Interior and Boundary vertices of BSV Neutrosophic Graphs

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Abstract---In the present article, we deduce a characterization of BSVN interior and boundary vertices. We established the relations between BSVN cut node and BSVN boundary nodes. Further, we studied properties of BSVN boundary nodes and BSVN interior nodes. Application of boundary node, interior is given on modeling wireless sensor network in terms of BSVN graphs.

Keywords---distance, BSVN boundary nodes, BSVN interior nodes

Introduction

The Neutrosophic sets launch by Smarandache [15, 16] is a great exact implement for the situation uncertainty in the real world. This uncertainty idea comes from the theories of fuzzy sets [9], intuitionistic fuzzy sets [6, 8] and interval valued intuitionistic fuzzy sets [7]. The representation of the neutrosophic sets are truth, indeterminacy and falsity value. These T, I, F values belongs to standard or nonstandard unit interval denoted by] −0, 1+ [[10,14].

The idea of subclass of the NS and SVNS introduced by Wang et al. [17]. The idea of SVNS initiation by intuitionistic fuzzy sets [5,11], in this the functions Truth, Indeterminacy, Falsity are not dependent and these values are present within [0, 1] [12]. Neutrosophic theory is widely expands in all fields especially authors discoursed about topology with respect to neutrosophic [18].

Graph theory has at this time turn into a most important branch of mathematics. It is the division of combinatory. The Graph is a extensively important to analyze combinatorial complication in dissimilar areas in mathematics, optimization and computer science. Mainly significant object is well-known. The uncertainty on the subject of vertice and edges or both representation to be a fuzzy graph.

In a graph theory the new graph model was invites by using BSVN set is known as BSVN Graph (BSVNG). In [3, 4, 13] Broumi et al. explained BSVN graphs from the recall of fuzzy, bipolar fuzzy and single valued neutrosophic graphs.

In this manuscript, discus about BSVN graphs and neutrosophic usual distance between two vertices of the graph based on this define BSVN eccentricity, radius, diameter, center and periphery with respect to distance. Also find some important results on these topics.

I. Preliminaries:

Explanation 2.1 BSVN sets:-

A BSVN set is explained as the membership functions represented as an object in W is denoted by $\left\{< w, T^P, I^P, F^P, T^N, I^N, F^N >: w \in W\right\}$, the functions T^P, I^P, F^P are mapping from W to $[0,1]$ and T^N, I^N, F^N are mapping from W to $[-1,0]$.

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Explanation 2.2 BSVN relation on W

Let W be a non-empty set. Then we call mapping $Z=\left(W,T^{P},I^{P},F^{P},T^{N},I^{N},F^{N}\right)$, $F^{N}\left(w_1,w_2\right):W\times W\rightarrow[-1,0]\times[0,1]$ is a BSVN relation on W such that $T_Z^P\left(w_1,w_2\right)\in[0,1],I_Z^P\left(w_1,w_2\right)\in[0,1],F_Z^P\left(w_1,w_2\right)\in[0,1]$

$T_Z^N\left(w_1,w_2\right)\in[-1,0],I_Z^N\left(w_1,w_2\right)\in[-1,0],F_Z^N\left(w_1,w_2\right)\in[-1,0]$.

Explanation 2.3 Let $Z_1=\left(T_{Z_1}^P,I_{Z_1}^P,F_{Z_1}^P,T_{Z_1}^N,I_{Z_1}^N,F_{Z_1}^N\right)$ and $Z_2=\left(T_{Z_2}^P,I_{Z_2}^P,F_{Z_2}^P,T_{Z_2}^N,I_{Z_2}^N,F_{Z_2}^N\right)$ be a BSVN graphs on a set W. If Z_2 is a BSVN relation on Z_1, then $T_{Z_2}^P\left(w_1,w_2\right)\le\min\left(T_{Z_2}^P\left(w_1\right),T_{Z_2}^P\left(w_2\right)\right)\ge\max\left(T_{Z_2}^N\left(w_1\right),T_{Z_2}^N\left(w_2\right)\right)$

$I_{Z_2}^P\left(w_1,w_2\right)\ge\max\left(I_{Z_1}^P\left(w_1\right),I_{Z_1}^P\left(w_2\right)\right)\le\min\left(I_{Z_1}^N\left(w_1\right),I_{Z_1}^N\left(w_2\right)\right)$

$F_{Z_2}^P\left(w_1,w_2\right)\ge\max\left(F_{Z_1}^P\left(w_1\right),F_{Z_1}^P\left(w_2\right)\right)\le\min\left(F_{Z_1}^N\left(w_1\right),F_{Z_1}^N\left(w_2\right)\right)$ for all $w_1,w_2\in W$

Explanation 2.4. The symmetric property defined on **BSVN** relation Z on W is explained by

$T_Z^P\left(w_1,w_2\right)=T_Z^P\left(w_2,w_1\right)$, $I_Z^P\left(w_1,w_2\right)=I_Z^P\left(w_2,w_1\right)$, $F_Z^P\left(w_1,w_2\right)=F_Z^P\left(w_2,w_1\right)$

$T_Z^N\left(w_1,w_2\right)=T_Z^N\left(w_2,w_1\right)$, $I_Z^N\left(w_1,w_2\right)=I_Z^N\left(w_2,w_1\right)$, $F_Z^N\left(w_1,w_2\right)=F_Z^N\left(w_2,w_1\right)$ for all $w_1,w_2\in W$

Explanation 2.5 BSVN graph

The new graph in SVN is denoted by $G^*=\left(V,E\right)$ is a pair $G=\left(Z_1,Z_2\right)$, where $Z_1=\left(T_{Z_1}^P,I_{Z_1}^P,F_{Z_1}^P,T_{Z_1}^N,I_{Z_1}^N,F_{Z_1}^N\right)$ is a BSVNS in V and $Z_2=\left(T_{Z_2}^P,I_{Z_2}^P,F_{Z_2}^P,T_{Z_2}^N,I_{Z_2}^N,F_{Z_2}^N\right)$ is BSVNS in V^2 defined as

$T_{Z_2}^P\left(w_1,w_2\right)\le\min\left(T_{Z_1}^P\left(w_1\right),T_{Z_1}^P\left(w_2\right)\right)$

$I_{Z_2}^P\left(w_1,w_2\right)\ge\max\left(I_{Z_1}^P\left(w_1\right),I_{Z_1}^P\left(w_2\right)\right)$

$F_{Z_2}^P\left(w_1,w_2\right)\ge\max\left(F_{Z_1}^P\left(w_1\right),F_{Z_1}^P\left(w_2\right)\right)$

$T_{Z_2}^N\left(w_1,w_2\right)\ge\max\left(T_{Z_1}^N\left(w_1\right),T_{Z_1}^N\left(w_2\right)\right)$

$I_{Z_2}^N\left(w_1,w_2\right)\le\min\left(I_{Z_1}^N\left(w_1\right),I_{Z_1}^N\left(w_2\right)\right)$

$F_{Z_2}^N\left(w_1,w_2\right)\le\min\left(F_{Z_1}^N\left(w_1\right),F_{Z_1}^N\left(w_2\right)\right)$ for all $w_1,w_2\in V$

The BSVNSG of an edge denoted by $w_1w_2\in V^2$

Explanation 2.6 Let $G=\left(Z_1,Z_2\right)$ be a BSVNSG and $a_1,c_1\in V$

A path $P: a_1 = w_0, w_1, w_2, ... w_{k-1}, w_k = c_1$ in G is sequence of distinct vertices such that $\begin{pmatrix} T^P_{Z_2}\left(w_{m-1}, w_m\right) > 0,\ I^P_{Z_2}\left(w_{m-1}, w_m\right) > 0,\ F^P_{Z_2}\left(w_{m-1}, w_m\right) > 0, \\ T^N_{Z_2}\left(w_{m-1}, w_m\right) > 0,\ I^N_{Z_2}\left(w_{m-1}, w_m\right) > 0,\ F^N_{Z_2}\left(w_{m-1}, w_m\right) > 0 \end{pmatrix}$, $m = 1, 2, ..., k$ and length of the path is k ,where is a_1 called initial vertex and c_1 is called terminal vertex in the path.

Explanation 2.7 A BSVN graph $G = \left(Z_1, Z_2\right)$ of $G^* = \left(V, E\right)$ is called strong BSVN graph if

$$T^P_{Z_2}\left(w_1, w_2\right) = \min\left(T^P_{Z_1}\left(w_1\right), T^P_{Z_1}\left(w_2\right)\right)$$

$$I^P_{Z_2}\left(w_1, w_2\right) = \max\left(I^P_{Z_1}\left(w_1\right), I^P_{Z_1}\left(w_2\right)\right)$$

$$F^P_{Z_2}\left(w_1, w_2\right) = \max\left(F^P_{Z_1}\left(w_1\right), F^P_{Z_1}\left(w_2\right)\right)$$

$$T^N_{Z_2}\left(w_1, w_2\right) = \max\left(T^N_{Z_1}\left(w_1\right), T^N_{Z_1}\left(w_2\right)\right)$$

$$I^N_{Z_2}\left(w_1, w_2\right) = \min\left(I^N_{Z_1}\left(w_1\right), I^N_{Z_1}\left(w_2\right)\right)$$

$$F^N_{Z_2}\left(w_1, w_2\right) = \min\left(F^N_{Z_1}\left(w_1\right), F^N_{Z_1}\left(w_2\right)\right) \text{ for all } \left(w_1, w_2\right) \in E$$

If $P: a_1 = w_0, w_1, w_2, ... w_{k-1}, w_k = c_1$ be a path of length k between a_1 and c_1 then $\left(T^P_{Z_2}\left(a_1, c_1\right), I^P_{Z_2}\left(a_1, c_1\right), F^P_{Z_2}\left(a_1, c_1\right)\right)^k$ and $\left(T^N_{Z_2}\left(a_1, c_1\right), I^N_{Z_2}\left(a_1, c_1\right), F^N_{Z_2}\left(a_1, c_1\right)\right)^k$ is defined as

$$\left(T^P_{Z_2}\left(a_1, c_1\right), I^P_{Z_2}\left(a_1, c_1\right), F^P_{Z_2}\left(a_1, c_1\right)\right)^k = \begin{cases} \sup\left\{T^P_{Z_2}\left(a_1, w_1\right) \wedge T^P_{Z_2}\left(w_1, w_2\right) \wedge ..... \wedge T^P_{Z_2}\left(w_{k-1}, c_1\right)\right\}, \\ \inf\left\{I^P_{Z_2}\left(a_1, w_1\right) \vee I^P_{Z_2}\left(w_1, w_2\right) \vee ..... \vee I^P_{Z_2}\left(w_{k-1}, c_1\right)\right\}, \\ \inf\left\{F^P_{Z_2}\left(a_1, w_1\right) \vee F^P_{Z_2}\left(w_1, w_2\right) \vee ..... \vee F^P_{Z_2}\left(w_{k-1}, c_1\right)\right\} \end{cases}$$

$$\left(T^N_{Z_2}\left(a_1, c_1\right), I^N_{Z_2}\left(a_1, c_1\right), F^N_{Z_2}\left(a_1, c_1\right)\right)^k = \begin{cases} \sup\left\{T^N_{Z_2}\left(a_1, w_1\right) \vee T^N_{Z_2}\left(w_1, w_2\right) \vee ..... \vee T^N_{Z_2}\left(w_{k-1}, c_1\right)\right\}, \\ \inf\left\{I^N_{Z_2}\left(a_1, w_1\right) \wedge I^N_{Z_2}\left(w_1, w_2\right) \wedge ..... \wedge I^N_{Z_2}\left(w_{k-1}, c_1\right)\right\}, \\ \inf\left\{F^N_{Z_2}\left(a_1, w_1\right) \wedge F^N_{Z_2}\left(w_1, w_2\right) \wedge ..... \wedge F^N_{Z_2}\left(w_{k-1}, c_1\right)\right\} \end{cases}$$

$\left(T^P_{Z_2}\left(a_1, c_1\right), I^P_{Z_2}\left(a_1, c_1\right), F^P_{Z_2}\left(a_1, c_1\right)\right)^\infty$ and $\left(T^N_{Z_2}\left(a_1, c_1\right), I^N_{Z_2}\left(a_1, c_1\right), F^N_{Z_2}\left(a_1, c_1\right)\right)^\infty$ is said to be the strength of connectedness between two vertices a_1 and c_1 in G, where

$$\left(T^P_{Z_2}\left(a_1, c_1\right), I^P_{Z_2}\left(a_1, c_1\right), F^P_{Z_2}\left(a_1, c_1\right)\right)^\infty = \left(\sup_{k \in N}\left\{T^P_{Z_2}\left(a_1, c_1\right)\right\}, \inf_{k \in N}\left\{I^P_{Z_2}\left(a_1, c_1\right)\right\}, \inf_{k \in N}\left\{F^P_{Z_2}\left(a_1, c_1\right)\right\}\right)$$

$$\left(T^N_{Z_2}\left(a_1, c_1\right), I^N_{Z_2}\left(a_1, c_1\right), F^N_{Z_2}\left(a_1, c_1\right)\right)^\infty = \left(\inf_{k \in N}\left\{T^N_{Z_2}\left(a_1, c_1\right)\right\}, \sup_{k \in N}\left\{I^N_{Z_2}\left(a_1, c_1\right)\right\}, \sup_{k \in N}\left\{F^N_{Z_2}\left(a_1, c_1\right)\right\}\right)$$

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If $\left(T_{Z_2}^P(a_1,c_1)\ge\left(T_{Z_2}^P(a_1,c_1)\right)^\infty, I_{Z_2}^P(a_1,c_1)\le\left(I_{Z_2}^P(a_1,c_1)\right)^\infty, F_{Z_2}^P(a_1,c_1)\le\left(F_{Z_2}^P(a_1,c_1)\right)^\infty\right)$ and $\left(T_{Z_2}^N(a_1,c_1)\le\left(T_{Z_2}^N(a_1,c_1)\right)^\infty, I_{Z_2}^N(a_1,c_1)\ge\left(I_{Z_2}^N(a_1,c_1)\right)^\infty, F_{Z_2}^N(a_1,c_1)\ge\left(F_{Z_2}^N(a_1,c_1)\right)^\infty\right)$ then the arc a_1c_1 in G is called a strong arc.

A path a_1-c_1 is strong path if all arcs on the path are strong.

BSVN distance

Explanation 3.1

BSVN distance is defined as the length *a-c strong* path between *a* and*c if* there is no other strong path longer than *P* between *a* and *c* and we denote this by B*.S.N.d* (*a, c*). Any *a-c* strong path whose length is *B.S.N.d* (*a, c*) is called a*a-c BSVN* path.

BN boundary node of a BN graph

Explanation 4.1 In a connected BN graph *G*, a node $n_2$is said to be a BN *boundary* node of a node $n_1$if $B.N.d(n_1, n_2) \ge B.N.d(n_1, n_3)$ for each $n_3$in *G*, where $n_3$is a neighbor of n_2. The set of all BN boundary nodes of $n_1$denoted by n_1' B.N.D .

Explanation 4.2 If the BN sub graph formed by strong neighbor of a node $n_2$in a BN graph *G*, form a complete BN graph then the node $n_2$is said to be a complete node of *G*.

Theorem 4.3 *A node in a complete BN graph is BN boundary node of every other nodes iff the node is complete.*

Proof.Let a node $n_2$be a complete node in a connected BN graph *G*. Let $n_1$be a node of *G*. Each arc in *G* is strong, because of completeness of *G* [1]. So $B.N.d(n_1, n_2) = 1 = B.N.d(n_1, n_3)$, $\forall n_3 \in N(n_2)$. Therefore $n_2$is a BN boundary node of n_1.

Conversely, let $n_2$be a BN boundary node of every other node. Then each arc in *G* is strong, because of completeness of *G* [1]. Then $B.N.d(n_1, n_2) =1$, $\forall n_1 \in G$. So all neighbor of $n_2$are strong neighbor. Hence by Explanation 4.2, the node $n_2$is complete.

Theorem 4.4 *If a node in a connected BN graph G is a complete node of G, then the node is a BN boundary node of all other node.*

Proof.Let a node n_2 be a complete node in a connected BN graph *G* and let n_1 be another node of *G*. Assume that $n_1= w_0, w_1, \ldots, w_{k-1}, w_k= n_2$be a $n_1- n_2$BN and $n_3$be a strong neighbor of n_2. There arise two cases

Case 1: If $n_3= w_{k-1}$, then $B.N.d(n_1, n_3) \le B.N.d(n_1, n_2)$. Hence $n_2$be a BN boundary node of n_1.

Case 2: If $n_3 \ne w_{k-1}$, since $n_3$is a strong neighbor of n_2, so the arc (n_3, w_{k-1}) is a strong arc

and also $n_3 \ne w_{k-1}$. So the length of the path $n_1= w_0, w_1, \ldots, w_{k-1}, n_3, w_k= n_2$is greater than

than the length of the path $n_1= w_0, w_1, \ldots, w_{k-1}, w_k= n_2$. Hence $B.N.d(n_1, n_3)\le B.N.d(n_1, n_2)$.Therefore $n_2$is a BN boundary node of n_1.

Theorem 4.5 *A connected BN graph G is a BN tree iff G is BN graph.*

Proof.Let *G* be a BN tree. Then between any two nodes in *G*, there is exactly one BN strong path. So $B.N.d(n_1, n_2) = B.N.d(n_1, n_2)$ for any two nodes n_1, n_2in *G*. Hence *G* is BN graph.

Conversely, let *G* be a BN graph, which has $|V|$nodes. Then $B.N.d(n_1, n_2)= B.N.d(n_1, n_2)$for any two nodes n_1, n_2 in *G*. If $|V|$ = 2 then *G* is a BN tree.

Let $|V| \geq 3$. If possible, let G be not a BN tree. So $\exists$ two nodes p, q in G for which there is at least two strong path between p and q. Let Q_1 and Q_2 be two p−q bipolar neutrosophic strong paths. So $Q_1 \cup Q_2$ has a cycle $C(say)$ in G. If node $n_1$and $n_2$are adjacent nodes in G, then we have $B.N.d(n_1, n_2) = 1$. This contradicts the fact that $B.N.d(n_1, n_2) = B.N.d(n_1, n_2)$. Hence G is a BN tree.

Theorem 4.6 *In a BN tree G, a node n_2 is a BN boundary node of G iffn$_2$ cannot be a BN cut node of G.*

Proof.Let G be a BN tree and a node $n_2$in G be a BNboundary node of a node $n_3$in G. If possible, let $n_2$be a BN cut node of G.

Let Ebe a BN maximum spanning tree in G, which is unique in G. Since n_2 is a BN cut node, so $n_2$cannot be an internal node of E. Let $x \in N_{B.N.S}(n_2)$ such that x does not lie on the BN in E. Therefore $B.N.d(p, q)$ is same when p, q be any two nodes of E and G both. But $B.N.d(n_3, x) = B.N.d(n_3, n_2)+B.N.d(n_2, x) >B.N.d(n_3, n_2)$. This contradicts the fact that $n_2$is a BN *boundary* node of a node $n_3$in G. Therefore the node $n_2$cannot be a BN cut node of G.

Conversely, let $n_2$be not a BN cut node of the BN graph G. So $n_2$is end node of maximum bipolar spanning tree, which is unique. Then $n_2$has a strong neighbor which is also unique [2]. So there does not exist any extension of any BN for a node x to n_2. Hence $n_2$is a BN boundary node of G.

Explanation 4.7 A node $n_1$in a BN graph G is said to be a BN end node of G if $n_2$is only strong neighbor of n_1, where $n_2 \in G$.

Theorem 4.8 *A node n_2 in a BN tree G is a BN boundary node iffn$_2$ is a BN end node.*

Proof.Let a node $n_2$be a BN *boundary* node for a node n_1 in a BN tree G. Let Ebe a maximum bipolar spanning tree in G, which is unique in G [2]. By Explanation 4.*7*, each node of G is a BN cut node of G or a BN end node of G [2]. So by Explanation 4.*7*, $n_2$must be a BN end node of G.

Conversely, let $n_2$be a BN end node of a BN tree G. Let Ebe the maximum bipolar spanning tree of G. Then $n_2$is a BN end node of E. Hence $n_2$is not a BN cut node of G. Therefore by Explanation 4.*7*, $n_2$is a BN *boundary* node of G.

BN interior node of a BN graph

In a connected BN graph G, a node $n_2$lie between the nodes $n_1$and $n_3$in the sense of BN distance if $B.N.d(n_1, n_3) = B.N.d(n_1, n_2) + B.N.d(n_2 ,n_3)$.

Explanation 5.1 In a connected BN graph G, a node $n_2$is said to be a BN interior node if for each node $n_1$in G different from n_2, there is a node $n_3$in G for which $B.N.d(n_1, n_3) = B.N.d(n_1, n_2) + B.N.d(n_2, n_3)$.

Explanation 5.2 The set of all BN *interior* node of G, denoted by $Int_{B.N.d}(G)$, form a BN sub graph of G.

Theorem 5.3 *A node in a connected BN graph G is a BN boundary node of G iff the node cannot be a BN interior node of G.*

Proof.Let $n_2$be a BN boundary node of a node $n_1$in a connected BN graph G. If possible, let $n_2$be a BN interior node of G. So there exist a node $n_3$different from $n_1$and $n_2$such that $n_2$lies between $n_1$and n_3.

Let $U{:}n_1= w_1,w_2, \ldots , n_2= w_k,w_{k+1}, \ldots , w_l= n_3$be a $n_1− n_3$BN and $1 < k < l$. Then $w_{k+1} \in N_{B.N.S}(n_2)$, and this implies $B.N.D(n_1, w_{k+1}) > B.N.D(n_1, n_2)$, this is a contradiction. Hence $n_2$cannot be a BN interior node of G.

Conversely, let a node $n_2$in G, which is not a BN interior node of G. Then there exist a node $n_1$in G for which any node $n_3$different from $n_1$and n_2, $B.N.d(n_1, n_3) \neq B.N.d(n_1, n_2)+B.N.d(n_2, n_3)$. Therefore $B.N.d(n_1, q) \leq B.N.d(n_1, n_2)$ where $q \in N_{B.N.S}(n_2)$. This implies that $n_2$is a BN boundary node of n_1.

Theorem 5.4 *A BN end node of a connected BN graph G cannot be a BN interior node.*

Proof.Let q be a BN end node of a BN graph G. Then there is only one BN strong neighbor of q. So there is no strong BN for which $n_2$lies between $n_1$and n_3, where $n_1$and n_3 be two node of G and also different from n_2. Hence $n_2$is not a BN interior node of G..

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