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n-DOMINATION IN VERTEX SQUARED DOUBLE DIVIDE INTERVAL-VALUED FUZZY GRAPHS

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Abstract: In this paper we study different concepts like vertex squared double divide interval-valued fuzzy graph, vertex squared double divide cardinality, vertex squared double divide independent set, n- dominating set, n- domination number. We likewise, investigate a relationship between n - dominating set and vertex squared double divide independent set for vertex squared double divide interval-valued fuzzy graphs. The vertex squared double divide interval-valued fuzzy graphs are more adaptable and viable than fuzzy graphs because of the way that they have numerous applications in networks. This work will be useful to concentrate enormous vertex squared double divide interval-valued fuzzy graphs as a mix of little vertex squared interval-valued fuzzy graphs. Vertex squared double divide interval-valued fuzzy graph hypothesis is presently developing and growing its applications. The theoretical improvement in this space is talked about here.

Keywords and Phrases: Vertex Squared Double Divide Interval-Valued Fuzzy Graph (VSDDIVFG), n- Dominating Set, n- Domination Number, Vertex Squared Double Divide Independent Set.

2020 Mathematics Subject Classification: 05C72, 05C69.

1. Introduction

Fuzzy graphs differ from the classical ones in several ways, among them the most prominent one is connectivity. Distance and central concepts additionally assume important parts in applications related to fuzzy graphs. In 1965 Lotfi. A. Zadeh initiated fuzzy sets and later in 1983 Krassimir T. Bhattacharya [9] has discussed fuzzy graphs. M. Akram gave the idea that interval-valued Pythagorean fuzzy graphs and interval-valued neutrosophic graph structures and interval-valued fuzzy hyper graphs [2], [3], [4]. Kalaiarasi and Mahalakshmi have also expressed fuzzy strong graphs [16]. M. Akram and A. Dudek have also expressed self centered interval-valued fuzzy graphs and interval-valued fuzzy line graphs [5], [7]. M. Akram and N. O. Alshehri gave the notion of certain types of interval-valued fuzzy graphs [6].

Generalized theory and fuzzy logic have been concentrated by Zadeh [27, 28, 29]. Hongmei and Lianhun have also expressed interval-valued sub semigroups and subgroups [13]. Akram et al [1] gave the idea that fuzzy graphs. The concept of fuzzy sets has been concentrated by Turksen [25]. Pradip Debnath gave the characterization for a minimal dominating set [21]. Manjusha and Sunitha gave the notion of strong arcs [19].

In this paper, we build up the idea of n-domination in VSDDIVFG and many fascinating outcomes including these ideas are researched. Additionally, we talk about n- domination number and explored their many intriguing outcomes.

2. Vertex Squared Double Divide Interval-Valued Fuzzy Graph

Definition 2.1. *An vertex squared double divide interval-valued fuzzy set (VSDDIVFS) X_{IV} on a set V_{IV} is denoted by*
$X_{IV} = \left\{\left(i_{11}, \left[\frac{\left(\sigma^-_{X_{IV}}(i_{11})\right)^2}{2}, \frac{\left(\sigma^+_{X_{IV}}(i_{11})\right)^2}{2}\right]\right), i_{11} \in V_{IV}\right\}$, *where* $\frac{(\sigma^-_{X_{IV}})^2}{2}$ *and* $\frac{(\sigma^+_{X_{IV}})^2}{2}$ *are fuzzy subsets of* V_{IV} *such that* $\frac{(\sigma^-_{X_{IV}}(i_{11}))^2}{2} \le \frac{(\sigma^+_{X_{IV}}(i_{11}))^2}{2}$ *for all* $i_{11} \in V_{IV}$. *If* $G^*_{IV} = (V_{IV}, E_{IV})$ *is a crisp graph, then by an vertex squared double divide interval-valued fuzzy relation* Y_{IV} *on* V_{IV} *we mean an VSDDIVFS on* E_{IV} *such that* $\sigma^-_{Y_{IV}}(i_{11}i_{22}) \le min\left\{\frac{(\sigma^-_{X_{IV}}(i_{11}))^2}{2}, \frac{(\sigma^-_{X_{IV}}(i_{22}))^2}{2}\right\}$ *and*
$\sigma^+_{Y_{IV}}(i_{11}i_{22}) \le max\left\{\frac{(\sigma^+_{X_{IV}}(i_{11}))^2}{2}, \frac{(\sigma^+_{X_{IV}}(i_{22}))^2}{2}\right\}$ *for all* $i_{11}i_{22} \in E_{IV}$ *and we write*
$Y_{IV} = \{(i_{11}i_{22}, [\sigma^-_{Y_{IV}}(i_{11}i_{22}), \sigma^+_{Y_{IV}}(i_{11}i_{22})]), i_{11}i_{22} \in E_{IV}\}$.

Definition 2.2. *An VSDDIVFG of a graph* $G^*_{IV} = (V_{IV}, E_{IV})$ *is a pair* $G_{IV} = (X_{IV}, Y_{IV})$, *where* $X_{IV} = \left[\frac{(\sigma^-_{X_{IV}})^2}{2}, \frac{(\sigma^+_{X_{IV}})^2}{2}\right]$ *is an VSDDIVFS on* V_{IV} *and* $Y_{IV} = [\sigma^-_{Y_{IV}}, \sigma^+_{Y_{IV}}]$ *is an vertex squared double divide interval-valued fuzzy relation on* V_{IV}.

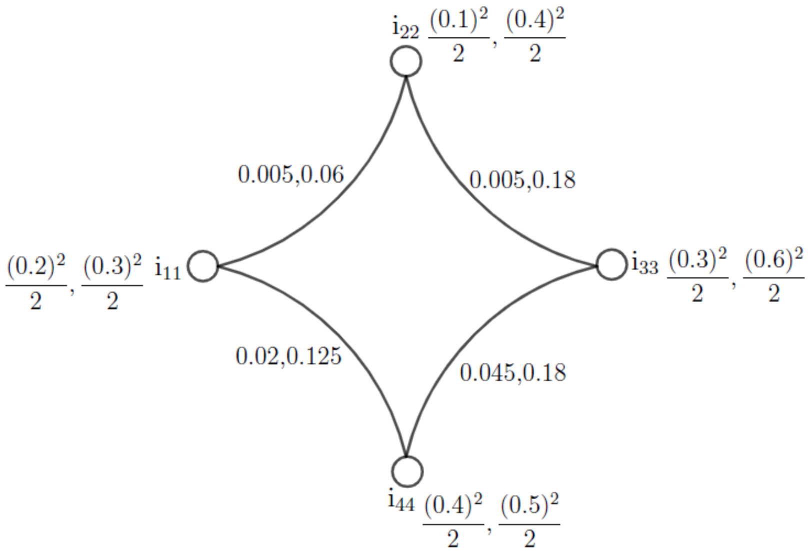

Figure 1: $VSDDIVFG(G_{IV})$

Example 2.3. In the above figure,

$V_{IV} = \{i_{11}, i_{22}, i_{33}, i_{44}\}$

$E_{IV} = \{i_{11}i_{22}, i_{22}i_{33}, i_{33}i_{44}, i_{44}i_{11}\}$

Here we take X_{IV} be an VSDDIVFS on V_{IV} and Y_{IV} be an VSDDIVFS on $E_{IV} \subseteq V_{IV} \times V_{IV}$ defined by

$$X_{IV} = \left\langle \left(\frac{i_{11}}{(0.2)^2/2}, \frac{i_{22}}{(0.1)^2/2}, \frac{i_{33}}{(0.3)^2/2}, \frac{i_{44}}{(0.4)^2/2} \right) \right\rangle \left\langle \left(\frac{i_{11}}{(0.3)^2/2}, \frac{i_{22}}{(0.4)^2/2}, \frac{i_{33}}{(0.6)^2/2}, \frac{i_{44}}{(0.5)^2/2} \right) \right\rangle$$

$$Y_{IV} = \left\langle \left(\frac{i_{11}i_{22}}{0.005}, \frac{i_{22}i_{33}}{0.005}, \frac{i_{33}i_{44}}{0.045}, \frac{i_{44}i_{11}}{0.02} \right) \right\rangle \left\langle \left(\frac{i_{11}i_{22}}{0.06}, \frac{i_{22}i_{33}}{0.18}, \frac{i_{33}i_{44}}{0.18}, \frac{i_{44}i_{11}}{0.125} \right) \right\rangle$$

Then $G_{IV} = (X_{IV}, Y_{IV})$ is an VSDDIVFG.

Definition 2.4. *The order p_{IV} and size q_{IV} of an VSDDIVFG $G_{IV} = (X_{IV}, Y_{IV})$ of a graph $G^*_{IV} = (V_{IV}, E_{IV})$ are denoted by*

$$p_{IV} = \sum_{i_{11} \in V_{IV}} \frac{1 + \frac{(\sigma^+_{X_{IV}}(i_{11}))^2}{2} - \frac{(\sigma^-_{X_{IV}}(i_{11}))^2}{2}}{2} \quad \textit{and}$$

$$q_{IV} = \sum_{i_{11}i_{22} \in V_{IV}} \frac{1 + \sigma^+_{Y_{IV}}(i_{11}i_{22}) - \sigma^-_{Y_{IV}}(i_{11}i_{22})}{2}$$

Definition 2.5. *Let $G_{IV} = (X_{IV}, Y_{IV})$ be an VSDDIVFG on $G^*_{IV} = (V_{IV}, E_{IV})$ and $S_{IV} \subseteq V_{IV}$. Then the vertex squared double divide cardinality of S_{IV} is defined to be*

$$\sum_{i_{11}\in V_{IV}} \frac{1+\frac{(\sigma^+_{X_{IV}}(i_{11}))^2}{2}-\frac{(\sigma^-_{X_{IV}}(i_{11}))^2}{2}}{2}$$

Definition 2.6. *An arc $e_{IV} = i_{11}i_{22}$ of the VSDDIVFG is called a vertex squared double divide effective edge if*

$$\sigma^-_{Y_{IV}}(i_{11}i_{22}) = \min\left\{\frac{(\sigma^-_{X_{IV}}(i_{11}))^2}{2}, \frac{(\sigma^-_{X_{IV}}(i_{22}))^2}{2}\right\} \quad \textit{and}$$
$$\sigma^+_{Y_{IV}}(i_{11}i_{22}) = \max\left\{\frac{(\sigma^+_{X_{IV}}(i_{11}))^2}{2}, \frac{(\sigma^+_{X_{IV}}(i_{22}))^2}{2}\right\}.$$

Definition 2.7. *A set S_{IV} of vertices of the VSDDIVFG is called the vertex squared double divide independent set (VSDDIS) if*

$$\sigma^-_{Y_{IV}}(i_{11}i_{22}) < \min\left\{\frac{(\sigma^-_{X_{IV}}(i_{11}))^2}{2}, \frac{(\sigma^-_{X_{IV}}(i_{22}))^2}{2}\right\} \quad \textit{and}$$
$$\sigma^+_{Y_{IV}}(i_{11}i_{22}) < \max\left\{\frac{(\sigma^+_{X_{IV}}(i_{11}))^2}{2}, \frac{(\sigma^+_{X_{IV}}(i_{22}))^2}{2}\right\} \quad \textit{for all } i_{11}, i_{22} \in S_{IV}.$$

3. n-Domination in Vertex Squared Double Divide Interval-Valued Fuzzy Graph

Definition 3.1. *Let $G_{IV} = (X_{IV}, Y_{IV})$ be an VSDDIVFG on V_{IV} and $i_{11}, i_{22} \in V_{IV}$. We say '$i_{11}$' n-dominates '$i_{22}$' if*

$$\sigma^-_{Y_{IV}}(i_{11}i_{22}) = \min\left\{\frac{\frac{(\sigma^-_{X_{IV}}(i_{11}))^2}{2}}{n}, \frac{\frac{(\sigma^-_{X_{IV}}(i_{22}))^2}{2}}{n}\right\} \quad \textit{and}$$
$$\sigma^+_{Y_{IV}}(i_{11}i_{22}) = \max\left\{\frac{\frac{(\sigma^+_{X_{IV}}(i_{11}))^2}{2}}{n}, \frac{\frac{(\sigma^+_{X_{IV}}(i_{22}))^2}{2}}{n}\right\}.$$

Example 3.2. G_{IV} :
In the above figure,

$V_{IV} = \{i_{11}, i_{22}, i_{33}\}$

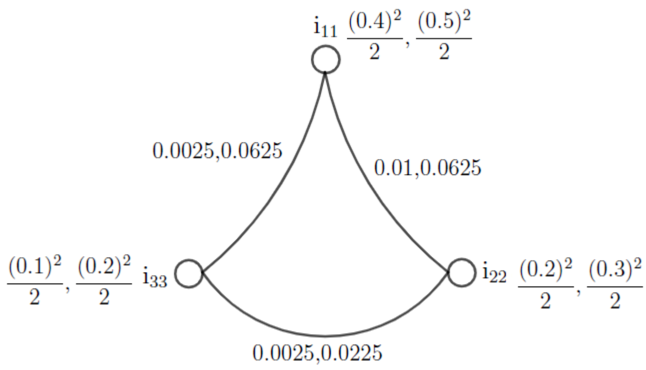

Figure 2: VSDDIVFG(G_{IV}) with 2-Dominates

$E_{IV} = \{i_{11}i_{22}, i_{22}i_{33}, i_{33}i_{11}\}$

Here we take X_{IV} be an VSDDIVFS on V_{IV} and Y_{IV} be an VSDDIVFS on $E_{IV} \subseteq V_{IV} \times V_{IV}$ denoted by

$$X_{IV} = \left\langle \left(\frac{i_{11}}{(0.4)^2/2}, \frac{i_{22}}{(0.2)^2/2}, \frac{i_{33}}{(0.1)^2/2} \right) \right\rangle \left\langle \left(\frac{i_{11}}{(0.5)^2/2}, \frac{i_{22}}{(0.3)^2/2}, \frac{i_{33}}{(0.2)^2/2} \right) \right\rangle$$
$$Y_{IV} = \left\langle \left(\frac{i_{11}i_{22}}{0.01}, \frac{i_{22}i_{33}}{0.0025}, \frac{i_{33}i_{11}}{0.0025} \right) \right\rangle \left\langle \left(\frac{i_{11}i_{22}}{0.0625}, \frac{i_{22}i_{33}}{0.0225}, \frac{i_{33}i_{11}}{0.0625} \right) \right\rangle$$

Then $G_{IV} = (X_{IV}, Y_{IV})$ is an VSDDIVFG.
In figure 2, $n = 2$,

$$\begin{aligned} \sigma^{-}_{Y_{IV}}(i_{11}i_{22}) &= \min \left\{ \frac{\frac{(\sigma^{-}_{X_{IV}}(i_{11}))^2}{2}}{n}, \frac{\frac{(\sigma^{-}_{X_{IV}}(i_{22}))^2}{2}}{n} \right\} \\ &= \min \left\{ \frac{\frac{(0.4)^2}{2}}{2}, \frac{\frac{(0.2)^2}{2}}{2} \right\} \\ &= 0.01 \end{aligned}$$

$$\sigma^+_{Y_{IV}}(i_{11}i_{22}) = \max\left\{\frac{\frac{(\sigma^+_{X_{IV}}(i_{11}))^2}{2}}{n}, \frac{\frac{(\sigma^+_{X_{IV}}(i_{22}))^2}{2}}{n}\right\}$$
$$= \max\left\{\frac{\frac{(0.5)^2}{2}}{2}, \frac{\frac{(0.3)^2}{2}}{2}\right\}$$
$$= 0.0625$$

Similarly,
$\sigma^-_{Y_{IV}}(i_{22}i_{33}) = 0.0025$ and $\sigma^+_{Y_{IV}}(i_{22}i_{33}) = 0.0225$,
$\sigma^-_{Y_{IV}}(i_{11}i_{33}) = 0.0025$ and $\sigma^+_{Y_{IV}}(i_{11}i_{33}) = 0.0625$.
Therefore all edges are 2-dominate edges.

Definition 3.3. *A subset S_{IV} of V_{IV} is called a n-dominating set (n-DS) in VSDDIVFG if for every $i_{22} \notin S_{IV}$, there exist $i_{11} \in S_{IV}$ such that i_{11} n- dominates i_{22}. A n-DS R_{IV} of a VSDDIVFG is called the minimal n-dominating set if no proper subset of R_{IV} is a n-DS of VSDDIVFG.*

Definition 3.4. *The minimal vertex squared double divide cardinality of a n-DS in VSDDIVFG is said to be n-domination number of VSDDIVFG and is denoted by $\gamma_{nD}(G_{IV})$.*

Example 3.5. In Figure 3,

$$V_{IV} = \{i_{11}, i_{22}, i_{33}\}$$

$$E_{IV} = \{i_{11}i_{22}, i_{22}i_{33}, i_{33}i_{11}\}$$

Here we take X_{IV} be an VSDDIVFS on V_{IV} and Y_{IV} be an VSDDIVFS on $E_{IV} \subseteq V_{IV} \times V_{IV}$ denoted by

$$X_{IV} = \left\langle\left(\frac{i_{11}}{(0.4)^2/2}, \frac{i_{22}}{(0.3)^2/2}, \frac{i_{33}}{(0.2)^2/2}\right)\right\rangle\left\langle\left(\frac{i_{11}}{(0.5)^2/2}, \frac{i_{22}}{(0.4)^2/2}, \frac{i_{33}}{(0.4)^2/2}\right)\right\rangle$$
$$Y_{IV} = \left\langle\left(\frac{i_{11}i_{22}}{0.0225}, \frac{i_{22}i_{33}}{0.01}, \frac{i_{33}i_{11}}{0.01}\right)\right\rangle\left\langle\left(\frac{i_{11}i_{22}}{0.0625}, \frac{i_{22}i_{33}}{0.04}, \frac{i_{33}i_{11}}{0.0625}\right)\right\rangle$$

Then $G_{IV} = (X_{IV}, Y_{IV})$ is an VSIVFG
G_{IV} :

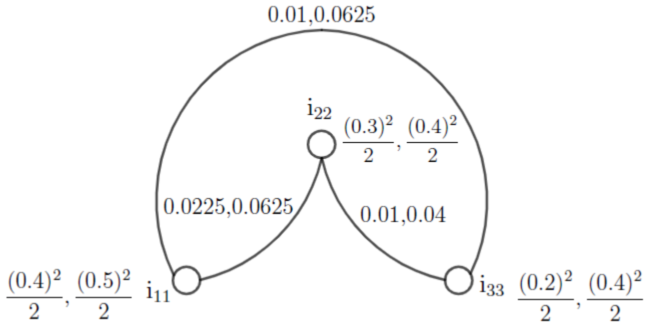

Figure 3: VSDDIVFG(G_{IV}) with 2-Domination Number

For n=2, the 2-dominating sets (2-DSs) are

$$D_1 = \{i_{11}\} = \frac{\frac{1+(0.5)^2}{2} - \frac{(0.4)^2}{2}}{2} = 0.5225$$

$$D_2 = \{i_{=22}\} = \frac{\frac{1+(0.4)^2}{2} - \frac{(0.3)^2}{2}}{2} = 0.5175$$

$$D_3 = \{i_{33}\} = \frac{\frac{1+(0.4)^2}{2} - \frac{(0.2)^2}{2}}{2} = 0.53$$

$$D_4 = \{i_{11}, i_{22}\} = \frac{\frac{1+(0.5)^2}{2} - \frac{(0.4)^2}{2}}{2} + \frac{\frac{1+(0.4)^2}{2} - \frac{(0.3)^2}{2}}{2} = 1.04$$

$$D_5 = \{i_{22}, i_{33}\} = \frac{\frac{1+(0.4)^2}{2} - \frac{(0.3)^2}{2}}{2} + \frac{\frac{1+(0.4)^2}{2} - \frac{(0.2)^2}{2}}{2} = 1.0475$$

$$D_6 = \{i_{11}, i_{33}\} = \frac{\frac{1+(0.5)^2}{2} - \frac{(0.4)^2}{2}}{2} + \frac{\frac{1+(0.4)^2}{2} - \frac{(0.2)^2}{2}}{2} = 1.0525$$

Then the minimal vertex squared double divide cardinality of a 2-dominating set is $\{i_{22}\}$ and $\gamma_{2D}(G_{IV}) = 0.5175$.

Theorem 3.6. *A vertex squared double divide independent set is a maximal vertex squared double divide independent set of a VSDDIVFG iff it is a vertex squared double divide independent set and n-DS.*

Proof. Let S_{IV} is a maximal vertex squared double divide independent set of a VSDDIVFG. Thus for each $x \in V_{IV} - S_{IV}$, the set $S_{IV} \cup \{x\}$ is not vertex squared double divide independent set. In this way, for each vertex $x \in V_{IV} - S_{IV}$, there is a vertex $y \in S_{IV}$ to such an extent that y is n-dominated by x. Consequently S_{IV} is a n-DS. Hence S_{IV} is an vertex squared double divide independent and n-DS.

Conversely, let S_{IV} be vertex squared double divide independent set and n-DS. If conceivable, assume S_{IV} is not a maximal vertex squared double divide independent set. Then there exists $x \in V_{IV} - S_{IV}$ to such an extent that the set $S_{IV} \cup \{x\}$ is vertex squared double divide independent set. Then no vertex in S_{IV} is n-dominated by x. Hence S_{IV} cannot be a n-DS, which is a contradiction. Hence S_{IV} should be a maximal vertex squared double divide independent set.

Example 3.7. G_{IV} :

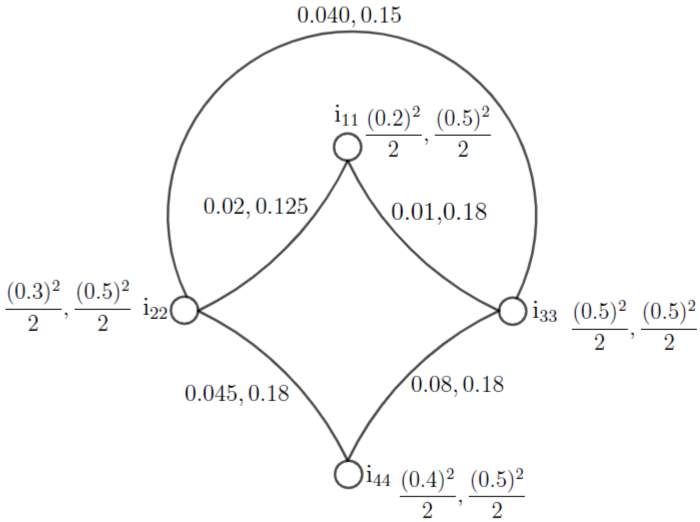

Figure 4: VSDDIVFG(G_{IV}) with 2-Dominating Set

In the above figure the maximal vertex squared double divide independent sets are $S_1 = \{i_{11}, i_{22}, i_{33}\}, S_2 = \{i_{22}, i_{33}, i_{44}\}$. This S_1 and S_2 is also a vertex squared double divide independent set and 2-DS.

Theorem 3.8. *In a VSDDIVFG, every maximal vertex squared double divide independent set is a minimal n-dominating set.*

Proof. Let S_{IV} be a maximal vertex squared double divide independent set in VSDDIVFG. By the theorem 3.6, S_{IV} is a n-DS. Assume S_{IV} be not a minimal n-dominating set. Then there exists somewhere around one vertex $x \in S_{IV}$ for which $S_{IV} - \{x\}$ is a n-DS. Yet, if $S_{IV} - \{x\}$ n-dominates $V_{IV} - (S_{IV} - \{x\})$ then at least one vertex in $S_{IV} - \{x\}$ must n- dominate x. This contradicts the way that S_{IV} is a VSDDIS of VSDDIVFG. Hence S_{IV} should be a minimal n- dominating set.

Example 3.9. G_{IV} :

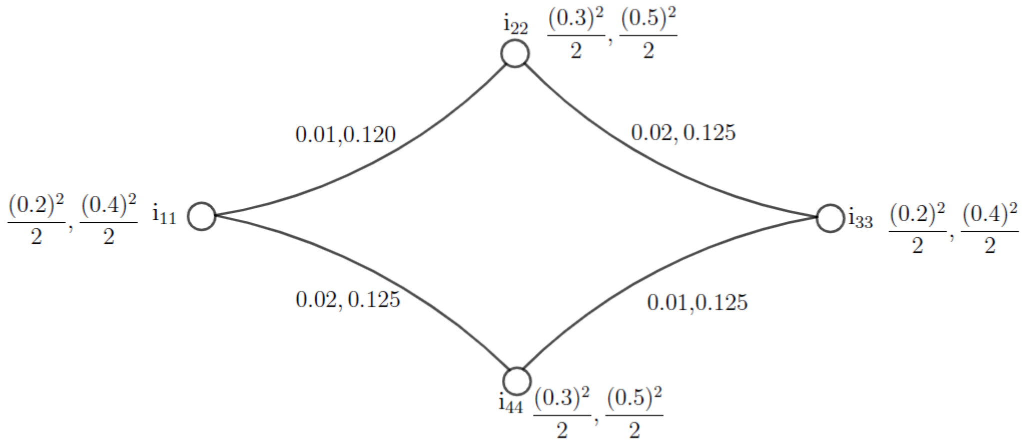

Figure 5: VSDDIVFG(G_{IV}) with 2-Dominating Set

In the above figure the maximal vertex squared double divide independent sets are $S_1 = \{i_{11}, i_{22}\}, S_2 = \{i_{33}, i_{44}\}$, and 2-DSs are

$$D_1 = \{i_{11}, i_{22}\} = \frac{\frac{1+(0.4)^2}{2} - \frac{(0.2)^2}{2}}{2} + \frac{\frac{1+(0.5)^2}{2} - \frac{(0.3)^2}{2}}{2} = 1.07$$
$$D_2 = \{i_{33}, i_{44}\} = \frac{\frac{1+(0.4)^2}{2} - \frac{(0.2)^2}{2}}{2} + \frac{\frac{1+(0.5)^2}{2} - \frac{(0.3)^2}{2}}{2} = 1.07$$

This shows that every maximal vertex squared double divide independent set is a minimal 2-DS.

Theorem 3.10. *Let G_{IV} be a VSDDIVFG with n-dominate edges. If S_{IV} is a minimal n- dominating set, then $V_{IV} - S_{IV}$ is a n-DS.*

Proof. Let S_{IV} be a minimal n-dominating set of VSDDIVFG. Assume $V_{IV} - S_{IV}$ is not n-DS. Then there exist a vertex to $x \in S_{IV}$ such an extent that x is not n-dominated by anyone vertex in $V_{IV} - S_{IV}$. Since G_{IV} has n- dominate edges, x is a n-dominate of somewhere around one vertex in $S_{IV} - \{x\}$. Then $S_{IV} - \{x\}$ is a n-DS, which contradicts the minimality of S_{IV}. Subsequently, every vertex in S_{IV} is a n-dominate of no less than one vertex in $V_{IV} - S_{IV}$. Hence $V_{IV} - S_{IV}$ is a n-DS.

Example 3.11. G_{IV} :

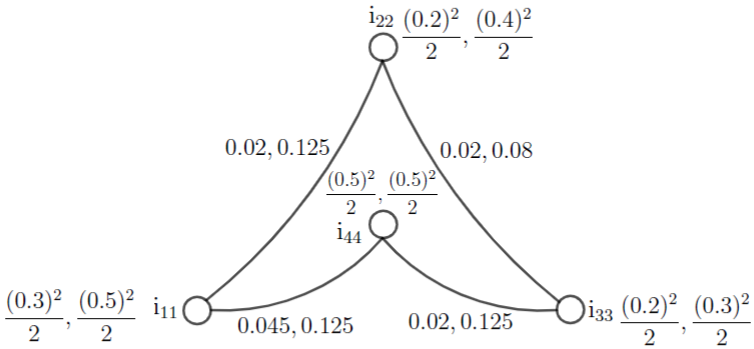

Figure 6: VSDDIVFG(G_{IV}) with 2-Dominating Set

For n=2, the 2-DSs are

$$D_1 = \{i_{11}, i_{22}\} = \frac{\frac{1+(0.5)^2}{2} - \frac{(0.3)^2}{2}}{2} + \frac{\frac{1+(0.4)^2}{2} - \frac{(0.2)^2}{2}}{2} = 1.07$$

$$D_2 = \{i_{11}, i_{33}\} = \frac{\frac{1+(0.5)^2}{2} - \frac{(0.3)^2}{2}}{2} + \frac{\frac{1+(0.3)^2}{2} - \frac{(0.2)^2}{2}}{2} = 1.0525$$

$$D_3 = \{i_{11}, i_{44}\} = \frac{\frac{1+(0.5)^2}{2} - \frac{(0.3)^2}{2}}{2} + \frac{\frac{1+(0.5)^2}{2} - \frac{(0.5)^2}{2}}{2} = 1.04$$

$$D_4 = \{i_{22}, i_{33}\} = \frac{\frac{1+(0.4)^2}{2} - \frac{(0.2)^2}{2}}{2} + \frac{\frac{1+(0.3)^2}{2} - \frac{(0.2)^2}{2}}{2} = 1.0425$$

$$D_5 = \{i_{22}, i_{44}\} = \frac{\frac{1+(0.4)^2}{2} - \frac{(0.2)^2}{2}}{2} + \frac{\frac{1+(0.5)^2}{2} - \frac{(0.5)^2}{2}}{2} = 1.03$$

$$D_6 = \{i_{33}, i_{44}\} = \frac{\frac{1+(0.2)^2}{2} - \frac{(0.3)^2}{2}}{2} + \frac{\frac{1+(0.5)^2}{2} - \frac{(0.5)^2}{2}}{2} = 1.0125$$

Then the minimal vertex squared double divide cardinality of a 2-DS is $\{i_{33}, i_{44}\}$ and $\gamma_{2D}(G_{IV}) = 1.0125$. Here $V_{IV} = \{i_{11}, i_{22}, i_{33}, i_{44}\}$, then $V_{IV} - D_6 = \{i_{11}, i_{22}\}$ is also a 2-DS.

4. Conclusion

The dominance theory survey is intriguing because of the wide range of applications and dominant features that can be established. The new thought has been explained in this paper for vertex squared double divide cardinality, vertex squared double divide effective edge, n- dominating set, and n- domination number. Theorems identified with this concept are inferred and the relation between n- domination set and vertex squared double divide independent set are set up. Vertex squared double divide interval-valued fuzzy graphs are more adaptable and practical than fuzzy graphs because of their many applications in networks. The fuzzy graph hypothesis with vertex squared double divide interval-valued is actively being explored and modified. We trust our investigation will empower us to expand fuzzy graph classes, for example, interval-valued double divide fuzzy incidence graphs and intuitionistic fuzzy incidence graphs.

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