where V denotes a finite set of nodes V= { 1, 2, …,n} and E denotes 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, two nodes denoted s (source) and t (target) are specified, which represent the source node and the destination node. The path is defined as sequence P_{ij} = {i=i_1, (i_1, i_2), i_2, …, i_{l-1}, (i_{l-1}, i_l), i_l=j} of alternating nodes and edges. The existence of at least one P_{si} in G = (V, E) is supposed for every i $\in$ V-{s}.

d_{ij} denotes an interval valued neutrosophic number assigned with the edge (i,j), corresponding to the length necessary to traverse (i, j) from i to j. In real problems, the lengths correspond to the time, the distance, the cost, etc. Hence, the interval valued neutrosophic distance along the path is denoted as d(P) and is expressed as follows:

$$\text{D(P)} = \sum_{(\text{i,j} \in \text{P})} d_{ij} \qquad (10)$$

Remark: A node i is called predecessor of node j if

(i) Node i and node j is connected directly.

(ii) The direction of path connected the node i and the node j is from i to j.

IV. INTERVAL VALUED NEUTROSOPHIC DIJKSTRA ALGORITHM

In this subsection, we modified the fuzzy Dijkstra's algorithm adapted from [33] for computing the shortest path on a network where the edge weights are characterized by an interval valued neutrosophic numbers.

This algorithm finds the shortest path and the shortest distance between a source node and any other node in the network. The interval valued neutrosophic Dijikstra' algorithm forwards from a node i to an immediately successive node j using a neutrosophic labeling procedure. Let $\tilde{u}_i$ be the shortest distance from node 1 to node i and $\text{s}(\tilde{d}_{ij}) \geq 0$ be the length of (i, j) edge. Then, the neutrosophic label for node j is defined as:

$$[\tilde{u}_j, \text{i}] = [\tilde{u}_i \oplus \tilde{d}_{ij}, \text{i}]. \quad \text{S}(\tilde{d}_{ij}) \geq 0 . \qquad (11)$$

Here label [$\tilde{u}_j$, i] mean we are coming from nodes i after covering a distance $\tilde{u}_j$ from the starting node. Dijikstra' algorithm classified the nodes into two classes: temporary set (T) and permanent set (P). A temporary neutrosophic label can be changed into another temporary neutrosophic label, if shortest path to the same neutrosophic node is checked. If no better path can be found then, the status of temporary neutrosophic label is replaced to permanent status.

In the following, we introduce the four steps of interval valued neutrosophic Dijkstra' algorithm as follows:

Step 1: Assign to source node (say node 1) the permanent label P [< [0, 0], [1, 1], [1, 1]>, -]. Set i=1.

Making a node permanent means that it has been included in the short path.

P denotes a permanent label, while – means that there is no sequence to the source node.

Step 2: Determine the temporary neutrosophic label [$\tilde{u}_i \oplus \tilde{d}_{ij}$, i] for each node j that can be arrived from i, provided j is not permanently labeled. If node j is previously labeled as [$\tilde{u}_j$, k] through another node K, and if S($\tilde{u}_i \oplus \tilde{d}_{ij}$) < S($\tilde{u}_j$) change [$\tilde{u}_j$, k] with [$\tilde{u}_i \oplus \tilde{d}_{ij}$, i].

Step 3: When all the nodes are permanently labeled, the algorithm terminates. Otherwise, choose the label [$\tilde{u}_r$, s] with shortest distance ($\tilde{u}_r$) from the list of temporary neutrosophic labels. Set i=r and repeat step 2.

Step 4: Select the shortest path between source node 1 and the destination node j by tracing backward through the network using the label's information.

Remark:

At each iteration among all temporary nodes, make those nodes permanent which have smallest distance. Note that at any iteration we can not move to permanent node, however,

reverse is possible. After all the nodes have permanent labels and only one temporary node remains, make it permanent.
After describing the interval valued neutrosophic Dijkstra' algorithm, in next section a numerical example is given to explain the proposed algorithm.
The flow diagram of interval valued neutrosophic Dijkstra algorithm is depicted in figure1

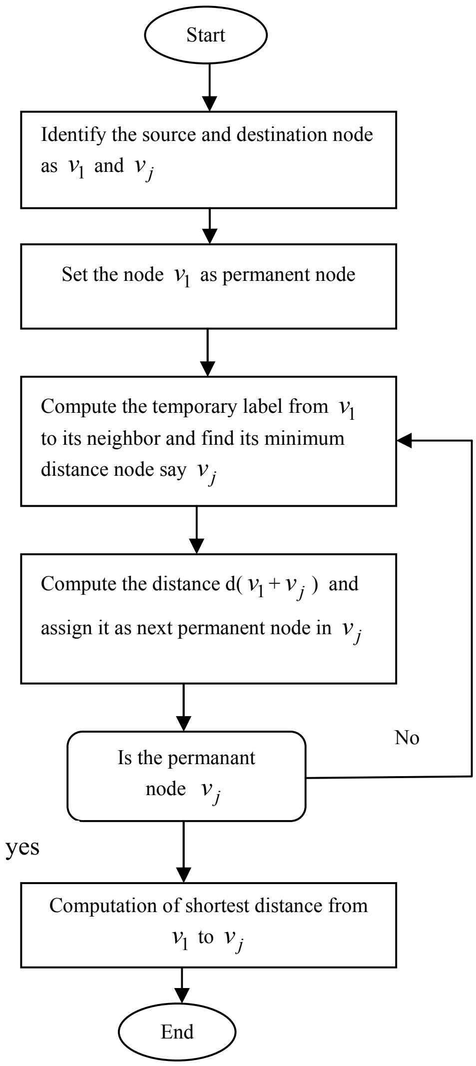

Fig. 1. Flow diagram representing the interval valued neutrosophic Dijkstra algorithm.

V. ILLUSTRATIVE EXAMPLE

In this subsection, an hypothetical example is used to verify the proposed approach. For this, we consider the network shown in figure2, then, we computed the shortest path from node 1 to node 6 where edges is represented by an interval valued neutrosophic numbers is computed. The extended Dijikstra algorithm is applied to the following network.

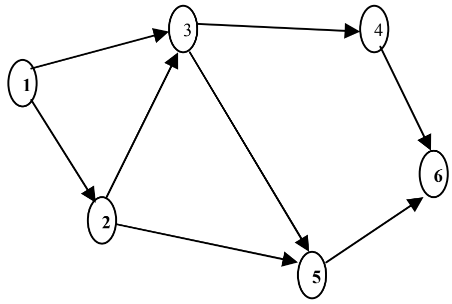

Fig.2. A network with interval valued neutrosophic weights
In this network each edge has been assigned to interval valued neutrosophic number as follows:

Table 1. Weights of the graphs

Edges	Interval valued neutrosophic distance
1-2	< [0.1,0.2], [0.2, 0.3], [0.4, 0.5]>
1-3	< [0.2,0.4], [0.3, 0.5], [0.1, 0.2]>
2-3	<[0.3,0.4], [0.1, 0.2], [0.3,0.5]>
2-5	<[0.1,0.3], [0.3, 0.4], [0.2, 0.3]>
3-4	< [0.2, 0.3], [0.2, 0.5], [0.4, 0.5]>
3-5	< [0.3, 0.6], [0.1, 0.2], [0.1, 0.4]>
4-6	< [0.4, 0.6], [0.2, 0.4], [0.1, 0.3]>
5-6	< [0.2, 0.3], [0.3, 0.4], [0.1, 0.5]>

Following the interval valued neutrosophic Dijkstra's algorithm, the details of calculations are defined below.
Iteration 0: Assign the permanent label [<[0, 0], [1, 1], [1, 1]>, -] to node1 .
Iteration 1: Node 2 and node 3 can be arrived from (the last permanently labeled) node 1. Hence, the list of labeled nodes (Temporary and permanently) is available in the following table

Nodes	Label	Status
1	[<[0, 0], [1, 1], [1, 1]>, -]	P
2	[<[0.1, 0.2], [0.2, 0.3], [0.4, 0.5]>, 1]	T
3	[<[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]>, 1]	T

In order to compare <[0.1, 0.2], [0.2, 0.3], [0.4, 0.5]>and <[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]> we use Eq.8
S (<[0.1, 0.2], [0.2, 0.3], [0.4, 0.5]>) =0.1
S (<[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]>)=0.175
Since the rank of [<[0.1, 0.2], [0.2, 0.3], [0.4, 0.5]>, 1] is less than [<[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]>, 1]. Hence, the status of node 2 is replaced by the permanent status.

Iteration 2: Node 3 and node 5 can be arrived from node 2. Hence, the list of labeled nodes (temporary and permanent) is available in the following table

Nodes	Label	Status
1	[<[0, 0], [1, 1], [1, 1]>, -]	P
2	[<[0.1, 0.2], [0.2, 0.3], [0.4, 0.5]>, 1]	P
3	[<[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]> , 1] or [<[0.37, 0.52], [0.02, 0.06], [0.12, 0.25]>, 2]	T
5	[<[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]>, 2]	T

S (<[0.37, 0.52], [0.02, 0.06], [0.12, 0.25] >) =0.59
S (<[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]>) =0.51
Among the temporary labels [<[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]>, 1] or [<[0.37, 0.52], [0.02, 0.06], [0.12, 0.25]>, 2], [<[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]>, 2] and since the rank of<[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]> is less than of <[0.37, 0.52], [0.02, 0.06], [0.12, 0.25]> and <[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]>, So the status of node 3 is replaced by a permanent status.

Iteration 3 : Node 4 and node 5 can be arrived from node 3. Hence, the list of labeled nodes (temporary and permanently) is available in the following table

Nodes	Label	Status
1	[<[0, 0], [1, 1], [1, 1]>, -]	P
2	[<[0.1, 0.2], [0.2, 0.3], [0.4, 0.5]>, 1]	P
3	[<[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]> , 1]	P
4	[<[0.36, 0.58], [0.06, 0.25], [0.04, 0.1]> , 3]	T
5	[<[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]> , 2] or [<[0.44, 0.76], [0.03, 0.1], [0.01, 0.08]>, 3]	T

S (< [0.36, 0.58], [0.06, 0.25], [0.04, 0.1]>) =0.54
S (< [0.44, 0.76], [0.03, 0.1], [0.01, 0.08]>) =0.71
Among the temporary labels [<[0.36, 0.58], [0.06, 0.25], [0.04, 0.1]> , 3] or [<[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]>, 2], [<[0.44, 0.76], [0.03, 0.1], [0.01, 0.08]>, 3] and since the rank of <[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]>,is less than of <[0.36, 0.58], [0.06, 0.25], [0.04, 0.1]> and <[0.44, 0.76], [0.03, 0.1], [0.01, 0.08]>. So the status of node 5 is replaced by a permanent status.

Iteration 4: Node 6 can be arrived from node 5. Hence, the list of labeled nodes (temporary and permanent) is available in the following table.

Nodes	Label	Status
1	[<[0, 0], [1, 1], [1, 1]>, -]	P
2	[<[0.1, 0.2], [0.2, 0.3], [0.4, 0.5]>, 1]	P
3	[<[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]>, 1]	P
4	[<[0.36, 0.58], [0.06, 0.25], [0.04, 0.1]>, 3]	T
5	[<[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]>, 2]	P
6	[<[0.35, 0.60], [0.01, 0.04], [0.008, 0.075]>, 5]	T

Since, there exist one permanent node from where we can arrive at node 6. So, make temporary label [<[0.35, 0.60], [0.01, 0.04], [0.008, 0.075]>, 5] as permanent.

Iteration 5: The only temporary node is 4, this node can be arrived from node 3 and node 6. Hence, the list of labeled nodes (temporary and permanent) is available in the following table

Nodes	label	status
1	[<[0, 0], [1, 1], [1, 1]>, -]	P
2	[<[0.1, 0.2], [0.2, 0.3], [0.4, 0.5]>, 1]	P
3	[<[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]>, 1]	P
4	[<[0.36, 0.58], [0.06, 0.25], [0.04, 0.1]>, 3] or [<[0.61, 0.84, [0.002, 0.016], [0.01, 0.023]>, 6]	T
5	[<[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]>, 2]	P
6	[<[0.35, 0.60], [0.01, 0.04], [0.008, 0.075]>, 5]	P

In order to compare <[0.36, 0.58], [0.06, 0.25], [0.04, 0.1]> and <[0.61, 0.48], [0.002, 0.016], [0.01, 0.023]> we use the Eq.8
S (<[0.36, 0.58], [0.06, 0.25], [0.04, 0.1]>) =0.54 and
S (<[0.61, 0.84], [0.002, 0.016], [0.01, 0.023]>) = 0.84
Since the rank of [<[0.36, 0.58], [0.06, 0.25], [0.04, 0.1]>, 3] is less than [<[0.61, 0.84, [0.002, 0.016], [0.01, 0.023]>, 6].

And the node 4 is the only one temporary node remains then, the status of node 4 is replaced by a permanent status.

Nodes	Label	Status
1	[<[0, 0], [1, 1], [1, 1]>, -]	P
2	[<[0.1, 0.2], [0.2, 0.3], [0.4, 0.5]>, 1]	P
3	[<[0.2, 0.4], [0.3, 0.5], [0.1, 0.2]>, 1]	P
4	[<[0.36, 0.58], [0.06, 0.25], [0.04, 0.1]>, 3]	T
5	[<[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]>, 2]	P
6	[<[0.35, 0.60], [0.01, 0.04], [0.008,0.075]>, 5]	P

Based on the step 4, the shortest path from node 1 to node 6 is determined using the following sequence.

(6) $\rightarrow$ [< [0.35, 0.60], [0.01, 0.04], [0.008, 0.075]>, 5] $\rightarrow$ (5) $\rightarrow$ [<[0.19, 0.44], [0.06, 0.12], [0.08, 0.15]>, 2] $\rightarrow$ (2) $\rightarrow$ [<[0.1, 0.2], [0.2, 0.3], [0.4, 0.5]>, 1] $\rightarrow$ (1)
Hence, the required shortest path is $1 \rightarrow 2 \rightarrow 5 \rightarrow 6$

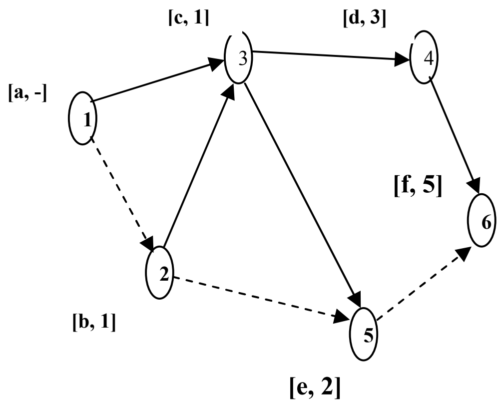

Fig 3. Network with interval valued neutrosophic shortest distance of each node from node 1.

Where, the neutrosophic label of each node is:
[a, -]= [< [0, 0], [1, 1], [1, 1] >, -]
[b, 1]= [< [0.1, 0.2], [0.2, 0.3], [0.4, 0.5], 1]
[c, 1]= [< [0.2, 0.4], [0.3, 0.5], [0.1, 0.2] >, 1]
[d, 3]= [< [0.36, 0.58], [0.06, 0.25], [0.04, 0.1] >, 3]
[e, 2]= [< [0.19, 0.44], [0.06, 0.12], [0.08, 0.15] >, 2]
[f, 5] = [< [0.35, 0.60], [0.01, 0.04], [0, 0.075] >, 5]

VI. CONCLUSION

This paper extended the single valued neutrosophic Dijkstra's algorithm for solving the shortest path problem of a network where the edge weights are characterized by an interval valued neutrosophic number. The use of interval valued neutrosophic numbers as weights in the graph express more precision than single valued neutrosophic numbers. Finally, a numerical example has been solved to check the efficiency of the proposed method. In future, we will research the application of this algorithm.

Acknowledgment

The authors are very grateful to the chief editor and reviewers for their comments and suggestions, which is helpful in improving the paper.

RFERENCES

[1] F. Smarandache, A unifying field in logic. Neutrosophy: neutrosophic probability, set and logic, American Research Press, Rehoboth, 1998.
[2] F. Smarandache, A Geometric Interpretation of the Neutrosophic set-A generalization of the Intuitionistic fuzzy set, Granular Computing (GrC), 2011 IEEE International Conference, 2011, pp.602-606.
[3] L. Zadeh, Fuzzy Sets. Inform and Control, 8, 1965, pp.338-353.
[4] K. Atanassov, Intuitionistic Fuzzy Sets, Fuzzy Sets and Systems, Vol 20, 1986, pp.87-96.
[5] I. Turksen, Interval Valued Fuzzy Sets Based on Normal forms, Fuzzy Sets and Systems, Volv20.1986, pp.191-120.
[6] K. Atanassov and G. Gargov, Interval valued intuitionstic fuzzy sets. Fuzzy Sets and systems, vol.31, 1989, pp.343-349.
[7] H. Wang, F. Smarandache, Y. Zhang and R. Sunderraman, Single Valued Neutrosophic Sets, Multispace and Multistructure 4, 2010, pp.410-413.
[8] H. Wang, F.Smarandache, Y. Q. Zhang and R.Sunderraman, Interval Neutrosophic Sets and Logic: Theory and Application in Computing. Hexis, phoenix, AZ, 2005.
[9] http://fs.gallup.unm.edu/NSS
[10] R. Şahin and P.D.Liu,Maximaizing Deviation Method for Neutrosophic Multiple Attribute Decision Making with Incomplete Weight Information, Neural Computing and Applications, 2015.DOI:10.1007/s00521-015-1995-8
[11] H.Y. Zhang, J. Q. Wang and X.H. Chen, Interval Neutrosophic Sets and Their Application in Multicriteria Decision Making Problems, Scientific World Journal, 2014. DOI: 10.1155/2014/65953.
[12] Y. Gao, shortest path problem with uncertain arc lengths. Computers and Mathematics with Applications 62, 2011, pp.2591-2600.
[13] A. Sengupta, T. K. Pal, Solving the shortest Path Problem with Interval Arcs, fuzzy Optimization and Decision Making, 5, 2006, pp.71-89.
[14] P. Jayagowri and G. G. Ramani, Using Trapezoidal Intuitionistic Fuzzy Number to Find Optimized Path in a network, volum 2014, Advances in Fuzzy Systems, 2014, 6 pages.
[15] A. Kumar and M. Kaur, A New Algorithm for Solving shortest Path Problem on a Network with Imprecise Edge Weight, Applications and Applied Mathematics, Vol.6, issue 2,2011,pp.602-619.
[16] A. Kumar and M. Kaur, Solution of Fuzzy Maximal Flow Problems using Fuzzy Linear Programming, World Academy of science and Technology, 87, 2011,pp.28-31
[17] S. Majumder and A. Pal, shortest Path Problem on Intuitionisitic Fuzzy Network, Annals of Pure And Applied Mathematics, Vol. 5, No. 1, November 2013, pp. 26-36.
[18] S. Okada and M. Gen, Fuzzy shortest path problems, Computers and industrial Engineering, Vol 27, N 1-4, 1994, pp.465-468.
[19] E. W.Dijikstra, A Note on two Problems in Connexion with Graphs, Numerishe Mathematik,1959, pp.269-271.
[20] S. Broumi, M. Talea, A. Bakali and F. Smarandache, Single Valued Neutrosophic Graphs, Journal of New Theory, N 10, 2016, pp. 86-101.
[21] S. Broumi, M.Talea, A. Bakali and F. Smarandache, On Bipolar Single Valued Neutrosophic Graphs, Journal of New Theory, N11, 2016, pp.84-102.
[22] S. Broumi, M. Talea, A. Bakali, F. Smarandache, Interval Valued Neutrosophic Graphs, (2016) in press.
[23] S. Broumi, A .Bakali, M. Talea and F. Smarandache, Isolated Single Valued Neutrosophic Graphs, Neutrosophic Sets and Systems, Vol .11, 2016, pp.74-78.
[24] S. Broumi, F. Smarandache, M. Talea and A. Bakali, An Introduction to Bipolar Single Valued Neutrosophic Graph Theory, Applied Mechanics and Materials, Vol.841, 2016, pp.184-191.
[25] S. Broumi, M.Talea, F. Smarandache and A. Bakali, Single Valued Neutrosophic Graphs: Degree, Order and Size, IEEE World Congress on Computational Intelligence, 2016, pp.2444-2451.
[26] F.Smarandache, symbolic Neutrosophic Theory, Europanova asbl, Brussels, 2015, 195p.
[27] F. Smarandche, Types of Neutrosophic Graphes and Neutrosophic Algebric Structures together with their Applications in Technology,Seminar, Universitatea Transilvania din Brasov, Facultatea de Design de Produssi Mediu, Brasov, Romania 06 June 2015.
[28] W. B. Kandasamy, Ilanthenral and F.Smarandache, Neutrosophic Graphs: A New Dimension to Graph Theory, Kindle Edition, USA, 2015, 127p.
[29] S. Broumi, A. Bakali, M. Talea, and F. smarandache, A Computation of Shortest Path Problem in a Network with Single Valued Neutrosophic Number Based On Ranking Method, 2016 (Submitted).
[30] S. Broumi, A. Bakali, M. Talea , F. Smarandache and M. Ali, Shortest Path Problem Under Bipolar Neutrosophic Setting, Applied Mechanics and Materials ,Vol .859, pp.59-66.
[31] S.Broumi, A.Bakali, M. Talea and F. Smarandache, Shortest Path Problem Under Interval Valued Neutrosophic Setting, 2016 (submitted).
[32] S. Broumi, A. Bakali, M. Talea and F. Smaranadche, Applying Dijkstra's Algorithm for Solving Neutrosophic Shortest Path Problem, 2016(submitted)
[33] N.Bhatia, Algorithms for Some Fuzzy Network Problems Using Ranking Function, (master Thesis, Thapar university Pataiala-147004(PUNJAB), School of Mathematics and Computer Applications, 2009.