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INTERVAL VALUED NEUTROSOPHIC GRAPHS

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The notion of interval valued neutrosophic sets is a generalization of fuzzy sets, intuitionistic fuzzy sets, interval valued fuzzy sets, interval valued intuitionstic fuzzy sets and single valued neutrosophic sets. We apply for the first time the concept of interval valued neutrosophic sets, an instance of neutrosophic sets, to graph theory. We introduce certain types of interval valued neutrosophc graphs (IVNG) and investigate some of their properties with proofs and examples.
Keywords: Interval valued neutrosophic set, interval valued neutrosophic graph, strong interval valued neutrosophic graph, constant interval valued neutrosophic graph, complete interval valued neutrosophic graph, degrre of interval valued neutrosophic graph.

1. PRELIMINARIES

Neutrosophic sets (NSs) proposed by Smarandache [13, 14] is a powerful mathematical tool for dealing with incomplete, indeterminate and inconsistent information in real world. They are a generalization of the theory of fuzzy sets [31], intuitionistic fuzzy sets [28, 30], interval valued fuzzy set [23] and interval-valued intuitionistic fuzzy sets [29]. The neutrosophic sets are characterized by a truth-membership function (t), an indeterminacy-membership function (i) and a falsity-membership function (f) independently, which are within the real standard or nonstandard unit interval $]^{-}0, 1^{+}[$. In order to practice NS in real life applications conveniently, Wang et al. [17] introduced the concept of a single-valued neutrosophic sets (SVNS), a subclass of the neutrosophic sets. The same authors [16, 18] introduced the concept of interval valued neutrosophic sets (IVNS), which is more precise and flexible than single valued neutrosophic sets. The IVNS is a generalization of single valued neutrosophic sets, in which three membership functions are independent and their value belong to the unit interval [0, 1]. Some more work on single valued neutrosophic sets, interval valued neutrosophic sets and their applications may be found on [3-6, 19-27, 39, 41-48, 52, 56].

Graph theory has now become a major branch of applied mathematics and it is generally regarded as a branch of combinatorics. Graph is a widely used tool for solving a combinatorial problems in different areas such as geometry, algebra, number theory, topology, optimization and computer science [49-51]. Most important thing which is to be noted is that, when we have uncertainty regarding either the set of vertices or edges or both, the model becomes a fuzzy graph. The extension of fuzzy graph [7, 9, 38] theory have been developed by several researchers including intuitionistic fuzzy graphs [8, 32, 40] considered the vertex sets and edge sets as intuitionistic fuzzy sets. Interval valued fuzzy graphs [33, 34] considered the vertex sets and edge sets as interval valued fuzzy sets. Interval valued intuitionstic fuzzy graphs [2, 48] considered the vertex sets and edge sets as interval valued intuitionstic fuzzy sets. Bipolar fuzzy graphs [35, 36] considered the vertex sets and edge sets as bipolar fuzzy sets. M-polar fuzzy graphs [37] considered the vertex sets and edge sets as m-polar fuzzy sets. But, when the relations between nodes(or vertices) in problems are indeterminate, the fuzzy graphs and their extensions are failed. For this purpose, Samarandache [10, 11, 12, 54] have defined four main categories of neutrosophic graphs, two based on literal indeterminacy (I), which called them; I-edge neutrosophic graph and I-vertex neutrosophic graph, these concepts are studied deeply and has gained popularity among the researchers due to its applications via real world problems [1, 15, 53, 56]. The two others graphs are based on (t, i, f) components and called them; The (t, i, f)-Edge neutrosophic graph and the (t, i, f)-vertex neutrosophic graph, these concepts are not developed at all. Later on, Broumi et al. [47] introduced a third neutrosophic graph model. This model allows the attachment of truth-membership (t), indeterminacy –membership (i) and falsity- membership degrees (f) both to vertices and edges, and investigated some of their properties. The third neutrosophic graph model is called single valued neutrosophic graph (SVNG for short). The single valued neutrosophic graph is the generalization of fuzzy graph and intuitionstic fuzzy graph. Also the same authors [46] introduced neighborhood degree of a vertex and closed neighborhood degree of vertex in single valued neutrosophic graph as a generalization of neighborhood degree of a vertex and closed neighborhood degree of vertex in fuzzy graph and intuitionistic fuzzy graph. In the literature the study of interval valued neutrosophic graphs (IVN-graph) is still blank, we shall focus on the study of interval valued neutrosophic graphs in this paper.

In this paper, some certain types of interval valued neutrosophic graphs are developed and some interesting properties are explored.

2. PRELIMINARIES

In this section, we mainly recall some notions related to neutrosophic sets, single valued neutrosophic sets, interval valued neutrosophic sets, single valued neutrosophic graphs, relevant to the present work. See especially [13, 17, 18, 47] for further details and background.

Definition 2.1 [13]. Let X be a space of points (objects) with generic elements in X denoted by x; then the neutrosophic set A (NS A) is an object having the form A = {< x: $\mathrm{T_A}(x)$, $\mathrm{I_A}(x)$, $\mathrm{F_A}(x)$>, x ∈ X}, where the functions T, I, F: X→]−0,1+[define respectively the a truth-membership function, an indeterminacy-membership function, and a falsity-membership function of the element x ∈ X to the set A with the condition:

$$^{-}0 \leq \mathrm{T_A}(x)+ \mathrm{I_A}(x)+ \mathrm{F_A}(x) \leq 3^{+}. \qquad (1)$$

The functions $\mathrm{T_A}(x)$, $\mathrm{I_A}(x)$ and $\mathrm{F_A}(x)$ are real standard or nonstandard subsets of $]^{-}0,1^{+}[$.

Since it is difficult to apply NSs to practical problems, Wang et al. [16] introduced the concept of a SVNS, which is an instance of a NS and can be used in real scientific and engineering applications.

Definition 2.2 [17]. Let X be a space of points (objects) with generic elements in X denoted by x. A single valued neutrosophic set A (SVNS A) is characterized by truth-membership function $\mathrm{T_A}(x)$, an indeterminacy-membership function $\mathrm{I_A}(x)$, and a falsity-membership function $\mathrm{F_A}(x)$. For each point x in X $\mathrm{T_A}(x)$, $\mathrm{I_A}(x)$, $\mathrm{F_A}(x) \in [0, 1]$. A SVNS A can be written as

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

Definition 2.3 [47]. Let $A = (T_A,\ I_A, F_A)$ and $B = (T_B,\ I_B, F_B)$ be single valued neutrosophic sets on a set *X*. If $A = (T_A,\ I_A, F_A)$ is a single valued neutrosophic relation on a set *X*, then $A =(T_A,\ I_A, F_A)$ is called a single valued neutrosophic relation on $B = (T_B,\ I_B, F_B)$ if $\mathrm{T_B}(x, y) \leq \min(\mathrm{T_A}(x), \mathrm{T_A}(y))$, $\mathrm{I_B}(x, y) \geq \max(\mathrm{I_A}(x), \mathrm{I_A}(y))$ and $\mathrm{F_B}(x, y) \geq \max(\mathrm{F_A}x), \mathrm{F_A}(y))$ for all x, y ∈ X.

A single valued neutrosophic relation *A* on *X* is called symmetric if $T_A(x, y) = T_A(y, x)$, $I_A(x, y) = I_A(y, x)$, $F_A(x, y) = F_A(y, x)$ and $T_B(x, y) = T_B(y, x)$, $I_B(x, y) = I_B(y, x)$ and $F_B(x, y) = F_B(y, x)$, for all *x*, *y* ∈ *X*.

Definition 2.4 [47]. A single valued neutrosophic graph (SVN-graph) with underlying set V is defined to be a pair G= (A, B) where

1. The functions T_A:V→[0, 1], I_A:V→[0, 1] and F_A:V→[0, 1] denote the degree of truth-membership, degree of indeterminacy-membership and falsity-membership of the element $v_i \in$ V, respectively, and

$$0\leq T_A(v_i) + I_A(v_i) + F_A(v_i) \leq 3 \text{ for all } v_i \in \mathrm{V}\ (i=1, 2, \ldots,n)$$

2. The functions T_B: E ⊆ V x V →[0, 1], I_B:E ⊆ V x V →[0, 1] and F_B: E ⊆ V x V →[0, 1] are defined by

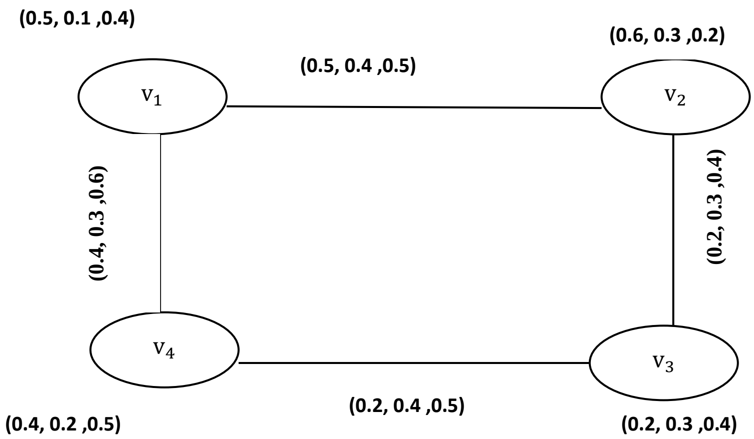
$T_B(\{v_i, v_j\}) \leq \min\ [T_A(v_i), T_A(v_j)]$, $I_B(\{v_i, v_j\}) \geq \max\ [I_A(v_i), I_A(v_j)]$ and

$F_B(\{v_i, v_j\}) \geq \max\ [F_A(v_i), F_A(v_j)]$

Denotes the degree of truth-membership, indeterminacy-membership and falsity-membership of the edge $(v_i, v_j) \in$ E respectively, where
$0 \leq T_B(\{v_i, v_j\}) + I_B(\{v_i, v_j\}) + F_B(\{v_i, v_j\}) \leq 3$ for all $\{v_i, v_j\} \in$ E (i, j = 1, 2,…, n)

We call A the single valued neutrosophic vertex set of V, B the single valued neutrosophic edge set of E, respectively, Note that B is a symmetric single valued neutrosophic relation on A. We use the notation (v_i, v_j) for an element of E Thus, G = (A, B) is a single valued neutrosophic graph of G^*= (V, E) if
$T_B(v_i, v_j) \leq$ min $[T_A(v_i), T_A(v_j)]$, $I_B(v_i, v_j) \geq$ max $[I_A(v_i), I_A(v_j)]$ and

$\geq$ max $[F_A(v_i), F_A(v_j)]$ for all $(v_i, v_j) \in$ E.



$F_B(v_i, v_j)$

Figure 1: single valued neutrosophic graph

Definition 2.5 [47]. Let G= (**A**, **B**) be a single valued neutrosophic graph. Then the degree of any vertex **v** is sum of degree of truth-membership, sum of degree of indeterminacy-membership and sum of degree of falsity-membership of all those edges which are incident on vertex **v** denoted by d(v)= ($d_T(v)$, $d_I(v)$, $d_F(v)$) where
$d_T(v)=\sum_{u \neq v} T_B(u, v)$ denotes degree of truth-membership vertex.

$d_I(v)=\sum_{u \neq v} I_B(u, v)$ denotes degree of indeterminacy-membership vertex.

$d_F(v)=\sum_{u \neq v} F_B(u, v)$ denotes degree of falsity-membership vertex.

Definition 2.6 [18]. Let X be a space of points (objects) with generic elements in X denoted by x. An interval valued neutrosophic set (for short IVNS A) A in X is characterized by truth-membership function $T_A(x)$, indeteminacy-membership function $I_A(x)$ and falsity-membership function $F_A(x)$. For each point x in X, we have that $T_A(x)= [T_{AL}(x), T_{AU}(x)]$, $I_A(x) = [I_{AL}(x), I_{AU}(x)]$, $F_A(x) = [F_{AL}(x), F_{AU}(x)] \subseteq [0, 1]$ and $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

Definition 2.7 [18]. Let X and Y be two non-empty crisp sets. An interval valued neutrosophic relation R(X, Y) is a subset of product space X × Y, and is characterized by the truth membership function $T_R(x, y)$, the indeterminacy membership function $I_R(x, y)$, and the falsity membership function $F_R(x, y)$, where x ∈ X and y ∈ Y and $T_R(x, y)$, $I_R(x, y)$, $F_R(x, y) \subseteq [0, 1]$.

3. INTERVAL VALUED NEUTROSOPHIC GRAPHS

Throught this paper, we denote G^* = (V, E) a crisp graph, and G =(A, B) an interval valued neutrosophic graph

Definition 3.1. By an interval-valued neutrosophic graph of a graph G^* = (V, E) we mean a pair G = (A, B), where A =< [T_{AL}, T_{AU}], [I_{AL}, I_{AU}], [F_{AL}, F_{AU}]> is an interval-valued neutrosophic set on V and B =< [T_{BL}, T_{BU}], [I_{BL}, I_{BU}], [F_{BL}, F_{BU}]> is an interval-valued neutrosophic relation on E satisfies the following condition:

1.V= $\{v_1, v_2, \ldots, v_n\}$ such that T_{AL}:V→[0, 1], T_{AU}:V→[0, 1], I_{AL}:V→[0, 1], I_{AU}:V→[0, 1] and F_{AL}:V→[0, 1], F_{AU}:V→[0, 1] denote the degree of truth-membership, the degree of indeterminacy- membership and falsity-membership of the element $y \in$ V, respectively, and

$$0 \leq T_A(v_i) + I_A(v_i) + F_A(v_i) \leq 3 \text{ for all } v_i \in V \text{ (i=1, 2, …,n)}$$

2. The functions T_{BL}:V x V →[0, 1], T_{BU}:V x V →[0, 1], I_{BL}:V x V →[0, 1], I_{BU}:V x V →[0, 1] and F_{BL}:V x V →[0,1], F_{BU}:V x V →[0, 1] are such that

$T_{BL}(\{v_i, v_j\}) \leq \min\,[T_{AL}(v_i), T_{AL}(v_j)]$, $T_{BU}(\{v_i, v_j\}) \leq \min\,[T_{AU}(v_i), T_{AU}(v_j)]$

$I_{BL}(\{v_i, v_j\}) \geq \max[I_{BL}(v_i), I_{BL}(v_j)]$, $I_{BU}(\{v_i, v_j\}) \geq \max[I_{BU}(v_i), I_{BU}(v_j)]$ And

$F_{BL}(\{v_i, v_j\}) \geq \max[F_{BL}(v_i), F_{BL}(v_j)]$, $F_{BU}(\{v_i, v_j\}) \geq \max[F_{BU}(v_i), F_{BU}(v_j)]$

Denotes the degree of truth-membership, indeterminacy-membership and falsity-membership of the edge $(v_i, v_j) \in$ E respectively, where

$0 \leq T_B(\{v_i, v_j\}) + I_B(\{v_i, v_j\}) + F_B(\{v_i, v_j\}) \leq 3$ for all $\{v_i, v_j\} \in$ E (i, j = 1, 2,…, n)

We call A the interval valued neutrosophic vertex set of V, B the interval valued neutrosophic edge set of E, respectively, Note that B is a symmetric interval valued neutrosophic relation on A. We use the notation (v_i, v_j) for an element of E Thus, G = (A, B) is an interval valued neutrosophic graph of G^*= (V, E) if

$T_{BL}(v_i, v_j) \leq \min\,[T_{AL}(v_i), T_{AL}(v_j)]$, $T_{BU}(v_i, v_j) \leq \min\,[T_{AU}(v_i), T_{AU}(v_j)]$

$I_{BL}(v_i, v_j) \geq \max[I_{BL}(v_i), I_{BL}(v_j)]$, $I_{BU}(v_i, v_j) \geq \max[I_{BU}(v_i), I_{BU}(v_j)]$ And

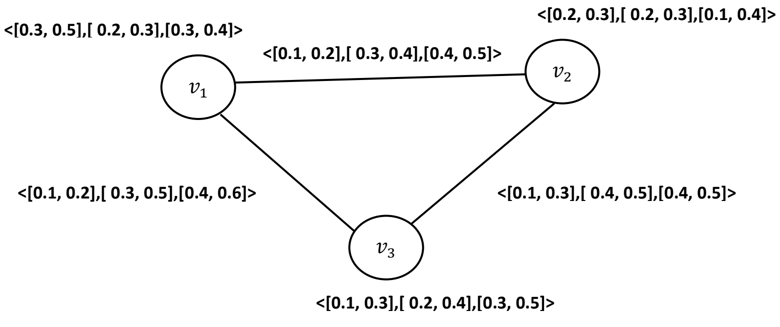
$F_{BL}(v_i, v_j) \geq \max[F_{BL}(v_i), F_{BL}(v_j)]$, $F_{BU}(v_i, v_j) \geq \max[F_{BU}(v_i), F_{BU}(v_j)]$ for all $(v_i, v_j) \in$ E

Example 3.2. Consider a graph G^* such that V= $\{v_1, v_2, v_3, v_4\}$, E=$\{v_1v_2, v_2v_3, v_3v_4, v_4v_1\}$. Let A be a interval valued neutrosophic subset of V and let B a interval valued neutrosophic subset of E denoted by where v_1=<[0.3, 0.5],[0.2, 0.3],[0.3, 0.4]>

v_2=<[0.2, 0.3],[0.2, 0.3],[0.1, 0.4]>, v_3=<[0.1, 0.3],[0.2, 0.4],[0.3, 0.5]>

v_1v_2=<[0.1, 0.2],[0.3, 0.4],[0.4, 0.5]>, v_2v_3=<[0.1, 0.3],[0.4, 0.5],[0.4, 0.5]>

=<[0.1, 0.2],[0.3, 0.5],[0.4, 0.6]>



v_3v_1

Figure 2:G: Interval valued neutrosophic graph

The interval valued neutrosophic graph G depicted in figure 3 is represented by the following adjacency matrix M_G

$$\boldsymbol{M_G} =$$
$$\begin{bmatrix} <[\mathbf{0.3},\mathbf{0.5}],[\mathbf{0.2},\mathbf{0.3}],[\mathbf{0.3},\mathbf{0.4}]> & <[\mathbf{0.1},\mathbf{0.2}],[\mathbf{0.3},\mathbf{0.4}],[\mathbf{0.4},\mathbf{0.5}]> & <[\mathbf{0.1},\mathbf{0.2}],[\mathbf{0.3},\mathbf{0.5}],[\mathbf{0.4},\mathbf{0.6} \\ <[\mathbf{0.1},\mathbf{0.2}],[\mathbf{0.3},\mathbf{0.4}],[\mathbf{0.4},\mathbf{0.5}]> & <[\mathbf{0.2},\mathbf{0.3}],[\mathbf{0.2},\mathbf{0.3}],[\mathbf{0.1},\mathbf{0.4}]> & <[\mathbf{0.1},\mathbf{0.3}],[\mathbf{0.4},\mathbf{0.5}],[\mathbf{0.4},\mathbf{0.5} \\ <[\mathbf{0.1},\mathbf{0.2}],[\mathbf{0.3},\mathbf{0.5}],[\mathbf{0.4},\mathbf{0.6}]> & <[\mathbf{0.1},\mathbf{0.3}],[\mathbf{0.4},\mathbf{0.5}],[\mathbf{0.4},\mathbf{0.5}]> & <[\mathbf{0.1},\mathbf{0.3}],[\mathbf{0.2},\mathbf{0.4}],[\mathbf{0.3},\mathbf{0.5} \end{bmatrix}$$

Definition 3.3. Let G= (**A**, **B**) be an interval valued valued neutrosophic graph. Then the degree of any vertex **v** is sum of degree of truth-membership, sum of degree of indeterminacy-membership and sum of degree of falsity-membership of all those edges which are incident on vertex **v** denoted by
d(v)= ([$d_{TL}(v)$, $d_{TU}(v)$], [$d_{IL}(v), d_{IU}(v)$], [$d_{FL}(v), d_{FU}(v)$]) where

$d_{TL}(v)=\sum_{u\neq v} T_{BL}(u,v)$ denotes degree of lower truth-membership vertex.

$d_{TU}(v)=\sum_{u\neq v} T_{BU}(u,v)$ denotes degree of upper truth-membership vertex,

$d_{IL}(v)=\sum_{u\neq v} I_{BL}(u,v)$ denotes degree of lower indeterminacy-membership vertex.

$d_{IU}(v)=\sum_{u\neq v} I_{BU}(u,v)$ denotes degree of upper indeterminacy-membership vertex.

$d_{FL}(v)=\sum_{u\neq v} F_{BL}(u,v)$ denotes degree of lower falsity-membership vertex.

$d_{FU}(v)=\sum_{u\neq v} F_{BU}(u,v)$ denotes degree of upper falsity-membership vertex.

Example 3. 4. Let us consider an intreval valued neutrosophic graph G= (A, B) of G^* = (V, E) where V ={v_1, v_2, v_3, v_4} and E={v_1v_2, v_2v_3, v_3v_4 , v_4v_1}.

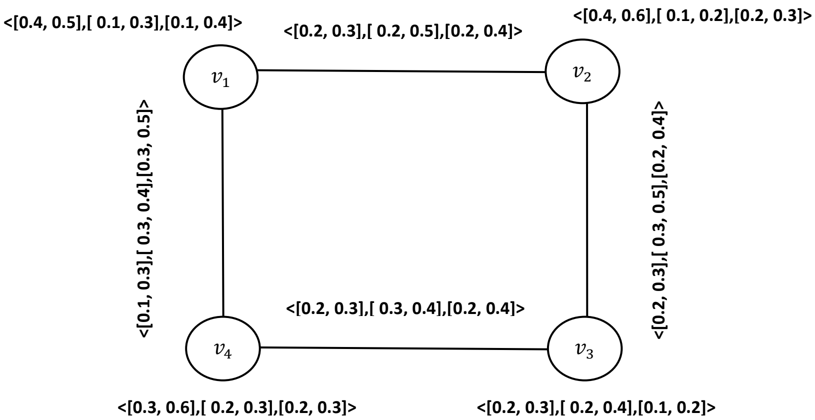


Figure 4: Degree of vertex of interval valued neutrosophic graph.

We have, the degree of each vertex as follows:
$d(v_1)$= ([0.3, 0.6], [0.5, 0.9], [0.5, 0.9]), $d(v_2)$= ([0.4, 0.6], [0.5, 1.0], [0.4, 0.8]), $d(v_3)$= ([0.4, 0.6], [0.6, 0.9], [0.4, 0.8]), $d(v_4)$= ([0.3, 0.6], [0.6, 0.8], [0.5, 0.9]),

Definition 3.5 . An interval valued neutrosophic graph G= (A, B) is called constant if degree of each vertex is k =([k_{1L}, k_{1U}], [k_{2L}, k_{2U}], [k_{3L}, k_{3U}]),That is, d(v) =([k_{1L}, k_{1U}], [k_{2L}, k_{2U}], [k_{3L}, k_{3U}]), for all v ∈ V.

Definition 3.6. An interval valued neutrosophic graph G=(A, B) of G^*= (V, E) is called strong interval valued neutrosophic graph if
$T_{BL}(v_i, v_j)$ = min [$T_{AL}(v_i)$, $T_{AL}(v_j)$], $T_{BU}(v_i, v_j)$ = min [$T_{AU}(v_i)$, $T_{AU}(v_j)$]

$I_{BL}(v_i, v_j)$ = max [$I_{AL}(v_i)$, $I_{AL}(v_j)$], $I_{BU}(v_i, v_j)$ = max [$I_{AU}(v_i)$, $I_{AU}(v_j)$]

$F_{BL}(v_i, v_j)$ = max [$F_{AL}(v_i)$, $F_{AL}(v_j)$], $F_{BU}(v_i, v_j)$ = max [$F_{AU}(v_i)$, $F_{AU}(v_j)$], for all $(v_i, v_j) \in$ E.

Example 3.7. Consider a graph G^* such that V= $\{v_1, v_2, v_3, v_4\}$, E=$\{v_1v_2, v_2v_3, v_3v_4, v_4v_1\}$. Let A be an interval valued neutrosophic subset of V and let B an interval valued neutrosophic subset of E denoted by

	v_1	v_2	v_3
T_{AL}	0.3	0.2	0.1
T_{AU}	0.5	0.3	0.3
I_{AL}	0.2	0.2	0.2
I_{AU}	0.3	0.3	0.4
F_{AL}	0.3	0.1	0.3
F_{AU}	0.4	0.4	0.5

	v_1v_2	v_2v_3	v_3v_1
T_{BL}	0.2	0.1	0.1
T_{BU}	0.3	0.3	0.3
I_{BL}	0.2	0.2	0.2
I_{BU}	0.3	0.4	0.4
F_{BL}	0.3	0.3	0.3
F_{BU}	0.4	0.4	0.5

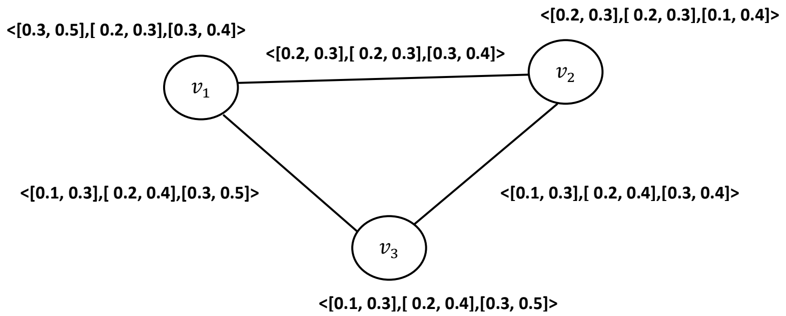


Figure5:Strong IVN-graph.

By routing computations, it is easy to see that G is a strong interval valued neutrosophic of G^*.

Definition 3.8. The complement of an interval valued neutrosophic graph G (A, B) on G^* is an interval valued neutrosophic graph $\bar{G}$ on G^* where:

1. $\bar{A}$ =A

2. $\overline{T_{AL}}(v_i)$= $T_{AL}(v_i)$, $\overline{T_{AU}}(v_i)$= $T_{AU}(v_i)$, $\overline{I_{AL}}(v_i)$= $I_{AL}(v_i)$, $\overline{I_{AU}}(v_i)$= $I_{AU}(v_i)$, $\overline{F_{AL}}(v_i)$ = $F_{AL}(v_i)$, $\overline{F_{AU}}(v_i)$ = $F_{AU}(v_i)$, for all $v_j \in$ V.

3. $\overline{T_{BL}}(v_i, v_j)$= min $\left[T_{AL}(v_i), T_{AL}(v_j)\right]$ -$T_{BL}\left(v_i, v_j\right)$, $\overline{T_{BU}}(v_i, v_j)$= min $\left[T_{AU}(v_i), T_{AU}(v_j)\right]$ -$T_{BU}\left(v_i, v_j\right)$,

$\overline{I_{BL}}(v_i, v_j)$= max $\left[I_{AL}(v_i), I_{AL}(v_j)\right]$ -$I_{BL}\left(v_i, v_j\right)$, $\overline{I_{BU}}(v_i, v_j)$= max $\left[I_{AU}(v_i), I_{AU}(v_j)\right]$ -$I_{BU}\left(v_i, v_j\right)$, and

$\overline{F_{BL}}(v_i, v_j)$= max $\left[F_{AL}(v_i), F_{AL}(v_j)\right]$ -$F_{BL}\left(v_i, v_j\right)$, $\overline{F_{BU}}(v_i, v_j)$= max $\left[F_{AU}(v_i), F_{AU}(v_j)\right]$ -$F_{BU}\left(v_i, v_j\right)$, For all $(v_i, v_j) \in$ E

Proposition 3.9. G= $\bar{\bar{G}}$ if and only if G is a strong interval valued neutrosophic graph.

Proof. it is obvious.

Definition 3.10. A strong interval valued neutrosophic graph G is called self complementary if G$\cong \bar{G}$. Where $\bar{G}$ is the complement of interval valued neutrosophic graph G.

Definition 3.11. An interval valued neutrosophic graph G= (A, B) is called complete if
$T_{BL}(v_i, v_j)$ = min($T_{AL}(v_i)$, $T_{AL}(v_j)$), $T_{BU}(v_i, v_j)$ = min($T_{AU}(v_i)$, $T_{AU}(v_j)$),

$I_{BL}(v_i, v_j)$ = max($I_A(v_i)$, $I_A(v_j)$), $I_{BU}(v_i, v_j)$ = max($I_{AU}(v_i)$, $I_{AU}(v_j)$), and

$F_{BL}(v_i, v_j)$ = max($F_A(v_i)$, $F_A(v_j)$), $F_{BU}(v_i, v_j)$ = max($F_{AU}(v_i)$, $F_{AU}(v_j)$), for all $v_i, v_j \in$ V.

4. CONCLUSION

In this paper, we have defined, for the first time, certain types of interval valued neutrosophic graphs, such as strong interval valued neutrosophic graph, constant interval valued neutrosophic graph and complete interval valued neutrosophic graphs. In future study, we plan to extend our research to regular interval valued neutrosophic graphs and irregular interval valued neutrosophic.

REFERENCES

1. A. V. Devadoss, A. Rajkumar & N. J. P .Praveena,.A Study on Miracles through Holy Bible using Neutrosophic Cognitive Maps (NCMS).International Journal of Computer Applications, 69(3) (2013).
2. A. Mohamed Ismayil and A.Mohamed Ali, On Strong Interval-Valued Intuitionistic Fuzzy Graph International Journal of Fuzzy Mathematics and Systems.Volume 4, Number 2 (2014)
161-168.
3. A. Q. Ansari, R.Biswas & S. Aggarwal, Neutrosophic classifier: An extension of fuzzy classifier. Elsevier- Applied Soft Computing, 13 (2013) 563-573, http://dx.doi.org/10.1016/j.asoc.2012.08.002.
4. A. Aydoğdu, On Similarity and Entropy of Single Valued Neutrosophic Sets, Gen. Math. Notes, Vol. 29, No. 1 (2015) 67-74.
5. A. Q. Ansari, R.Biswas & S. Aggarwal. (Poster Presentation) Neutrosophication of Fuzzy Models, IEEE Workshop On Computational Intelligence: Theories, Applications and Future Directions (hostedby IIT Kanpur), 14th July'13.
6. A. Q. Ansari, R.Biswas & S. Aggarwal Extension to fuzzy logic representation: Moving towards neutrosophic logic - A new laboratory rat, Fuzzy Systems (FUZZ), IEEE International Conference, (2013) 1–8,doi:10.1109/FUZZ-IEEE.2013.6622412.
7. A. Nagoor Gani . and M.Basheer Ahamed, Order and Size in Fuzzy Graphs, Bulletin of Pure and Applied Sciences, Vol 22E (No.1) (2003) 145-148.
8. A. Nagoor Gani. A and S. Shajitha Begum, Degree, Order and Size in Intuitionistic Fuzzy Graphs, International Journal of Algorithms, Computing and Mathematics,(3)3 (2010).
9. A. Nagoor Gani and S.R Latha, On Irregular Fuzzy Graphs, Applied Mathematical Sciences, Vol.6,no.11(2012) 517-523.
10. F. Smarandache. Refined Literal Indeterminacy and the Multiplication Law of Sub-Indeterminacies, Neutrosophic Sets and Systems, Vol. 9, (2015) 58- 63.
11. F. Smarandache, Types of Neutrosophic Graphs and neutrosophic Algebraic Structures together with their Applications in Technology, seminar, Universitatea Transilvania din Brasov, Facultatea de Design de Produs si Mediu, Brasov, Romania 06 June 2015.
12. F. Smarandache, *Symbolic Neutrosophic Theory, Europanova asbl, Brussels,* (2015)*195p,*
13. F. Smarandache , Neutrosophic set - a generalization of the intuitionistic fuzzy set, Granular Computing, 2006 IEEE International Conference,(2006)38 – 42,DOI: 10.1109/GRC.2006.1635754.
14. F. Smarandache, A geometric interpretation of the neutrosophic set — A generalization of the intuitionistic fuzzy set Granular Computing (GrC), 2011 IEEE International Conference, (2011)602 – 606, DOI 10.1109/GRC.2011.6122665.
15. Gaurav Garg, Kanika Bhutani, Megha Kumar and Swati Aggarwal, *Hybrid model for medical diagnosis using Neutrosophic Cognitive Maps with* Genetic Algorithms, FUZZ-IEEE 2015(IEEE International conference on fuzzy systems).
16. H .Wang,. Y. Zhang, R. Sunderraman, Truth-value based interval neutrosophic sets, Granular Computing, 2005 IEEE International Conference, Vol. 1, (2005) 274 - 277 DOI: 10.1109/GRC.2005.1547284.
17. H. Wang, F. Smarandache, Y. Zhang, and R. Sunderraman, Single valued Neutrosophic Sets, Multisspace and Multistructure 4 (2010) 410-413.
18. H .Wang, F. Smarandache ,Y.Q .Zhang and R.Sunderram, An Interval neutrosophic sets and logic: theory and applications in computing. Hexis, Arizona ,(2005).
19. H.Y. Zhang , J.Q .Wang , X.H .Chen, Interval neutrosophic sets and their application in multicriteria decision making problems, The Scientific World Journal, (2014), DOI:10.1155/2014/ 645953.
20. H, Zhang, J .Wang, X. Chen, An outranking approach for multi-criteria decision-making problems with interval-valued neutrosophic sets, Neural Computing and Applications, (2015)1-13 .
21. H.Y. Zhang , P. Ji, J. Q.Wang & X. HChen, An Improved Weighted Correlation Coefficient Based on Integrated Weight for Interval Neutrosophic Sets and its Application in Multi-criteria Decision-making Problems, International Journal of Computational Intelligence Systems ,V8, Issue 6 (2015), DOI:10.1080/18756891.2015.1099917.
22. I. Deli, M. Ali, F. Smarandache , Bipolar neutrosophic sets and their application based on multi-criteria decision making problems, Advanced Mechatronic Systems (ICAMechS), International Conference, (2015) 249 - 254, DOI: 10.1109/ICAMechS.2015.7287068.
23. I. Turksen, Interval valued fuzzy sets based on normal forms, Fuzzy Sets and Systems, vol. 20, (1986)191-210 .

24. J. Ye, vector similarity measures of simplified neutrosophic sets and their application in multicriteria decision making, *International Journal of Fuzzy Systems, Vol. 16, No. 2,* (2014) 204-211.
25. J. Ye, Single-Valued Neutrosophic Minimum Spanning Tree and Its Clustering Method, Journal of Intelligent Systems 23(3) (2014) 311–324.
26. J. Ye Similarity measures between interval neutrosophic sets and their applications in Multi-criteria decision-making, Journal of Intelligent and Fuzzy Systems, 26, 165-172 (2014).
27. J. Ye Some aggregation operators of interval neutrosophic linguistic numbers for multiple attribute decision making, Journal of Intelligent & Fuzzy Systems (27) (2014) 2231-2241
28. K. Atanassov, Intuitionistic fuzzy sets, Fuzzy Sets and Systems, vol. 20, (1986) 87-96.
29. K. Atanassov and G. Gargov, Interval valued intuitionistic fuzzy sets, Fuzzy Sets and Systems, vol.31 (1989).343-349.
30. K. Atanassov. Intuitionistic fuzzy sets: theory and applications. Physica, New York, 1999.
31. L. Zadeh, Fuzzy sets, Inform and Control, 8 (1965) 338-353.
32. M. Akram and B. Davvaz, Strong intuitionistic fuzzy graphs, Filomat, vol. 26, no. 1 (2012)177–196.
33. M. Akram and W. A. Dudek, Interval-valued fuzzy graphs, Computers & Mathematics with Applications, vol. 61, no. 2 (2011) 289–299.
34. M. Akram, Interval-valued fuzzy line graphs,"Neural Computing and Applications, vol. 21 (2012) 145–150.
35. M. Akram, Bipolar fuzzy graphs, Information Sciences, vol. 181, no. 24 (2011) 5548–5564.
36. M. Akram, "Bipolar fuzzy graphs with applications," Knowledge Based Systems, vol. 39 (2013) 1–8.
37. M. Akram and A. Adeel, m- polar fuzzy graphs and m-polar fuzzy line graphs, Journal of Discrete Mathematical Sciences and Cryptography, 2015
38. P. Bhattacharya, Some remarks on fuzzy graphs, Pattern Recognition Letters 6 (1987) 297-302.
39. P. Liu and L. Shi The generalized hybrid weighted average operator based on interval neutrosophic hesitant set and its application to multiple attribute decision making, Neural Computing and Applications, 26 (2) (2015) 457-471.
40. R. Parvathi and M. G. Karunambigai, Intuitionistic Fuzzy Graphs, Computational Intelligence, Theory and applications, International Conference in Germany, Sept 18 -20, 2006.
41. R. Rıdvan, A. Küçük, Subsethood measure for single valued neutrosophic sets, Journal of Intelligent & Fuzzy Systems, vol. 29, no. 2(2015) 525-530,DOI: 10.3233/IFS-141304.
42. R. Şahin, Cross-entropy measure on interval neutrosophic sets and its applications in multicriteria decision making, Neural Computing and Applications, (2015) 1-11.
43. S. Aggarwal, R. Biswas, A. Q. Ansari, Neutrosophic modeling and control , Computer and Communication Technology (ICCCT), International Conference, (2010) 718 – 723, DOI:10.1109/ICCCT.2010.5640435
44. S. Broumi, F. Smarandache, New distance and similarity measures of interval neutrosophic sets, Information Fusion (FUSION), 2014 IEEE 17th International Conference (2014) 1 – 7.
45. S. Broumi, F. Smarandache, Single valued neutrosophic trapezoid linguistic aggregation operators based multi-attribute decision making, Bulletin of Pure & Applied Sciences- Mathematics and Statistics, (2014)135-155, DOI : 10.5958/2320-3226.2014.00006.X.
46. S. Broumi, M. Talea, F. Smarandache and A. Bakali, Single Valued Neutrosophic Graphs: Degree, Order and Size. IEEE International Conference on Fuzzy Systems (FUZZ),2016, pp. 2444-2451.
47. S. Broumi, M. Talea, A. Bakali, F. Smarandache, "Single Valued Neutrosophic Graphs," Journal of New Theory, N 10, 2016, pp. 86-101.
48. S. N. Mishra and A. Pal, Product of Interval Valued Intuitionistic fuzzy graph, Annals of Pure and Applied Mathematics Vol. 5, No.1 (2013) 37-46.
49. Victor Vladareanua, Radu I. Munteanub, Ali Mumtazc, Florentin Smarandachedand Luige Vladareanua *, "The optimization of intelligent control interfaces using Versatile Intelligent Portable Robot Platform", Procedia Computer Science 65 (2015): 225 – 232, ELSEVIER, DOI 10.1016/j.procs.2015.09.115, Publiched 2015
50. W. Cai, W., C. Yung, F. Smarandache, L. Vladareanu, Q. Zou, Y. Zhao, X. Li, "Extenics and Innovation Methods", CRC Press, Taylor&Francis Group, New York, 2013, pp. 336, ISBN 978-1-136-00049-0
51. Vladareanu, L., Tont, G., Ion, I., Munteanu, M. S., Mitroi, D., "Walking Robots Dynamic Control Systems on an Uneven Terrain", Advances in Electrical and Computer Engineering, ISSN 1582-7445, e-ISSN 1844-7600, vol. 10, no. 2, pp. 146-153, 2010, doi: 10.4316/AECE.2010.02026
52. Y. Hai-Long, G. She, Yanhonge, L. Xiuwu, On single valued neutrosophic relations, Journal of Intelligent & Fuzzy Systems, vol. Preprint, no. Preprint, (2015)1-12.
53. W. B. Vasantha Kandasamy and F. Smarandache, Fuzzy Cognitive Maps and Neutrosophic Congtive Maps,2013.
54. W. B. Vasantha Kandasamy, K. Ilanthenral and Florentin Smarandache, Neutrosophic Graphs: A New Dimension to Graph Theory, Kindle Edition, 2015.
55. Nicolae Pop, Luige Vladareanu, Ileana Nicoleta Popescu, Constantin Ghiţă, Ionel Alexandru Gal, Shuang Cang, Hongnian Yu, Vasile Bratu, Mingcong Deng, A numerical dynamic behaviour model for 3D contact problems with friction, Computational Materials Science, Vol. 94, pp. 285-291, Elsevier 2014
56. W.B. Vasantha Kandasamy and F. Smarandache, Analysis of social aspects of migrant laborers living with HIV/AIDS using Fuzzy Theory and Neutrosophic Cognitive Maps, Xiquan, Phoenix (2004).