Product Intuitionistic Fuzzy Graph

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ABSTRACT
In this paper, we introduce product intuitionistic fuzzy graphs and prove several results which are analogous to intuitionistic fuzzy graphs. We conclude by giving properties for a product partial intuitionistic fuzzy sub graph.

Key words: Intuitionistic Fuzzy Graphs, Product Intuitionistic fuzzy graphs.

1. INTRODUCTION
The first definition of fuzzy graphs was proposed by Kafmann, from the fuzzy relations introduced by Zadeh. Although Rosenfeld [1] introduced another elaborated definition, including fuzzy vertex and fuzzy edges, and several fuzzy analogs of graph theoretic concepts such as paths, cycles, connectedness and etc. The first definition of intuitionistic fuzzy graphs was proposed by Atanassov[2]. Dr. V. Ramaswamy and Poornima .B introduce the concept of product fuzzy graph. In this paper we develop the concept of Product Intuitionistic fuzzy graphs of intuitionistic fuzzy graphs. Further investigate properties Product Intuitionistic fuzzy graphs.

2. DEFINITION AND MAIN RESULTS
Definition 2.1 An intuitionistic fuzzy graph (IFG) is of the form $G = (V,E)$, where $V = \{v_1,v_2,\ldots,v_n\}$ such that $\mu_1:V\to [0,1]$, $\gamma_1: V\to [0,1]$ denote the degree of membership and nonmember ship of the element $v_i\in V$ respectively and $0 \le \mu_1(v_i) + \gamma_1(v_i) \le 1$ for every $v_i \in V,(i =1,2,\ldots n)$ (ii) $E \subseteq V\times V$ where $\mu_2:V \times V \to [0,1]$ and $\gamma_2:V\times V \to [0,1]$ are such that $\mu_2(v_i,v_j) \le \mu_1(v_i) \wedge \mu_1(v_j)$, $\gamma_2(v_i,v_j) \le \gamma_1(v_i) \wedge \gamma_1(v_j)$ and $0 \le \mu_2(v_i,v_j) + \gamma_2(v_i,v_j) \le 1$.

Definition 2.2 Let G = (V, E) be an intuitionistic fuzzy graph. If $\mu_2(x, y) \le \mu_1(x) \times \mu_1(y)$ and $\gamma_2(x, y) \le \gamma_1(x) \times \gamma_1(y)$ the intuition fuzzy graph is called product partial intuitionistic fuzzy sub graph of G.

Remark: If G = (V,E) is a product intuitionistic fuzzy graph then since $\mu_1(x)$ and $\mu_1(y)$, are less than or equal to 1, it follows that $\mu_2(v_i, v_j) \le \mu_1(v_i) \times \mu_1(vj) \le \mu_1(v_i) \wedge\mu_1(v_j)$ and $\gamma_2(v_i, v_j) \le \gamma_1(v_i) \times \gamma_1(v_j) \le \gamma_1(v_i) \wedge \gamma_1(v_j)$ for all $x, y \in V$. Thus every product intuitionistic fuzzy graph is an intuitionistic fuzzy graph.

Definition 2.3 A product Intuitionistic fuzzy graph G = (V,E) is said to be complete if $\mu_2(x, y) = \mu_1(x) \times \mu_1(y)$ and $\gamma_2(x, y) = \gamma_1(x) \times \gamma_1(y)$ for all $x, y \in V$.

Proposition 2.1 Let G = (V, E) be a complete product intuitionistic fuzzy graph where μ_1 and γ_1 are normal. Then $\mu_2^n(x, y) = \mu_2(x, y)$ and $\gamma_2^n(x, y) = \gamma_2(x, y)$ for all $x, y \in V$ and for all positive integer n for $n \ge 2$

$$\mu_2^n(x, y) = \vee_{z\in V} \{\mu_2^{n-1} (x, y) \times \mu_2(x, y)\}$$
$$\gamma_2^n(x, y) = \vee_{z\in V} \{\gamma_2^{n-1} (x, y) \times \gamma_2(x, y)\}$$

Proof: We prove by method of induction .Let n =2 then for all $x, y \in V$, we have

$\mu_2^2(x, y) = \vee_{z\in V} \{\mu_2 (x, z) \times \mu_2(z, y)\}$
$\mu_2^2(x, y) = \vee_{z\in V} \{[\mu_1 (x) \times \mu_1(z)] \times [\mu_1 (z) \times \mu_1(y)]\}$
$\mu_2^2(x, y) = \vee_{z\in V} \{\mu_1 (x) \times \mu_1(y) \times \mu_1 (z)^2 \}$
Since $\mu_1 (z)^2 \le 1$ for all z [$\therefore \mu_1 (z) \le 1$]

$$\mu_2^2(x, y) = \vee_{z\in V} \{\mu_1 (x) \times \mu_1(y)\}$$
$$\mu_2^2(x, y) = \mu_2(x, y) \quad \to (1)$$

and $\gamma_2^2(x, y) = \vee_{z\in V} \{\gamma_2 (x, z) \times \gamma_2(z, y)\}$
$\gamma_2^2(x, y) = \vee_{z\in V} \{[\gamma_1 (x) \times \gamma_1(z)] \times [\gamma_1 (z) \times \gamma_1(y)]\}$
$\gamma_2^2(x, y) = \vee_{z\in V} \{\gamma_1 (x) \times \gamma_1(y) \times \gamma_1 (z)^2 \}$
since $\gamma_1 (z)^2 \le 1$ for all z [$\therefore \gamma_1 (z) \le 1$]

$$\gamma_2^2(x, y) = \vee_{z\in V} \{\gamma_1 (x) \times \gamma_1(y)\}$$
$$\gamma_2^2(x, y) = \gamma_2(x, y) \quad \to (2)$$

If μ_1 and γ_1 normal, then $\mu_1 (t) =1$ and $\gamma_1 (t) =1$ for some t. Then

$$\mu_2^2(x, y) = \vee_{z\in V} \{\mu_1 (x) \times \mu_1(y) \times \mu_1 (z)^2 \}$$
$$\ge \mu_1 (x) \times \mu_1(y) \times \mu_1 (t)^2$$
$$= \mu_1 (x) \times \mu_1(y) \qquad [\therefore \mu_1 (t)^2 = 1]$$
$$\mu_2^2(x, y) \ge \mu_1 (x) \times \mu_1(y)$$

$\mu_2(x, y) \ge \mu_2(x, y) \to (3)$ [since $\mu_2^2(x, y) = \mu_1 (x) \times \mu_1(y)$ G is complete]
from (1) and (3) we get $\mu_2(x, y) = \mu_2(x, y) \to (4)$
If γ_1 normal, $\gamma_1 (t) =1$ for some t. Then

$$\gamma_2^2(x, y) = \vee_{z\in V} \{\gamma_1 (x) \times \gamma_1(y) \times \gamma_1 (z)^2 \}$$
$$\ge \gamma_1 (x) \times \gamma_1(y) \times \gamma_1 (t)^2$$
$$= \gamma_1 (x) \times \gamma_1(y) \qquad [\therefore \mu_1 (t)^2 = 1]$$
$$\gamma_2^2(x, y) \ge \gamma_1 (x) \times \gamma_1(y)$$

$\gamma_2(x, y) \ge \gamma_2(x, y) \to (5)$ [since $\gamma_2^2(x, y) = \gamma_1 (x) \times \gamma_1(y)$,G is complete]
from (2) and (5) we get $\gamma_2(x, y) = \gamma_2(x, y) \to (6)$
Now assuming that $\mu_2^k(x, y) = \mu_2(x, y)$ and $\gamma_2^k(x, y) = \gamma_2(x, y)$ we will prove $\mu_2^{k+1}(x, y) = \mu_2(x, y)$ and $\gamma_2^{k+1}(x, y) = \gamma_2(x, y)$ we have
$\mu_2^{k+1}(x, y) = \vee_{z\in V} \{\mu_2^k (x, z) \times \mu_2(z, y)\}$
$\mu_2^2(x, y) = \vee_{z\in V} \{[\mu_2 (x, z) \times \mu_2(z, y)]\}= \mu_2^2(x, y)$
$\mu_2^{k+1}(x, y) = \mu_2(x, y)$ using (5)
Similarly we get $\gamma_2^{k+1}(x, y) = \gamma_2(x, y)$
Hence proved

Definition 2.4 The complement of product intuitionistic fuzzy graph G = (V,E) is $G^c = (V^c, E^c)$ where $V^c = (\mu^c_1, \gamma^c_1)$ and $E^c = (\mu^c_2, \gamma^c_2)$ here $\mu^c_1 = \gamma^c_1$, $\mu^c_1 = \gamma^c_1$ and
$\mu^c_2(x, y) = \mu_1(x) \times \mu_1(y) - \mu_2(x, y)$,
$\gamma^c_2(x, y) = \gamma_1(x) \times \gamma_1(y) - \gamma_2(x, y)$.
Remark: The complement of a G^c is G.

Definition2.5 Let $G_1 = (V_1, E_1)$ and $G_2 = (V_2, E_2)$ be a product intuitionistic fuzzy graph. Here $V_1 = (\mu_{11}, \gamma_{11})$, $E_1 = (\mu_{12}, \gamma_{12})$, $V_2 = (\mu_{21}, \gamma_{21})$ and $E_2 = (\mu_{22}, \gamma_{22})$. Let X' denotes the set of all arcs joining the vertices V_1 and V_2. We further assume that $V_1 \cap V_2 = \phi$. Then the join of G_1 and G_2 is defined as $(V_1 + V_2, E_1 + E_2)$ where $V_1 + V_2 = (\mu_{11} + \mu_{21}, \gamma_{11} + \gamma_{21})$ and $V_1 + V_2 = (\mu_{12} + \mu_{22}, \gamma_{12} + \gamma_{22})$ here
$(\mu_{11} + \mu_{21}) = \mu_{11}(u)$ if $u \in V_1$
$= \mu_{21}(u)$ if $u \in V_2$
$(\gamma_{11} + \gamma_{21}) = \gamma_{11}(u)$ if $u \in V_1$
$= \gamma_{21}(u)$ if $u \in V_2$
$(\mu_{12} + \mu_{22})(u, v) = \mu_{12}(u, v)$ if $(u, v) \in E_1$
$= \mu_{22}(u, v)$ if $(u, v) \in E_2$
$= \mu_{11}(u) \times \mu_{21}(v)$ if $(u, v) \in X'$
$(\gamma_{12} + \gamma_{22})(u, v) = \gamma_{12}(u, v)$ if $(u, v) \in E_1$
$= \gamma_{22}(u, v)$ if $(u, v) \in E_2$
$= \gamma_{11}(u) \times \gamma_{21}(v)$ if $(u, v) \in X'$.

Proposition 2.2 $G_1 + G_2$ is a product intuitionistic fuzzy sub graph of G = (V, E) where and $E = E_1 \cup E_2 \cup X'$

Proof: We have to prove that
$(\mu_{12} + \mu_{22})(u, v) \le (\mu_{11} + \mu_{21})(u) \times (\mu_{11} + \mu_{21})(v) \rightarrow$ (i)
for all $(u, v) \in V$
and $(\gamma_{12} + \gamma_{22})(u, v) \le (\gamma_{11} + \gamma_{21})(u) \times (\gamma_{11} + \gamma_{21})(v) \rightarrow$ (ii)
for all $(u, v) \in V$
Case 1: If $(u, v) \in X_1$, then $u, v \in V_1$ so that
$(\mu_{12} + \mu_{22})(u, v) = \mu_{12}(u, v) \rightarrow$ (iii)
And $(\mu_{11}+\mu_{21})(u) \times (\mu_{11}+\mu_{21})(v) = \mu_{11}(u) \times \mu_{11}(v) \rightarrow$ (iv)
from (iii) and (iv) we get (i)
$(\gamma_{12}+\gamma_{22})(u,v)=\gamma_{12}(u,v) \rightarrow$ (v)
and $(\gamma_{11}+\gamma_{21})(u)\times(\gamma_{11}+\gamma_{21})(v)=\gamma_{11}(u)\times\gamma_{11}(v) \rightarrow$ (vi)
from (v) and (vi) we get (ii)
Therefore we get $G_1 + G_2$ is a product intuitionistic fuzzy sub graph of G.
Similarly we can prove $(u, v) \in X_1$.
Case 2: If $(u, v) \in X'$ then $u \in V_1$ and $v \in V_2$. Now $(\mu_{12} + \mu_{22})(u, v) \le (\mu_{11}(u) \times \mu_{21}(v)$ whereas $(\mu_{11} + \mu_{21})(u) \times (\mu_{11} + \mu_{21})(v) = \mu_{11}(u) \times \mu_{21}(v)$ therefore we get $(\mu_{12}+\mu_{22})(u,v) = (\mu_{11} + \mu_{21})(u) \times (\mu_{11} + \mu_{21})(v) \rightarrow$ (vii)
Similarly we get
$(\gamma_{12} + \gamma_{22})(u,v) = (\gamma_{11}+\gamma_{21})(u) \times (\gamma_{11}+\gamma_{21})(v) \rightarrow$ (viii)
From (vii) and (viii) $G_1 + G_2$ is a product intuitionistic fuzzy sub graph of G.Hence proved.

Proposition 2.3 $G_1 + G_2$ is complete if and only if G_1 and G_2 are both complete.

Proof: First we are assuming that G_1 and G_2 are both complete. We will prove that $G_1 + G_2$ is complete.
Case 1: If $(u, v) \in X_1$ therefore $u, v \in V_1$ **.**we get
$(\mu_{12} + \mu_{22})(u, v) = \mu_{12}(u, v) = \mu_{11}(u) \times \mu_{11}(v)$ [since G_1 is complete]
$(\mu_{11} + \mu_{21})(u) \times (\mu_{11} + \mu_{21})(v) = \mu_{11}(u) \times \mu_{11}(v)$
and $(\gamma_{12} + \gamma_{22})(u, v) = \gamma_{12}(u, v) = \gamma_{11}(u) \times \gamma_{11}(v)$ [since G_1 is complete]
$(\gamma_{11} + \gamma_{21})(u) \times (\gamma_{11} + \gamma_{21})(v) = \gamma_{11}(u) \times \gamma_{11}(v)$
Therefore $G_1 + G_2$ is complete.
Similarly we argue $(u, v) \in X_2$ therefore $u, v \in V_2$.
Case 2: Suppose $(u, v) \in X'$. Then $u \in V_1$ and $v \in V_2$,
we get $(\mu_{12} + \mu_{22})(u, v) = \mu_{11}(u) \times \mu_{21}(v)$ whereas
$(\mu_{11} + \mu_{21})(u) \times (\mu_{11} + \mu_{21})(v) = \mu_{11}(u) \times \mu_{21}(v)$
Therefore, $(\mu_{12} + \mu_{22})(u, v) = (\mu_{11} + \mu_{21})(u) \times (\mu_{11}(u) \times \mu_{21})(v)$
And $(\gamma_{12} + \gamma_{22})(u, v) = \gamma_{11}(u) \times \gamma_{21}(v)$ whereas
$(\gamma_{11} + \gamma_{21})(u) \times (\gamma_{11} + \gamma_{21})(v) = \gamma_{11}(u) \times \gamma_{21}(v)$
Therefore, $(\gamma_{12} + \gamma_{22})(u, v) = (\gamma_{11} + \gamma_{21})(u) \times (\gamma_{11} + \gamma_{21})(v)$
Therefore $G_1 + G_2$ is complete.
Conversely assume that $G_1 + G_2$ is complete, we will prove G_1, G_2 are complete. First we
G_1 complete, we have prove that for al $(u, v) \in E_1$, $\mu_{12}(u, v) = \mu_{11}(u) \times \mu_{11}(v)$ and $\gamma_{12}(u, v) = \gamma_{11}(u) \times \gamma_{11}(v)$.
$G_1 + G_2$ is complete therefore
$(\mu_{12} + \mu_{22})(u, v) = \mu_{12}(u, v) \rightarrow$ (i) [since $(u, v) \in E_1$] and
$(\gamma_{12} + \gamma_{22})(u, v) = \gamma_{12}(u, v) \rightarrow$ (ii) [since $(u, v) \in E_2$]
whereas $(\mu_{11}+\mu_{21})(u) \times (\mu_{11}+\mu_{21})(v) = \mu_{11}(u) \times \mu_{11}(v) \rightarrow$ (iii) and
$(\gamma_{11} + \gamma_{21})(u) \times (\gamma_{11} + \gamma_{21})(v) = \gamma_{11}(u) \times \gamma_{11}(v) \rightarrow$ (iv)
We know that $(\mu_{12} + \mu_{22})(u, v) = (\mu_{11} + \mu_{21})(u) \times (\mu_{11} + \mu_{21})(v)$
$(\gamma_{12} + \gamma_{22})(u, v) = (\gamma_{11} + \gamma_{21})(u) \times (\gamma_{11} + \gamma_{21})(v)$
using (i), (ii), (iii),(iv) we get $\mu_{12}(u, v) = \mu_{11}(u) \times \mu_{11}(v)$ and $\gamma_{12}(u, v) = \gamma_{11}(u) \times \gamma_{11}(v)$. Therefore G_1 is complete. Similarly we prove G_2 is complete.
Hence proved.

Proposition 2.4 Let G_1 and G_2 be product partial intuitionistic fuzzy sub graph, then
$(\mu_{11} + \mu_{21}, \mu_{12} + \mu_{22})^c = (\mu_{11}^c \cup \mu_{21}^c, \mu_{12}^c \cup \mu_{22}^c)$
$(\gamma_{11} + \gamma_{21}, \gamma_{12} + \gamma_{22})^c = (\gamma_{11}^c \cup \gamma_{21}^c, \gamma_{12}^c \cup \gamma_{22}^c)$

Proof: If $u \in V_1$ then $(\mu_{11} + \mu_{21})^c = (\mu_{11} + \mu_{21})(u) = \mu_{11}(u)$ and max $(\mu_{11}^c(u), \mu_{21}^c(u) = \max(\mu_{11}(u), \mu_{21}(u)) = \mu_{11}(u)$
$\Rightarrow (\mu_{11} + \mu_{21})^c(u) = (\mu_{11}^c \cup \mu_{21}^c)(u)$.
Similarly $u \in V_2$.
Suppose $(u, v) \in X_1$, then $u, v \in V_1$ and
$(\mu_{12} + \mu_{22})^c(u, v) = (\mu_{11} + \mu_{21})(u) \times (\mu_{11} + \mu_{21})(v) - (\mu_{12} + \mu_{22})(u, v)$
$= \mu_{11}(u) \times \mu_{11}(v) - \mu_{12}(u, v)$
$= \mu_{12}^c(u, v)$
Max $(\mu_{12}^c(u, v), \mu_{21}^c(u, v)) = \mu_{12}^c(u, v)$
$\Rightarrow (\mu_{12} + \mu_{22})^c(u, v) = (\mu_{12}^c \cup \mu_{22}^c)$.
Similarly $(u, v) \in X_2$.
Suppose $(u, v) \in X'$. Then $u \in V_1$ and $v \in V_2$ therefore
$(\mu_{12} + \mu_{22})^c(u, v) = (\mu_{11} + \mu_{21})(u) \times (\mu_{11} + \mu_{21})(v) - (\mu_{12} + \mu_{22})(u, v)$
$= \mu_{11}(u) \times \mu_{21}(v) - (\mu_{11}(u) \times \mu_{21}(v)) = 0$
Max $(\mu_{12}^c, \mu_{22}^c) =$ Max $(\mu_{12}^c(u, v), \mu_{22}^c(u, v)) = 0$ [since $u \in V_1$ and $v \in V_2$]
This implies $(\mu_{11} + \mu_{21}, \mu_{12} + \mu_{22})^c = (\mu_{11}^c \cup \mu_{21}^c, \mu_{12}^c \cup \mu_{22}^c)$
$(\gamma_{11} + \gamma_{21}, \gamma_{12} + \gamma_{22})^c = (\gamma_{11}^c \cup \gamma_{21}^c, \gamma_{12}^c \cup \gamma_{22}^c)$
Hence proved.

Proposition 2.5 Let G_1 and G_2 be product partial intuitionistic fuzzy sub graph, then

$((\mu_{11} \cup \mu_{21})^c, (\mu_{12} \cup \mu_{22})^c) = (\mu_{11}^c + \mu_{21}^c, \mu_{12}^c + \mu_{22}^c)$
$((\gamma_{11} \cup \gamma_{21})^c, (\gamma_{12} \cup \gamma_{22})^c) = (\gamma_{11}^c + \gamma_{21}^c, \gamma_{12}^c + \gamma_{22}^c)$

Proof:
Case 1: If $u \in V_1$, then $(\mu_{11} \cup \mu_{21})^c (u) = (\mu_{11} \cup \mu_{21}) (u) = \mu_{11}(u)$ $(\mu_{11}^c + \mu_{21}^c)(u) = \max (\mu_{11}(u), \mu_{21} (u))^c = \max(\mu_{11}^c(u), \mu_{21}^c(v)) = \mu_{11}(u)$
This implies $((\mu_{11} \cup \mu_{21})^c = (\mu_{11}^c + \mu_{21}^c)$. similarly we can prove $u \in V_2$.
Case 2: If $(u, v) \in X_1$, then $u, v \in V_1$, therefore
$(\mu_{12} \cup \mu_{22})^c(u, v) = (\mu_{11} \cup \mu_{21})(u) \times (\mu_{11} \cup \mu_{21})(v) - (\mu_{12} \cup \mu_{22})(u, v)$
$= \mu_{11}(u) \times \mu_{11}(v) - \mu_{12}(u, v)$
$= \mu_{12}^c (u, v)$.
Case 3: If $(u, v) \in X_2$, then $u, v \in V_2$, therefore
$(\mu_{12} \cup \mu_{22})^c(u, v) = (\mu_{11} \cup \mu_{21})(u) \times (\mu_{11} \cup \mu_{21})(v) - (\mu_{12} \cup \mu_{22})(u, v)$
$= \mu_{21}(u) \times \mu_{21}(v) - \mu_{22}(u, v)$
$= \mu_{22}^c (u, v)$.
Case 4: If $(u, v) \in X'$, then $u \in V_1$ and $v \in V_2$, therefore
$(\mu_{12} \cup \mu_{22})^c(u, v) = (\mu_{11} \cup \mu_{21})(u) \times (\mu_{11} \cup \mu_{21})(v) - (\mu_{12} \cup \mu_{22})(u, v)$
$= \mu_{11}(u) \times \mu_{21}(v)$
[since $\mu_{12}(u, v) = \mu_{22}(u, v) = 0$]
$= \mu_{11}^c(u) \times \mu_{21}^c(v)$
$= \mu_{12}^c + \mu_{22}^c$
Hence proved.

Proposition 2.6 Let G_1 and G_2 be product partial intuitionistic fuzzy sub graph, then $G1 \times G_2$ be product partial intuitionistic fuzzy sub graph

Proof: $u_1, v_1 \in V_1$ and $u_2, v_2 \in V_2$, we have
$(\mu_{12} \times \mu_{22})((u1, u_2), (v_1, v_2)) = \mu_{12}(u_1, v_1) \times \mu_{22}(u_2, v_2)$
$\leq [\mu_{11}(u_1) \times \mu_{11}(v_1)] \times [\mu_{21}(u_2) \times \mu_{21} (v_2)]$
$= [\mu_{11}(u_1) \times \mu_{21}(u_2)] \times [\mu_{11}(v_1) \times \mu_{21} (v_2)]$
$= (\mu_{11} \times \mu_{21}) (u_1,u_2) \times (\mu_{11} \times \mu_{21})(v_1, v_2)$
Therefore $(\mu_{12} \times \mu_{22})((u1, u_2), (v_1, v_2)) \leq (\mu_{11} \times \mu_{21}) (u_1,u_2) \times (\mu_{11} \times \mu_{21})(v_1, v_2)$
similarly we prove
$(\gamma_{12} \times \gamma_{22})((u_1,u_2), (v_1,v_2)) \leq (\gamma_{11} \times \gamma_{21}) (u_1,u_2) \times \gamma_{11} \times \gamma_{21})(v_1, v_2)$
Hence proved.

3. CONCLUSION

We are able to find the different types of intuitionistic fuzzy graph and its properties. Further we are try to find the engineering applications of the different types of intuitionist fuzzy graph.

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