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Complementary domination in Single valued neutrosophic graphs

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ABSTRACT

This paper deals with the concept of complementary domination corresponding to a Single valued neutrosophic graphs (SVNG). Further we study the bounds and characteristic of an inverse domination number (IDN) in various SVNG. A set $I \subseteq V$is supposed to be an CDS in SVNG's $G(A,B)$if $D \subseteq V$remains a DS of G. $I \subseteq (V-D)$ is a DS of $\langle V-D \rangle$. The least among all the CDS's is called an CDN $\gamma_{CD}(G)$ of $G(A,B)$. In this paper, we bring together the notion of a complementary domination (CD) in Single valued neutrosophic graphs (SVNG). Further we study the bounds as well as characteristic of a complementary domination number (CDN) in various SVNG.

1. Introduction

Neutrosophic set projected by Smarandache [1] is a great tool to deal with imperfect, unstipulated and unreliable evidence in real world. It is a oversimplification of the theory of FS, IFS's, IVFS's and IVIFS's, at that time the NS is categorized by a truth-membership degree (T), an indeterminacy-membership degree (I) and a falsity-membership degree (F) self-reliantly, which are within the real usual or nonstandard unit interval [0,1]. Wang et al. obtainable (SVNSs) whose functions of truth, indeterminacy and falsity lie in [0,1]. The similar authors familiarized the notion of IVNS's as subclass of NS in which the value of truth-membership, indeterminacy membership and falsity-membership degrees are intervals of numbers in its place of the real numbers. NS and its extensions such as SVNSs, IVN's, simplified NS.

The definition SVNG in [1] is given a pair $G(A,B)$with underlying set V, where, $T_1, I_1$and F_1 are the functions from $V \to [0,1]$ denote the truth membership, indeterminacy membership and falsity membership of the vertex" $v_i \in V$, respectively such that "$0 \leqslant T_1(v_i) + I_1(v_i) + F_1(v_i) \leqslant 3$. And T_2, I_2 and F_2 are the functions from $E \subseteq V \times V \to [0,1]$ defined by

$$T_2(v_i v_j) \leqslant T_1(v_i) \wedge T_1(v_j)$$
$$I_2(v_i v_j) \leqslant I_1(v_i) \wedge I_1(v_j)$$
$$F_2(v_i v_j) \leqslant F_1(v_i) \vee F_1(v_j)$$

Such that $0 \leqslant T_2(v_i v_j) + I_2(v_i v_j) + F_2(v_i v_j) \leqslant 3$ represents the truth membership, indeterminacy and falsity membership of the edge$(v_i v_j) \in E$ respectively.

In this paper, we bring together the notion of a complementary domination (CD) in Single valued neutrosophic graphs (SVNG). Further we study the bounds as well as characteristic of a complementary domination number (CDN) in various SVNG.

2. Complementary domination

In this section the notion of a complementary domination set (CDS) in SVNG is introduced and also discusses some characteristic and bounds of a complementary domination number in SVNG's.

Definition 2.1. [2]:. *A set $I \subseteq V$is supposed to be an CDS in SVNG's $G(A,B)$if*

i) $D \subseteq V$remains a DS of G .
ii) $I \subseteq (V-D)$ is a DS of $\langle V-D \rangle$.

The least among all the CDS's is called an CDN $\gamma_{CD}(G)$ of $G(A,B)$.

Theorem 2.1:. *If G(A,B) is a connected SVNG, then $\gamma_{CD}(G) \leqslant O(G) - \gamma(G)$.*

Proof:. *Consider a connected SVNG, let it be G.*

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Let $D \subset V$is a $\gamma_{CD}(G)$set of G. Since every vertex $v \in V - D$is dominated by $D \subset V$, note that each vertex $u \in D$is dominated by $(V - D)$. $\Rightarrow$ $(V - D)$is a CD set of $G(A,B)$, but not a $\gamma_{CD}(G)$set of G. Hence

$$\gamma_{CD}(G) \leqslant |V - D| = O(G) - \gamma(G)$$
$$\gamma_{CD}(G) \leqslant O(G) - \gamma(G)$$

Illustration 2.1:

In Fig. 2.1, $O(G) = 0.64$. The set $D = \{a, c\}$ is a $\gamma_{CD}(G)$set of G and $C = \{b, d, e\}$ is a $\gamma_{CD}(G)$ set of G. Hence $\gamma(G) = 0.24$ & $\gamma_{CD}(G) = 0.4$.

Theorem 2.2:. *In a complete SVNG, $\gamma_{CD}(G) = |v|$. here v is vertex having second lowest cardinality among all vertices in G.*

Proof:. *Let G be a complete SVNG and $D \subset V$is a $\gamma_B(G)$set of G.*

Assume that in G $u, v \in V$are vertices consuming the least two minimum cardinality between all the vertices in G. Note that $D = \{u\}$is a $\gamma_{CD}(G)$set of G, since G be a complete SVNG. The "sub graph induced by $< V - D >$" is also complete SVNG. Therefore $v \in (V - D)$ becomes a $\gamma_{CD}(G)$ set of $\langle V - D \rangle$, here the vertex "v" consuming second minimum cardinality between all the vertices of G.

This implies $v \in V$is a $\gamma_{CD}(G)$ set of G. Hence $\gamma_{CD}(G) = |v|$.

Illustration 2.2:

In Fig. 2.2, the value of the vertices in G are $|a| = 0.1$, $|b| = 0.14$, $|c| = 0.23$, $|d| = 0.26$. Here D is a $\gamma(G)$set of G with {a} and $\gamma_{CD}(G)$set of *G is C={b}*. Hence $\gamma(G) = 0.1$ & $\gamma_{CD}(G) = 0.14$.

Theorem 2.3:. *In a complete bipartite SVNG,$G(V_1, V_2, E)$ $\gamma_{CD}(G) = |u_2| + |v_2|$. here $u_2 \in V_1$ &, $v_2 \in V_2$ are the vertices having second lowest cardinality among all vertices in V_1 & V_2 respectively.*

Proof:. *Let G remain a complete bipartite SVNG and $D \subset V$be $\gamma_{CD}(G)$ set of G. Assume that $u, v \in V$are vertices having the least two minimum cardinality among all the vertices in V_1 & V_2 respectively. The set $D = \{u_1, v_1\}$is a $\gamma_{CD}(G)$set of G, since G be a complete bipartite SVNG. The induced sub graph $< V - D >$ is also a complete bipartite SVNG. Therefore $u_2, v_2 \in (V - D)$ is a $\gamma_{CD}(G)$set of $< V - D >$, here u_2, v_2 are the vertices having second lowest cardinality among all vertices in V_1 & V_2 respectively. This implies $\{u_2, v_2\} \in V$is a $\gamma_{CD}(G)$ set of G, Hence $\gamma_{CD}(G) = |u_2| + |v_2|$.*

Illustration 2.3:

In the above Fig. 2.3, the cardinality of the vertices in G are $|u_1| = .2$, $|u_2| = .2$, $|u_3| = .2$, $|v_1| = .2$,$|v_2| = .13$, $|v_3| = .17$. Here D is a $\gamma(G)$set of G with $\{u_1, v_2\}$ and $\gamma_{CD}(G)$set of G *is CD=*$\{u_2, v_3\}$. Hence $\gamma(G) = .33$ & $\gamma_{CD}(G) = 0.37$.

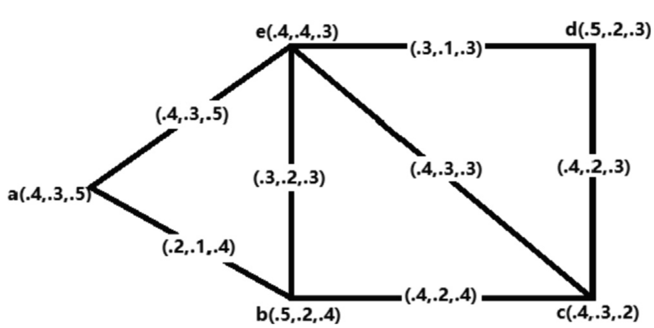

Fig. 2.1. Connected SVNG.

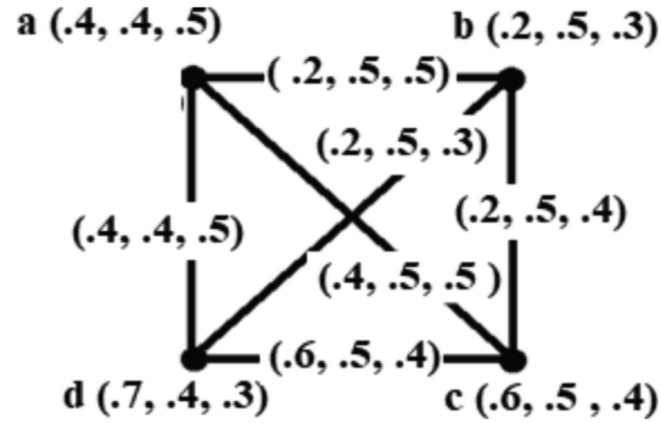

Fig. 2.2. Complete SVNG.

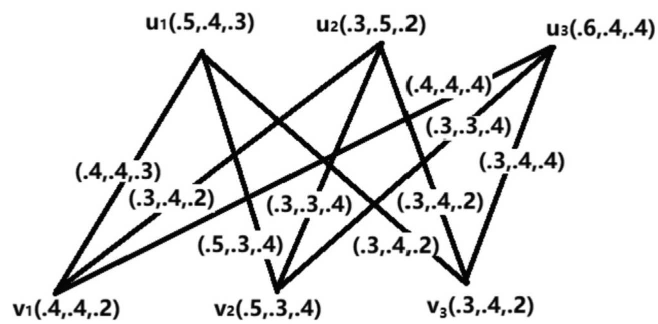

Fig. 2.3. Complete Bipartite SVNG.

Definition 2.2. [3]:. *Consider the two single valued neutrosophic graphs $G_1(V_1, E_1)$ and $G_2(V_2, E_2)$*

Their union$G_1 \cup G_2$ is defined by

$$(T_{11} + T_{21})(u) = \begin{cases} T_{11}(u), \text{ if } u \in V_1 \\ T_{21}(u), \text{ if } u \in V_2 \end{cases} \quad (I_{11} + I_{21})(u) = \begin{cases} I_{11}(u), \text{ if } u \in V_1 \\ I_{21}(u), \text{ if } u \in V_2 \end{cases}$$
$$(F_{11} + F_{21})(u) = \begin{cases} F_{11}(u), \text{ if } u \in V_1 \\ F_{21}(u), \text{ if } u \in V_2 \end{cases}$$

And the edge set E is defined by

$$(T_{12}+T_{22})(uv)=\begin{cases} T_{12}(uv), \text{if } uv \in E_1 \\ T_{21}(uv), \text{if } uv \in E_2 \end{cases} (I_{12}+I_{22})(uv)=\begin{cases} I_{11}(uv), \text{if } uv \in E_1 \\ I_{21}(uv), \text{if } uv \in E_2 \end{cases}$$
$$(F_{12}+F_{22})(uv)=\begin{cases} F_{11}(uv), \text{if } uv \in E_1 \\ F_{21}(uv), \text{if } uv \in E_2 \end{cases}$$

Theorem 2.4:. *In $G_1 \cup G_2$, $\gamma_{CD}(G_1 \cup G_2) = |C_1| + |C_2|$ where C_1 & C_2 are γ_{CD} sets of G_1 , G_2 respectively.*

Proof:. *Consider the union of two SVNG's G_1 , G_2 namely $G_1 \cup G_2$ .Let C_1 & C_2 are γ_{CD} sets of G_1 , G_2 respectively. Then the edges of $G_1 \cup G_2$ will be of the form $uv \in E_1$or $uv \in E_2$. Therefore C_1 complementary dominates the edges of the form $uv \in E_1$. Similarly C_2 inversely dominates the edges of the form $uv \in E_2$. This implies $C_1 \cup C_2$ be an inverse dominating set of $G_1 \cup G_2$. Hence we get $\gamma_{CD}(G_1 \cup G_2) = |C_1| + |C_2|$.*

Illustration 2.4:

€In the above Fig. 2.4, The γ_{CD}set of G_1 is $C_1 = \{b, c\}$ and γ_{CD}set of G_2 is $C_2 = \{g, h\}$minimal inverse dominating number $\gamma_{CD}(G_1) = 0.27$, $\gamma_{CD}(G_2) = 0.3$ and $\gamma_{CD}(G_1 \cup G_2) = 0.57$.

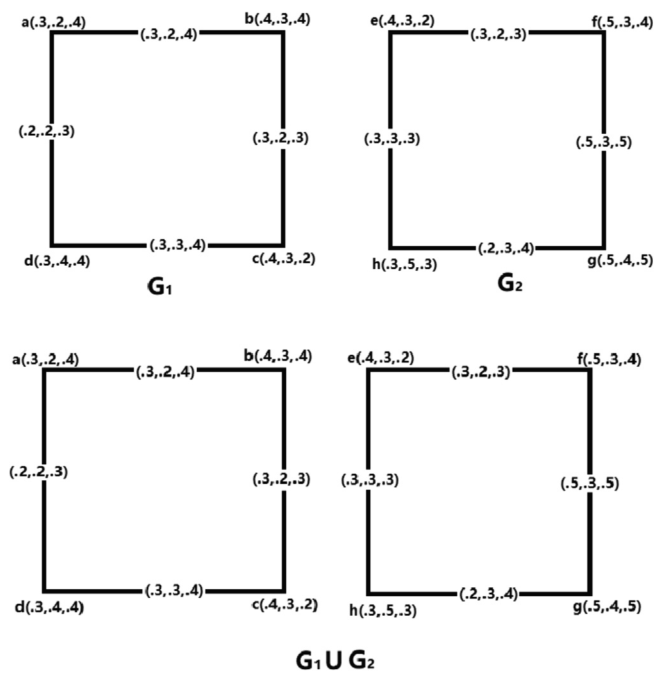

Fig. 2.4. Union of G_1 and G_2.

Definition 2.3. [4]:. *Consider the two single valued neutrosophic graphs* $G_1(V_1, E_1)$

and $G_2(V_2, E_2)$

Then the join of G_1 and G_2 is defined as

$$(T_{11}+T_{21})(u)=\begin{cases}T_{11}(u),\ if\ u\in V_1\\ T_{21}(u),\ if\ u\in V_2\end{cases}\quad (I_{11}+I_{21})(u)=\begin{cases}I_{11}(u),\ if\ u\in V_1\\ I_{21}(u),\ if\ u\in V_2\end{cases}$$

$$(F_{11}+F_{21})(u)=\begin{cases}F_{11}(u),\ if\ u\in V_1\\ F_{21}(u),\ if\ u\in V_2\end{cases}$$

And the edge set E is defined by

$$(T_{12}+T_{22})(uv)=\begin{cases}T_{12}(uv),\ \ if\ \ uv\in E_1\\ T_{22}(uv),\ \ if\ \ uv\in E_2\\ T_{11}(u)\wedge T_{21}(v),\ \ otherwise\end{cases}$$

$$(I_{12}+I_{22})(uv)=\begin{cases}I_{12}(uv),\ \ if\ \ uv\in E_1\\ I_{22}(uv),\ \ if\ \ uv\in E_2\\ I_{11}(u)\wedge I_{21}(v),\ \ otherwise\end{cases}$$

$$(F_{12}+F_{22})(uv)=\begin{cases}F_{12}(uv),\ \ if\ \ uv\in E_1\\ F_{22}(uv),\ \ if\ \ uv\in E_2\\ F_{11}(u)\vee F_{21}(v),\ \ otherwise\end{cases}$$

Theorem 2.5. : *In* $G_1 + G_2$, $\gamma_{CD}(G_1 + G_2) = |C_1| \wedge |C_2|$ *where* $C_1 \,\&\, C_2$ *be a* γ_{CD} *set of* G_1 , G_2 *respectively.*

Proof:. *Let* $G_1 + G_2$ *denote the joining of two SVNG's,* $G_1 \& G_2$. *Assume* $C_1 \,\&\, C_2$ *be a* γ_{CD} *set of* G_1 , G_2 *respectively, The edges of* $G_1 + G_2$ *will be either*

"$uv \in E_1$or $uv \in E_2$or $uv \in E$, *if* $u \in V_1$ *and* $v \in V_2$"

If $uv \in E_1$, C_1 complementary dominates the edges of the form. If $uv \in E_2$, C_2 complementary dominates the edges of the form. This implies $C_1 \cap C_2$ be a complementary dominating set of $G_1 + G_2$. If $uv \in E$ *if* $u \in V_1 \,\&\, v \in V_2$ this implies we get

$$(T_{12} + T_{22})(uv) = T_{11}(u) \wedge T_{21}(v)$$
$$(I_{12} + I_{22})(uv) = I_{11}(u) \vee I_{21}(v)$$
$$(F_{12} + F_{22})(uv) = F_{11}(u) \vee F_{21}(v)$$

There is a strong arc between $uv \in E$ *if* $u \in V_1 \,\&\, v \in V_2$. This implies $C_1 \cap C_2$ inversely dominates $V_1 \,\&\, V_2$ respectively. Hence $C_1 \cap C_2$ be a γ_{CD} set of $G_1 + G_2$and $\gamma_{CD}(G_1 + G_2) = |C_1| \wedge |C_2|$

Illustration 2.5:

The join of $G_1 \,\&\, G_2$in the Fig. 2.3 is given below

In the above Fig. 2.5, The γ_{CD}set of G_1 is $C_1 = \{b, c\}$ and γ_{CD}set of G_2 is $C_2 = \{g, h\}$minimal inverse dominating number $\gamma_{CD}(G_1) = 0.27$, $\gamma_{CD}(G_2) = 0.3$ and $\gamma_{CD}(G_1 + G_2) = 0.3$.

Definition 2.4. [5]:. *Let* $G_1(A_1, B_1)$*and* $G_2(A_2, B_2)$*be a SVNG of The Cartesian product* $G_1 \times G_2$*is defined by,*

$$\left.\begin{array}{l}(T_{12} \times T_{22})(x_1x_2) = T_{11}(x_1) \wedge T_{21}(x_2)\\ (I_{12} \times I_{22})(x_1x_2) = I_{11}(x_1) \wedge I_{11}(x_2)\\ (F_{12} \times F_{22})(x_1x_2) = F_{11}(x_1) \vee F_{11}(x_2)\end{array}\right. \text{ for each } x_1x_2 \in V = V_1 \times V_2,$$

and

$$\left.\begin{array}{l}(T_{12} \times T_{21})((x_1x_2)(y_1y_2)) = T_{11}(x_1) \wedge T_{22}(x_2y_2)\\ (I_{12} \times .I_{21})((x_1x_2)(y_1y_2)) = I_{11}(x_1) \wedge I_{22}(x_2y_2)\\ (F_{12} \times .F_{21})((x_1x_2)(y_1y_2)) = F_{11}(x_1) \vee F_{22}(x_2y_2)\end{array}\right. \text{ for all}$$

$x_2y_2 \in E_2$and $x_1 = y_1$.

$$\left.\begin{array}{l}(T_{12} \times .T_{21})((x_1x_2)(y_1y_2)) = T_{12}(x_1y_1) \wedge T_{21}(y_2)\\ (I_{12} \times .I_{21})((x_1x_2)(y_1y_2)) = I_{12}(x_1y_1) \wedge I_{21}(y_2)\\ (F_{12} \times .F_{21})((x_1x_2)(y_1y_2)) = F_{12}(x_1y_1) \vee F_{21}(y_2)\end{array}\right. \text{ for all}$$

$x_1y_1 \in E_1$and $x_2 = y_2$.

Theorem 2.4:. *In* $G_1 \times G_2$, $\gamma_{CD}(G_1 \times G_2) = (|C_1 \times V_2| \wedge |V_1 \times C_2|)$ *where* $C_1 \,\&\, C_2$ *be a* γ_{CD} *set of* $G_1 \,\&G_2$ *respectively,*

Proof:. *Let* $G_1 \times G_2$ *be a Cartesian product of two SVNG* $G_1 \& G_2$. *Assume* $C_1 \,\&\, C_2$ *be a* γ_{CD} *set of* $G_1 \,\&G_2$ *respectively, the edges in* $G_1 \times G_2$*will have one of the forms*

(i) $((x_1x_2)(x_1y_2))$, $x_1 \in V_1 \,\&\, x_2y_2 \in E_2$, (ii) $((x_1x_2)(y_1x_2))$, $x_2 \in V_2 \,\&\, x_1x_1 \in E_1$.

Case *((i):). If* $((x_1x_2)(x_1y_2))$, $x_1 \in V_1 \,\&\, x_2y_2 \in E_2$

If $((x_1x_2)(x_1y_2))$, $x_1 \in V_1 \,\&\, x_2y_2 \in E_2$.Suppose $u_2v_2 \in E_2$is strong edge in G_2 and $x_2 \in C_2$, this implies

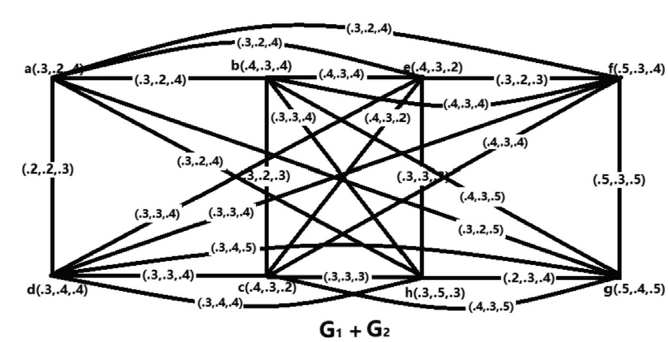

Fig. 2.5. Union of G_1 and G_2.

$$(T_{12} \times T_{21})((x_1x_2)(y_1y_2)) = T_{11}(x_1) \wedge T_{22}(x_2y_2)$$
$$= T_{11}(x_1) \wedge T_{21}(x_2) \wedge T_{21}(y_2)$$
$$= T_{11}(x_1) \wedge T_{21}(x_2) \wedge T_{11}(x_1) \wedge T_{21}(y_2)$$
$$(T_{12} \times T_{21})((x_1x_2)(y_1y_2)) = (T_{11} \times T_{21})(x_1x_2) \wedge (T_{11} \times T_{21})(y_1y_2)$$

$$(I_{12} \times I_{21})((x_1x_2)(y_1y_2)) = I_{11}(x_1) \wedge I_{22}(x_2y_2)$$
$$= I_{11}(x_1) \wedge I_{21}(x_2) \wedge I_{21}(y_2)$$
$$= I_{11}(x_1) \wedge I_{21}(x_2) \wedge I_{11}(x_1) \wedge I_{21}(x_2)$$
$$(I_{12} \times I_{21})((x_1x_2)(y_1y_2)) = (I_{11} \times I_{21})(x_1x_2) \wedge (I_{11} \times I_{21})(y_1y_2)$$

$$(F_{12} \times F_{21})((x_1x_2)(y_1y_2)) = F_{11}(x_1) \vee F_{22}(x_2y_2)$$
$$= F_{11}(x_1) \vee F_{21}(x_2) \vee F_{21}(y_2)$$
$$= F_{11}(x_1) \vee F_{21}(x_2) \vee F_{11}(x_1) \vee F_{21}(y_2)$$
$$(F_{12} \times F_{21})((x_1x_2)(y_1y_2)) = (F_{11} \times F_{21})(x_1x_2) \vee (F_{11} \times F_{21})(y_1y_2)$$

Therefore $(x_1x_2)(y_1y_2)$ is an effective edge in$G_1 \times G_2$, this implies $V_1 \times C_2$ inversely dominates the edges in this case. Since C_2 is a γ_{CD} set of G_2 .

Case *((ii):). If* $((x_1x_2)(y_1x_2)),\ x_2 \in V_2 \,\&\, x_1x_1 \in E_1$

If $((x_1x_2)(y_1x_2)),\ x_2 \in V_2 \,\&\, x_1x_1 \in E_1$.Suppose $x_1y_1 \in E_1$is strong edge in G_1 and $x_1 \in C_1$, this implies

$$(T_{12} \times T_{21})((x_1x_2)(y_1y_2)) = T_{12}(x_1y_1) \wedge T_{21}(x_2)$$
$$= T_{11}(x_1) \wedge T_{11}(y_1) \wedge T_{21}(x_2)$$
$$= T_{11}(x_1) \wedge T_{21}(x_2) \wedge T_{11}(y_1) \wedge T_{21}(y_2)$$
$$(T_{12} \times T_{21})((x_1x_2)(y_1y_2)) = (T_{11} \times T_{21})(x_1x_2) \wedge (T_{11} \times T_{21})(y_1y_2)$$

$$(I_{12} \times I_{21})((x_1x_2)(y_1y_2)) = I_{12}(x_1y_1) \wedge I_{21}(x_2)$$
$$= I_{11}(x_1) \wedge I_{11}(y_1) \wedge I_{21}(x_2)$$
$$= I_{11}(x_1) \wedge I_{21}(x_2) \wedge I_{11}(y_1) \wedge I_{21}(x_2)$$
$$(I_{12} \times I_{21})((x_1x_2)(y_1y_2)) = (I_{11} \times I_{21})(x_1x_2) \wedge (I_{11} \times I_{21})(y_1y_2)$$

$$(F_{12} \times F_{21})((x_1x_2)(y_1y_2)) = F_{12}(x_1y_1) \vee F_{21}(x_2)$$
$$= F_{11}(x_1) \vee F_{11}(y_1) \wedge F_{21}(x_2)$$
$$= F_{11}(x_1) \vee F_{21}(x_2) \vee F_{11}(y_1) \wedge F_{21}(x_2)$$
$$(F_{12} \times F_{21})((x_1x_2)(y_1y_2)) = (F_{11} \times F_{21})(x_1x_2) \vee (F_{11} \times F_{21})(y_1y_2)$$

Therefore $(x_1x_2)(y_1y_2)$ is an effective edge in $G_1 \times G_2$, this implies $C_1 \times V_2$ inversely dominates the edges in this case. Since C_I is a γ_{CD} set of G_1.

From case (i) & (ii), the sets $C_1 \times V_2$ and $V_1 \times C_2$are the complementary dominating sets of $G_1 \times G_2$. This implies $C = (C_1 \times V_2) \cap (V_1 \times C_2)$. Hence we get $\gamma_{CD}(G_1 \times G_2) = (|C_1 \times V_2| \wedge |V_1 \times C_2|)$.

Illustration 2.6:

In the above Fig. 2.6, The γ_{CD}set of G_1 is $C_1 = \{a, d\}$ and γ_{CD}set of G_2 is $C_2 = \{f, g\}$ minimal inverse dominating number $\gamma_{CD}(G_1) = 0.27$,
$\gamma_{CD}(G_2) = 0.3$,$C_1 \times V_2 = \{(ae), (af), (ag), (de), (df), (dg)\}$,
$V_1 \times C_2 = \{(\mathrm{af}), (\mathrm{bf}), (\mathrm{cf}), (\mathrm{df}), (\mathrm{ag}), (\mathrm{bg}), (\mathrm{cg}), (\mathrm{dg})\}$,
$|C_1 \times V_2| = 0.74$, $|V_1 \times C_2| = 0.6$ and$\gamma_{CD}(G_1 \times G_2) = 0.6$.

3. Conclusion

In this paper, we bring together the concept of complementary domination in "SVNG". Further we studied the bounds and characteristic of an complementary domination number (CDN) in various SVNG. In future we will describe various domination sets in SVNG and study charateristics and bounds of the domination parameters.

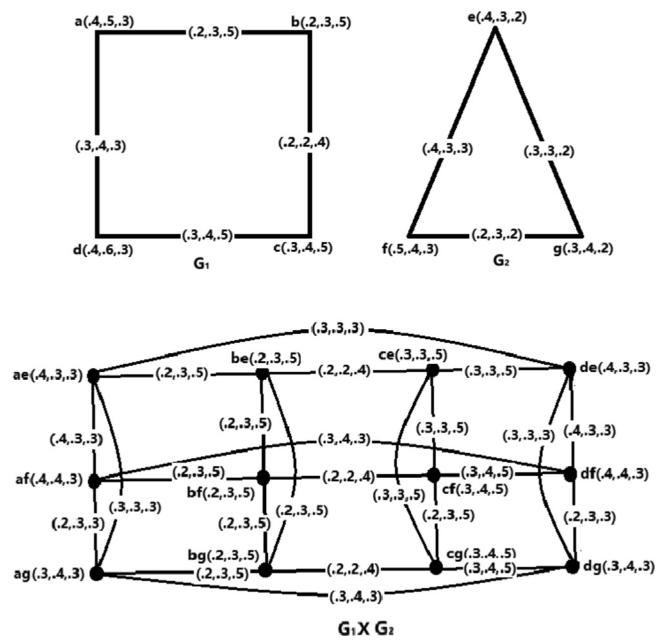

Fig. 2.6. Union of G_1 and G_2.

CRediT authorship contribution statement

R. Ramya: Conceptualization, Writing - review & editing. **N. Vinothkumar:** Methodology, Writing - review & editing. **E. Karuppasamy:** Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Further Reading

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