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Properties of Neighbourly Irregular Fuzzy Chemical Graphs

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Abstract: In this paper, continuing the works on Neighbourly irregular fuzzy chemical graphs. We are extending to the properties of G_{NIFC}. Like Cartesian product and direct sum of two distinct Neighbourly irregular fuzzy chemical graphs. We also define and prove the needed propositions with examples.

1 INTRODUCTION

Rosenfield introduced fuzzy graph theory in 1975.S.K.Ayyasamy .S .K [4] et al introduced the concept of neighbourly irregular graphs, A.Nagoor Gani [5] et al worked on regular properties of fuzzy graphs, J.Arockia Aruldoss [3] The concept of neighbourly irregular chemical graphsG_{NIFC}. Arockia aruldoss [2] et al introduced the concept of neighbourly irregular fuzzy chemical graphs. Here, we study some properties of neighbourly irregular fuzzy chemical graphs like Cartesian product and direct sum of two G_{NIFC} graphs.

Here, we discuss about 'Double layered neighbourly irregular fuzzy chemical graphs' G_{DLNIFC} and their total irregular value using method of vertex cut.

2 Basic Definitions

Definition 2.1. [6] A fuzzy graph has a pair of functions $G : (\sigma, \mu)$ where $\sigma : V \to [0,1]$ and $\mu : X \times X \to [0,1]$ with $\mu(u,v) \leq \sigma(u) \wedge \sigma(v) \forall u, v \in V$.

Definition 2.2. [4] In any graph $G = (V, E)$, if any two neighbouring vertices are of different degrees, then the graph is neighbourly irregular.

$d_G(u) \neq d_G(v)$; if u and v are adjacent.

Definition 2.3. [3] The structure of a molecule is turned to be chemical graph $G_c = (X, Y)$ where the vertices are atoms, and the edges are bonds. we usually represent these chemical graphs as $G_c = (V, X)$.

Definition 2.4. [3] In a chemical graph atoms have different valencies, such as any two neighbouring vertices have different degrees, then the graph is Neighbourly irregular chemical graphs.

$G_{NIC} = (V, X)$; such that $deg(u_i) \neq deg(u_j)$ if i, j are adjacent.

Definition 2.5. [2] A chemical graph $G_c : (\alpha, \beta)$ is called to be G_{NIFC} if any two neighbouring vertices have different degrees. It is denoted as,

$G_{NIFC} : (\sigma, \mu)$ such that $deg(u_i) \neq deg(u_j)$ if i, j are adjacent.

Definition 2.6. In any fuzzy graph, the deg of a vertex is associated with the summation of the membership values of incident edges.

Such that, $deg(u_i) = \sum_{j=1}^{n} \mu_j$.

Here $\delta(G_{NIFC}) = \wedge\{\deg(v) | v \in V\}$
$\Delta(G_{NIFC}) = \vee\{\deg(v) | v \in V\}$.

Note: In a k regular fuzzy chemical graph k is not necessarily an integer.

3 Cartesian Product of two neighbourly irregular fuzzy chemical Graphs

In this part, we discuss the properties of Cartesian product of any 2 neighbourly irregular fuzzy chemical graphs.

Definition 3.1. Cartesian product of two neighbourly irregular fuzzy chemical graphs ${G^1}_{NIFC}$ and ${G^2}_{NIFC}$ are defined as,

$G = {G^1}_{NIFC} \times {G^2}_{NIFC} = (\alpha_1 \times \alpha_2, \beta_1 \times \beta_2)$
whereas $G_{NIC} : (V, E)\,; V = V_1 \times V_2$ and
$E = \{((u_1, u_2)\,(v_1, v_2))\,|u_1 = v_1; u_1v_2 \in E_2$ or $u_2 = v_2; u_1v_1 \in E_1\}$
with the membership value for the vertex,
$(u_1, u_2) = \alpha_1\,(u_1) \wedge \alpha_2\,(u_2)\,; (u_1, u_2) \in v_1 \times v_2$
and the membership value for the edge

$$\begin{aligned}((u_1, u_2)(v_1, v_2)) &= \alpha_1(u_1) \wedge \beta_2(u_2v_2)\text{if } u_1 = v_1, u_2v_2 \in E_2\\ &= \alpha_2(u_2) \wedge \beta_1(u_1v_1)\text{if } u_2 = v_1, u_1v_1 \in E_1\end{aligned}$$

Remark 3.2.

(i) Product of any two Neighbourly irregular fuzzy chemical graphs may not be a Neighbourly irregular fuzzy chemical graphs.

(ii) let the crisp chemical graph $G_c^*\,(V, X)$ is neighbourly irregular, then the associated fuzzy graph $G_{FC}\,(\sigma, \mu)$ need not be neighbourly irregular. The converse does not hold.

Example 3.3. Let us take the graph $G_c^*\,(V, X)$

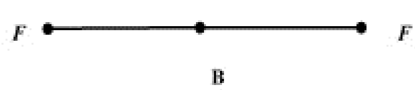
(i) Bromate ion - Bro_3.

(ii) Bromin trifluride - BrF_3.

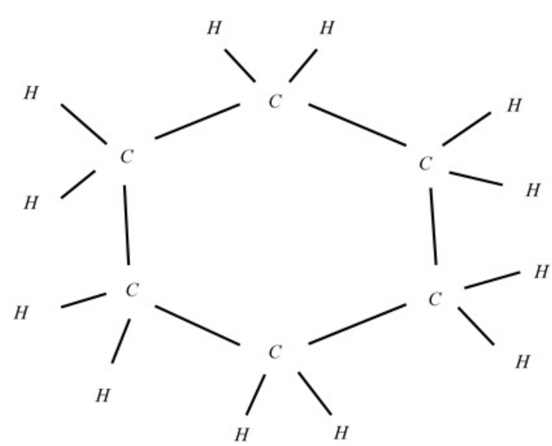
(iii) Anmonium Ion - NH_4.

(iv) Suffur Tetra fluride - SF_4.

(v) Difluoroboryl - BF_2.



(vi) Glucose C_6H_{12}.



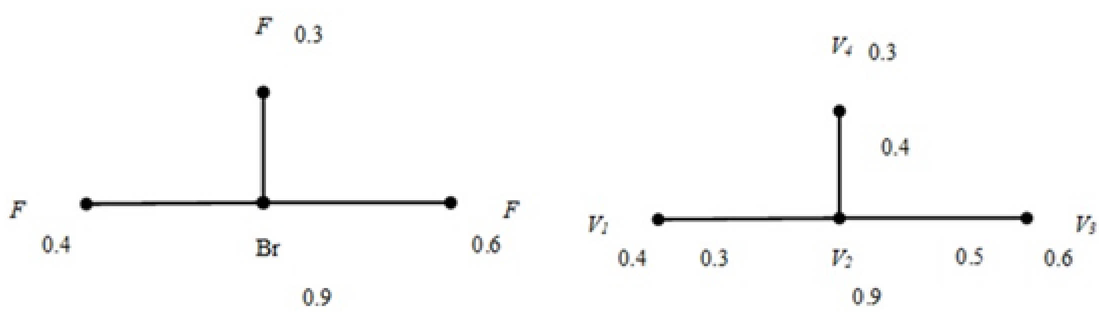
3.1 Full regular fuzzy chemical graph

The crisp chemical graph G_c^* are said to be full regular,if G_c regular fuzzy chemical graph. If G_c are regular and partially regular.

Note: G_{NIFC} has not full regular.

Example 3.4. For regular fuzzy graph of G_{NIC}.

Bromine Trifluride (BrF_3).



Proposition 3.5. *Any G_{NIC} can't be a regular G_{NIFC}.*

Proof. Let G_{NIC} be a Neighbourly irregular chemical graph of molecular structure of any molecule among S - block, P - block or S & P- block elements.

Such that $G_{NIC} = (V, X)$

where

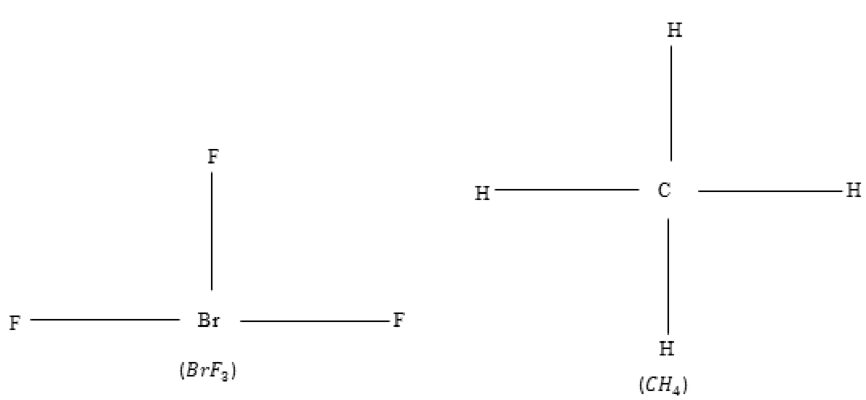
$$V = \{u_1, u_2, u_3, ..., u_n\},$$
$$X = \{x_1, x_2, x_3, ..., x_r\}$$

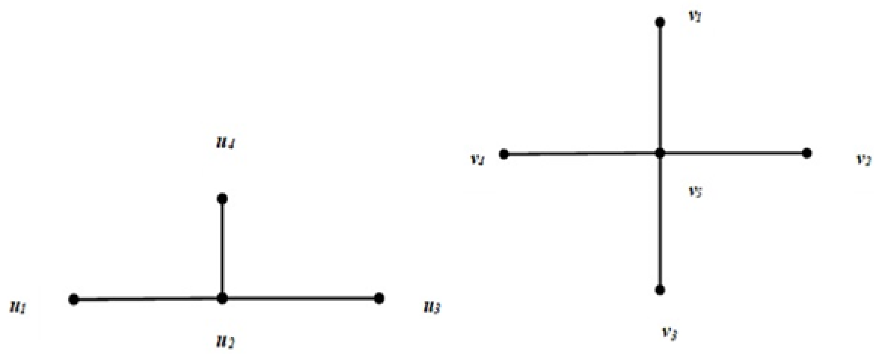
The corresponding fuzzy graph of above G_{NIC} be, $G_{NIFC} = (V, \sigma, \mu)$ using the required membership values.

We know, the degr of vertex are written as $d_{GNIFC}(u) \sum_{u \neq v} \mu(v, u)$ while in the G_{NIFC} graph, since any two neighbouring vertices are of different degrees, it is clearly true that, $d_{GNIFC}(v_{i-1}) \neq d_{GNIFC}(v - i) \neq d_{GNIFC}(v_{i+1})$ which is contradiction to regular fuzzy graph. □

Property 1: Let $G^1{}_{NIFC}$ and $G^2{}_{NIFC}$ being any two Neighbourly irregular fuzzy chemical graph graphs, then $G^1{}_{NIFC} \times G^2{}_{NIFC}$ need not be neighbourly irregular.

Example 3.6. Let $G^1{}_{NIFC}$ be Bromium Trifukuride $(B_r F_3)$ and $G^2{}_{NIFC}$ be Methane (CH_4) .





Then the product is
$V = \{(u_1, w_1), (u_1, v_2), (u_1, w_3), (u_1, w_4), (u_1, w_5), (u_2, w_1), (u_2, w_2), (u_2, w_3),$
$(u_2, w_4), (2, w_5), (u_3, w_1), (u_3, w_2), (u_3, w_3), (u_3, w_4), (u_3, w_5), (u_4, w_1),$
$(u_4, w_2), (u_4, w_3), (u_4, w_4), (u_4, w_5)\}$

Definition 3.7. The Cartesian product of two graphs G_c^1 and G_c^2 are such that the vertices $G_c^1 \times G_c^2$ is the cartesian product of the vertex sets w_1 and w_2 respectively and two vertices were adjacent in $G_c^1 \times G_c^2$ iff either $u = v$ and u' are neighbor to v' in G_c^2 or $u' = v'$ and u was neighbor to v in G.

Note:

(i) $d_{G_1 \times G_2}(u_i, v_j) = d_{G_1}(u_i) + d_{G_2}(v_j)$.

(ii) In $G_{NIFC} d_{G_1 \times G_2}(u_i, v_j)$ need not be equal.

(iii) $G_c^1 \times G_c^2$is not regular and $G^1{}_{NIFC} \times G^2{}_{NIFC}$ also regular or partially regular.

Proposition 3.8. *If $G_{NIC}{}^1 \times G_{NIC}{}^2$ be the Cartesian products of two distinct neighbourly irregular fuzzy chemical graphs, then the resultant graph is not regular.*

(or)

The Cartesian product of two Neighbourly irregular chemical graphs is not regular.

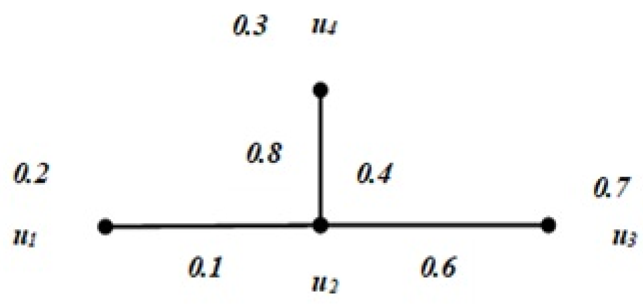
Proof. Let $G_{NIC}{}^1$ and $G_{NIC}{}^2$ be any two distinct graphs.
We know that they are not regular.
The product of two graphs is, $G_{NIC}{}^1 \times G_{NIC}{}^2 = (V_1 \times V_2, X)$.
Degree of each vertex of $V_1 \times V_2$ are as follows, such that

$$\begin{aligned} d(u_i, v_j) &= dG_{NIC}{}^1(u_i) + dG_{NIC}{}^2(v_j) \\ &= r + s. \end{aligned}$$

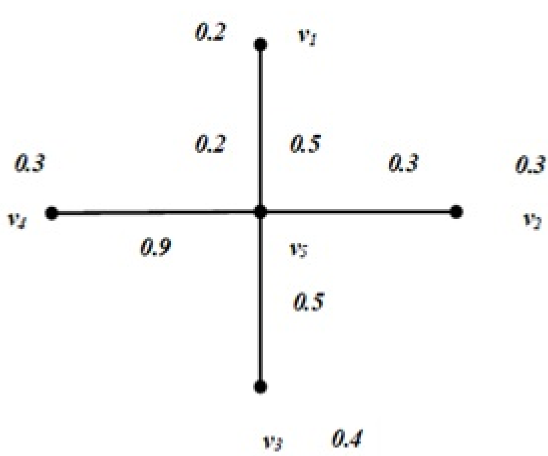
Since in $G_{NIC}{}^1$ and $G_{NIC}{}^2$ are neighbourly irregular.
$dG_{NIC}{}^1(u_i) \neq dG_{NIC}{}^2(u_{i+1})$
$\Rightarrow r \neq r'$
and $dG_{NIC}{}^1(v_j) \neq dG_{NIC}{}^2(v_{j+1})$
$s \neq s'$
$\Rightarrow dG_{NIC}{}^1(u_i) + dG_{NIC}{}^1(v_j) \neq dG_{NIC}{}^2(u_{i+1}) + dG_{NIC}{}^2(v_{j+1})$
$r + s \neq r' + s'$
Some adjacent vertices may be equal but not regular.
The product of any two G_{NIC} is not regular.
And in case of product fuzzy graphs of above two G_{NIFC} graphs also can't be regular by applying the membership values, by using the definition of Cartesian product.

□

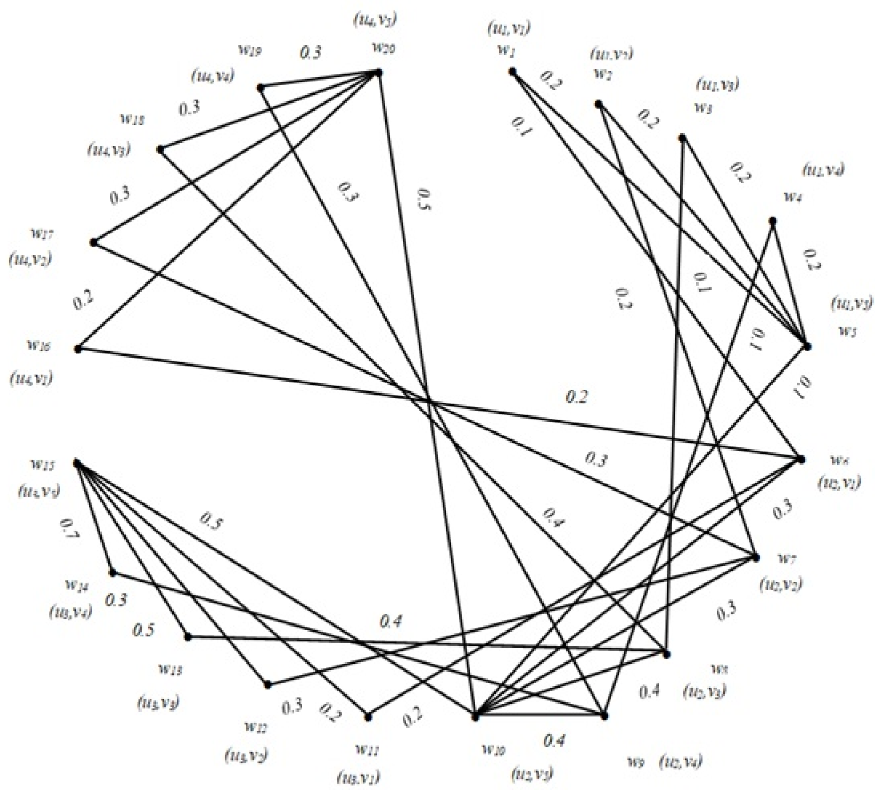
Example 3.9. Let us consider G_{NIFC} graphs BrF_3 and CH_4 respectively. Then the Cartesian Product is as follows.



G^1_{NIFC}



G^2_{NIFC}



$$\sigma(\omega_1) = 0.2, \sigma(\omega_2) = 0.2, \sigma(\omega_3) = 0.2, \sigma(\omega_4) = 0.2, \sigma(\omega_5) = 0.2,$$
$$\sigma(\omega_6) = 0.2, \sigma(\omega_7) = 0.3, \sigma(\omega_8) = 0.4, \sigma(\omega_9) = 0.3, \sigma(\omega_{10}) = 0.4,$$
$$\sigma(\omega_{11}) = 0.2, \sigma(\omega_{12}) = 0.3, \sigma(\omega_{13}) = 0.4, \sigma(\omega_{14}) = 0.3, \sigma(\omega_{15}) = 0.5,$$
$$\sigma(\omega_{16}) = 0.2, \sigma(\omega_{17}) = 0.3, \sigma(\omega_{18}) = 0.3, \sigma(\omega_{19}) = 0.3, \sigma(\omega_{20}) = 0.3.$$

and

$$\mu(\omega_1, \omega_5) = 0.2, \mu(\omega_1, \omega_6) = 0.1, \mu(\omega_2, \omega_5) = 0.2, \mu(\omega_2, \omega_7) = 0.2,$$
$$\mu(\omega_3, \omega_5) = 0.2, \mu(\omega_3, \omega_8) = 0.1, \mu(\omega_4, \omega_5) = 0.2, \mu(\omega_4, \omega_9) = 0.1,$$
$$\mu(\omega_5, \omega_{10}) = 0.1, \mu(\omega_6, \omega_{10}) = 0.3, \mu(\omega_6, \omega_{11}) = 0.2, \mu(\omega_6, \omega_{16}) = 0.2,$$
$$\mu(\omega_7, \omega_{10}) = 0.3, \mu(\omega_7, \omega_{12}) = 0.3, \mu(\omega_7, \omega_{17}) = 0.3, \mu(\omega_8, \omega_{10}) = 0.4,$$
$$\mu(\omega_8, \omega_{13}) = 0.4, \mu(\omega_8, \omega_{18}) = 0.4, \mu(\omega_9, \omega_{10}) = 0.4, \mu(\omega_9, \omega_{14}) = 0.3,$$
$$\mu(\omega_9, \omega_{19}) = 0.3, \mu(\omega_{10}, \omega_{15}) = 0.5, \mu(\omega_{10}, \omega_{20}) = 0.5, \mu(\omega_{11}, \omega_{15}) = 0.2,$$
$$\mu(\omega_{12}, \omega_{15}) = 0.3, \mu(\omega_{13}, \omega_{15}) = 0.5, \mu(\omega_{14}, \omega_{15}) = 0.7, \mu(\omega_{16}, \omega_{20}) = 0.2,$$
$$\mu(\omega_{17}, \omega_{20}) = 0.3, \mu(\omega_{18}, \omega_{20}) = 0.3, \mu(\omega_{19}, \omega_{20}) = 0.3.$$

Let ${G_{NIFC}}^1 \times {G_{NIFC}}^2 = G^*$

Now,
$d_{G^*}(\omega_1) = 0.3$ $d_{G^*}(\omega_{11}) = 0.4$
$d_{G^*}(\omega_2) = 0.4$ $d_{G^*}(\omega_{12}) = 0.6$
$d_{G^*}(\omega_3) = 0.3$ $d_{G^*}(\omega_{13}) = 0.9$
$d_{G^*}(\omega_4) = 0.3$ $d_{G^*}(\omega_{14}) = 1.0$
$d_{G^*}(\omega_5) = 0.9$ $d_{G^*}(\omega_{15}) = 2.2$
$d_{G^*}(\omega_6) = 0.8$ $d_{G^*}(\omega_{16}) = 0.4$
$d_{G^*}(\omega_7) = 1.1$ $d_{G^*}(\omega_{17}) = 0.6$
$d_{G^*}(\omega_8) = 1.2$ $d_{G^*}(\omega_{18}) = 0.7$
$d_{G^*}(\omega_9) = 1.1$ $d_{G^*}(\omega_{19}) = 0.6$
$d_{G^*}(\omega_{10}) = 2.5$ $d_{G^*}(\omega_{20}) = 1.6$

We get that G_{NIFC} is not regular.

Note:

1. A Cartesian product of two G_{NIC} graph is neither regular nor neibourly irregular.
2. The product graph is not a molecular structure of any molecules.

4 Direct sum of two neighbourly irregular fuzzy chemical graphs

Definition 4.1. Let $G^1_{NIC}\left(V_1, X_1\right)$ and $G^1_{NIC}\left(V_1, X_1\right)$ denote the two distinct neighbourly irregular chemical graphs. Then their direct sum is,

$$G^1_{NIC} \oplus G^1_{NIC} = (V, X)$$

so that $V = V_1 \cup V_2$ & $E = \{uv/u, v \in V,\ \text{either } uv \in X_1 \text{ or } uv \in\in X_2\}$.

Definition 4.2. Let $G^1_{NIFC}\left(\sigma_1, \mu_1\right)$ & $G^2_{NIFC}\left(\sigma_2, \mu_2\right)$ be two distinct neighbourly irregular fuzzy chemical graphs. So the direct sum was defined as,

$$G : (\sigma, \mu) = G^1_{NIFC} \oplus G^2_{NIFC}$$

where $V = V_1 \cup V_2$ and $E = \{u_1v_1|u_1v_1 \in V; u_1v_1 \in E_1 \text{ or } u_1v_1 \in E_2\}$, in mid

Such that, $\sigma\left(u\right) = \left\{\sigma^1\left(u\right) \vee \sigma^2\left(u\right)\ \text{if } u \in V_1 \cup V_2 | \sigma^1\left(u\right) \in V_1 \text{ and } \sigma^2\left(u\right) \in V_2\right\}$

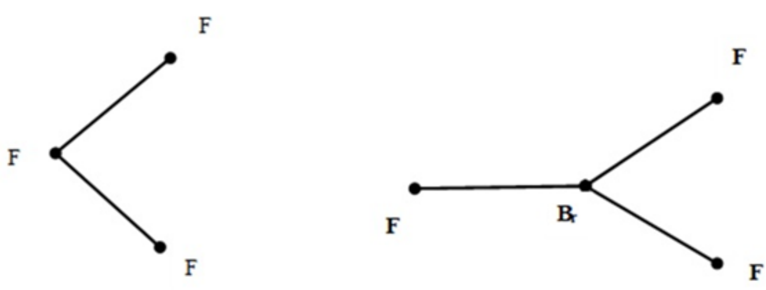
and $\mu\left(uv\right) = \begin{cases} \mu^1(uv); uv \in V_1. \\ \mu^2(uv); uv \in V_2. \end{cases}$

Also, if $uv \in X$, $\mu\left(uv\right) = \mu_1\left(uv\right) \leq \sigma_1\left(u\right) \wedge \sigma_1\left(v\right) \leq \sigma\left(u\right) \wedge \sigma\left(v\right)$.

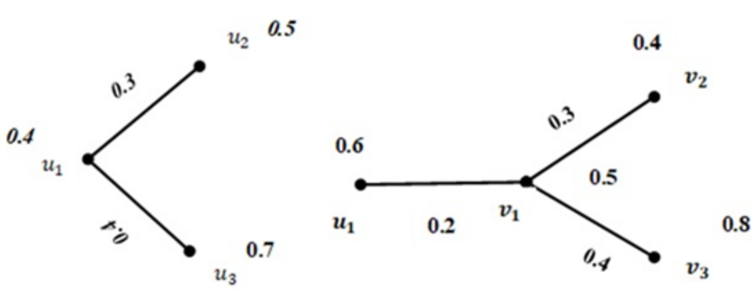
Similarly, if $uv \in X_1$, $\mu\left(uv\right) = \mu_2\left(uv\right) \leq \sigma_2\left(u\right) \wedge \sigma_2\left(v\right) \leq \sigma\left(u\right) \wedge \sigma\left(v\right)$.

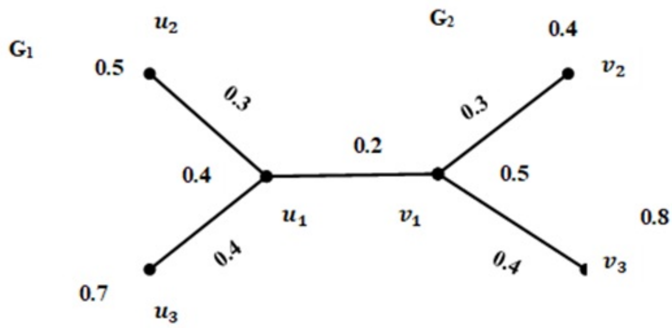
Example 4.3.

Case 1: Combining 2 fuzzy graphs with different sets of edges to form a direct sum.



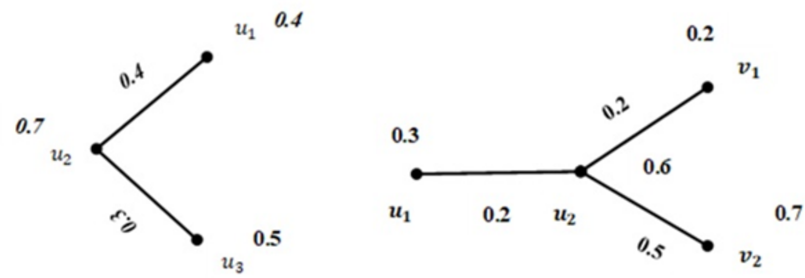
G^1_c Didluoro boryl (BF_2) G^2_c Bromin Trifluride (B_rF_3)

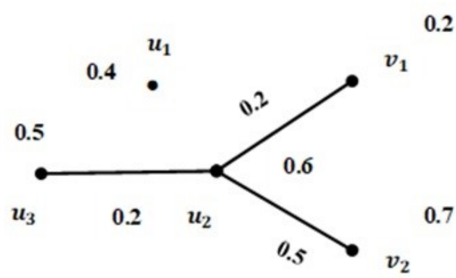




$G_1 \oplus G_2$

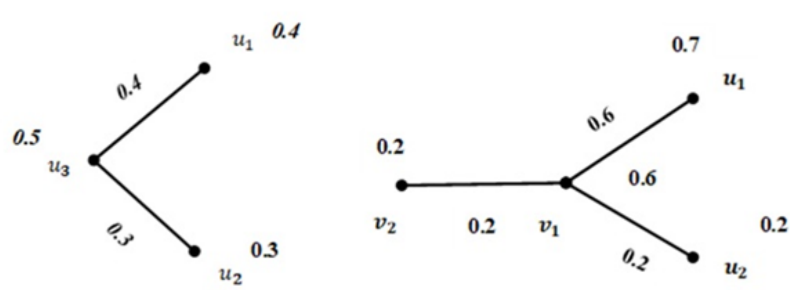
Case 2: $V_1 \cup V_2$ with non-disjoint edge sets.

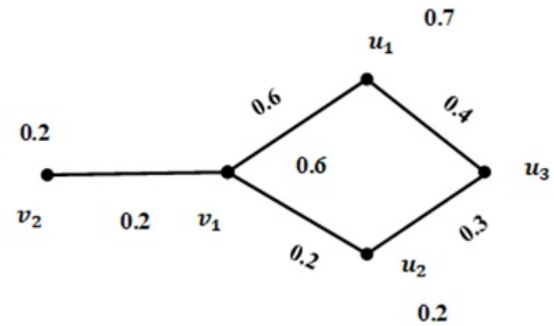




Definition 4.4. Two G_{NIFC} graphs are effective if $\mu(u, v) = \sigma(u) \wedge \sigma(v)$ for all $uv \in E$.

Note: If G^1_{NIFC} and G^2_{NIFC} be any two effective graphs, then their direct sum $G_1 \oplus G_2$ need not be an effective fuzzy graph.





Proposition 4.5. *The direct sum of two effective G_{NIFC} graph is effective if ['no edge of G_{ENIFC} has both ends in $V_1 \cap V_2$'] and that every edge of $\mu(uv)$ of G_{ENIFC} in which one end in $V_1 \cap V_2$ and $uv \in X_1$ (or X_2); such that $\sigma_1(u) \geq \sigma_1(v)$.*

Proposition 4.6. *If G^1_{NIFC} and G^2_{NIFC} are two effective graphs. Then $G^1 \oplus G^2$[may or may not be effective] is not neighbourly irregular fuzzy graph.*

Note:

(i) Direct sum of two effective neighbourly irregular fuzzy chemical graphs is not G_{NIFC} graphs.

(ii) Direct sum of two G^1_{NIFC}, G^2_{NIFC} graphs with non-disjointed edge sets can be a G_{NIFC} graphs.

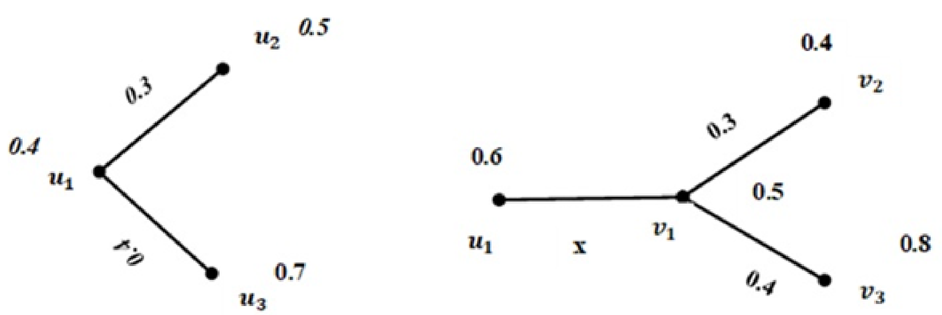
(iii) Direct sum of two effective G^1_{NIFC}, G^2_{NIFC} graphs also can't be neighbourly irregular.

(iv) A G_{NIFC} cannot be a regular so, G_{NIFC} is not totally regular fuzzy chemical graph as $'\mu(uv) = \{\sigma(u) \wedge \sigma(v) \,|u, v \in V\}'$.

Proposition 4.7. *Prove that, the degree of a vertex in $G^1_{NIFC} \oplus G^2_{NIFC}$, with respect to G^1_{NIFC} and G^2_{NIFC} is*

$$d_{GFC}(u) = \begin{cases} d^1_{GFC}(u); u \in V_1 \text{ not in } V_2 \\ d^2_{GFC}(u); u \in V_2 \text{ not in } V_1 \\ d^1_{GFC}(u) + d^2_{GFC}(u); u \in V_1 \cap V_2 \text{ and } X_1 \cap X_2 = \varphi \end{cases}$$

Example 4.8. Consider two G_{NIFC} graphs $G^1_{NIFC}(\sigma_1, \mu_1)$ and $G^2_{NIFC}(\sigma_2, \mu_2)$ of Di-fluro boryl (BF_2) and Bromin Trifluride (BrF_3) respectively with disjoint sets.



The deg of the vertices in the direct sum $G^1_{NIFC} \oplus G^2_{NIFC}$ are

$dG^1_{NIFC} \oplus G^2_{NIFC}(u_1) = 0.3 + 0.4 + 0.2 = 0.9$
$dG^1_{NIFC} \oplus G^2_{NIFC}(u_2) = 0.3$

$dG^1_{NIFC} \oplus G^2_{NIFC}\,(u_1) = 0.4$
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(v_1) = 0.3 + 0.4 = 0.7$
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(v_2) = 0.3$
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(v_3) = 0.4$

Now, finding the degree of the vertices of $G^1_{NIFC} \oplus G^2_{NIFC}$ with respect to the degrees of G^1_{NIFC} and G^2_{NIFC}.

In this case, clearly there is no edge in $E_1 \cap E_2$and $u_1 \in v_1 \cap v_2$, then
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(u_1) = dG^1_{NIFC}\,(u_1) + G^2_{NIFC}\,(u_1)$
i.e., $dG^1_{NIFC}\,(u_1) = 0.7$; $dG^2_{NIFC}\,(u_1) = 0.2$
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(u_1) = 0.7 + 0.2 = 0.9$
and the vertices $u_2, u_3 \in v_1 - v_2$
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(u_2) = dG^1_{NIFC}\,(u_2) = 0.3$
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(u_3) = dG^1_{NIFC}\,(u_3) = 0.4$

Similarly,
the vertices v_1, v_2 and $v_3 \in v_2 - v_1$ thus,
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(v_1) = dG^2_{NIFC}\,(v_1) = 0.7$
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(v_2) = dG^2_{NIFC}\,(v_2) = 0.3$
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(v_3) = dG^2_{NIFC}\,(v_3) = 0.4$

Example 4.9. Degree of G^1_{NIFC} and G^2_{NIFC} with edge sets are not disjoint.

Here also two G_{NIFC} graphs of BF_2 and BrF_3.
Here we have $\{u_1 u_2\} \in E_1 \cap E_2$
The $G^1_{NIFC} \oplus G^2_{NIFC}$ is this case is,
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(u_1) = 0.5$
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(u_2) = 0.5 + 0.4 + 0.9 = 1.1$
$dG^1_{NIFC} \oplus G^2_{NIFC}\,(u_4) = 0.4.$
Now, we find $dG^1_{NIFC} \oplus dG^2_{NIFC}$ with respect to the vertices of G^1_{NIFC} and G^2_{NIFC}.
Since $\{u_2 u_3\} \in E_1 \cap E_2$ are not in $G^1_{NIFC} \oplus G^2_{NIFC}$ and the vertex.

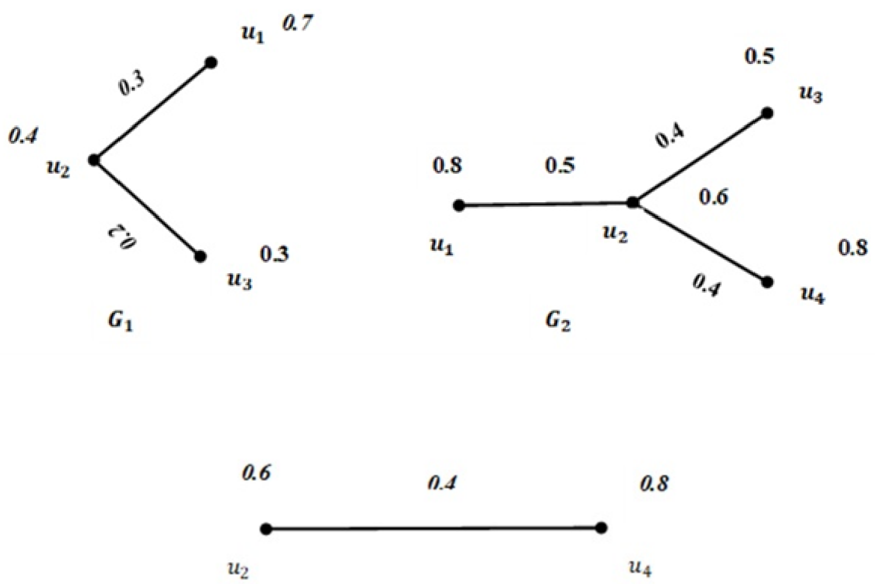


Figure 1.

$u_4 \in v_2 - v_1$ are the vertex
Hereby the previous case, $dG^1_{NIFC} \oplus G^2_{NIFC}\,(u_4) = dG^2_{NIFC}\,(u_4) = 0.4$

Since $\{u_1, u_2, u_3\} \in V_1 \cap V_2$

$$dG^1_{NIFC} \oplus G^2_{NIFC}(u_1) = dG^1_{NIFC}(u_1) + dG^2_{NIFC}(u_1)$$

$$- \sum [\mu_1(u_1, u_2) + \mu_2(u_1, u_2)]$$

$$= (0.3 + 0.5) - [(0.3 + 0.5)]$$

=0

similarly,

$$dG^1_{NIFC} \oplus G^2_{NIFC}(u_2) = dG^1_{NIFC}(u_2) + dG^2_{NIFC}(u_2)$$

$$- \sum [\mu_1(u_2, u_3) + \mu_2(u_2, u_3)]$$

$$= (0.5 + 1.3) - [0.2 + 0.4]$$

=1.8-0.6

=1.2

And

$$dG^1_{NIFC} \oplus G^2_{NIFC}(u_3) = dG^1_{NIFC}(u_3) + dG^2_{NIFC}(u_3)$$

$$- \sum [\mu_1(u_3, u_2) + \mu_2(u_3, u_2)]$$

$$= (0.2 + 0.4) - [(0.2 + 0.4)]$$

=0

5 Conclusion

In this paper, we have determined the Cartesian product of two Neighbourly irregular fuzzy chemical graphs and direct sum of two Neighbourly irregular fuzzy chemical graphs also found that their product and direct sum need not be a neighbourly irregular.

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