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Operations on Complex Intuitionistic Fuzzy Graph

L. Mahalakshmi[1], K. Abinaya[2]
Assistant Professor[1], PG Student[2], PG and Research Department of Mathematics, Cauvery college for Women (Autonomous), Trichy-18

Abstract: This study introduces the complex intuitionistic fuzzy graphs and analyzes certain fundamental theorem and applications. Further, new ideas in CIFG such as complete complex intuitionistic fuzzy graphs with example. Also, we defined operations on the Direct product, Semi strong product and Strong product of CIFG. Additionally, we presented the density of CIFG and balanced complex intuitionistic fuzzy graph.
Keywords: Complete complex intuitionistic fuzzy graph, Direct product of CIFG, Strong product of CIFG, Semi strong product of CIFG, Density and Balanced complex intuitionistic fuzzy graph.

I. INTRODUCTION

In 1965,Zadeh[21,22,23]introduced fuzzy set theory, is the best explanation for interacting with sources of uncertainty. Kalaiarasi and Mahalakshmi [3,4,7]introduced the new concept of fuzzy soft graph, complement of fuzzy soft graph and some application of μ-complement fuzzy soft graph and fuzzy strong graph, complement of fuzzy strong graph. They were additionally proposed a fuzzy coloring and coloring of regular fuzzy graph and also introduced strong arcs of coloring fuzzy graph. They were extended the concept of regular and irregular m-polar fuzzy graph.

In 1983, Atanassov [1], introduced the concept of intuitionistic fuzzy sets as a generalisation of fuzzy set. Atanassov added new components that determine the degree of non-membership, while intuitionistic fuzzy sets give both the degree of membership and degree of non-membership, which are more or less independent from each other. Intuitionistic fuzzy sets have been applied in a wide variety of field including Computer science, Engineering, Mathematics, Medicine, Chemistry and Economics. Nagoor Gani and Shajitha Begum [10] established the properties of various types of the degree, order and size of intuitionistic fuzzy graph, New definition for complete intuitionistic fuzzy graph and intuitionistic regular fuzzy graph.

Hossein et al [2] showed the rationality of some operation are defined on intuitionistic fuzzy graph are Direct product, Lexicographic product, Strong product. Yongsheng Rao et al [20] derived types of arcs in an intuitionistic fuzzy graph and intuitionistic fuzzy tree. Also studies the intuitionistic fuzzy bridge, intuitionistic fuzzy cutnode, intuitionistic fuzzy cycle, intuitionistic fuzzy tree.

Kalaiarasi and Divya [5,6] introduced interval valued intuitionistic fuzzy graph and the conception of strong interval valued intuitionistic fuzzy graph and also introduce intuitionistic trapezoidal neutrosophic fuzzy graph and its application to find the shortest path on chola period builded temples. Akram and Akmal [8], defined new operation on intuitionistic fuzzy graph structure. Some operation including union, join, cartesian product cross product, composition on intuitionistic fuzzy graph structure and some properties are defined.

Talal AL-Hawary and Bayan Hourani [17], introduced the Product Intuitionistic fuzzy graph and operation on product intuitionistic fuzzy graph. Parvathi, Karunambigai et al [11,12,15] extended into different types of product on intuitionistic fuzzy graph and they introduced complement of an intuitionistic fuzzy graph and some properties of self complementary intuitionistic fuzzy graph. A brand new development in the field of fuzzy system in the complex fuzzy set (CFS) defined by Ramot et al [13,14].Two dimensional membership function defined in complex fuzzy set.

Veeramani and Suresh [19] introduced the operations, Balanced, Path, length of the path, strongest and weakest path of complex fuzzy graph. Talal AL-Hawary and Laith Almomani [16,18] developed the concept of $*$-density of a fuzzy graph, $*$-balanced fuzzy graph and some example are discussed.

Naveed Yaqoob et al [9] introduced certain notion including union, join and composition of complex intuitionistic fuzzy graph and their application in cellular network provider companies.

This paper consists of three major sections, Section 1 covers the Introduction. Section 2 has Preliminaries whereas Section 3 defines an Operations on Complex intuitionistic fuzzy graph. Finally, Section 4 discusses the conclusion.

II. PRELIMINARIES

A. Definition 2.1

A Fuzzy graph (FG) is an ordered triple $G=(V,\rho,\chi)$ where V is the set of vertices $\{u_1,u_2,...,u_n\}$ and ρ is a fuzzy subset of V that is $\rho:V\to[0,1]$ and is denoted by $\rho=\{(u_1,\rho(u_1)),(u_2,\rho(u_2)),........,(u_n,\rho(u_n))\}$ and χ is a fuzzy relation on ρ.That is $\chi(u,v)\le\rho(u),\rho(v)$.

B. Definition 2.2

An Intuitionistic fuzzy graph (IFG) is of the form $G=(V,E)$ where

i) $V=\{v_0,v_1,....,v_n\}$ so that $\rho_1:V\to[0,1]$ and $\rho_2:V\to[0,1]$ denote the degree of membership and non-membership of the element $v_i\in V$,respectively, and $0\le\rho_1(v_i)+\rho_2(v_i)\le 1$,for $v_i\in V$, $(i=1,2,......,n)$.

ii) $E\subseteq V\times V$ where $\chi_1:V\times V\to[0,1]$ and $\chi_2:V\times V\to[0,1]$ so that

a) $\chi_1(v_i,v_j)\le\min(\rho_1(v_i),\rho_1(v_j))$ b) $\chi_2(v_i,v_j)\le\max(\rho_2(v_i),\rho_2(v_j))$ for every $(v_i,v_j)\in E$.

C. Definition 2.3

Let $G_1=(V_1,E_1)$ and $G_2=(V_2,E_2)$ be two graphs. The Direct product of G_1 and G_2 is a graph $G_1\Pi G_2=(V,E)$ with $V=V_1\times V_2$ and $E=\{((u_1,v_1),(u_2,v_2))\,|\,(u_1,u_2)\in E_1,(v_1,v_2)\in E_2\}$ if,

i) $(\rho_1\Pi\rho_2)(u_1,v_1)=\min(\rho_1(u_1),\rho_2(v_1))$ ii) $(\chi_1\Pi\chi_2)(u_1v_1,u_2v_2)=\min(\chi_1(u_1u_2),\chi_2(v_1v_2))$

D. Definition 2.4

Let $G_1=(V_1,E_1)$ and $G_2=(V_2,E_2)$ be two graphs. The Semi strong product of G_1 and G_2 is a graph $G_1*G_2=(V,E)$ with $V=V_1\times V_2$ and $E=\{((u_1,v_1),(u_2,v_2))\,|\,(u_1,u_2)\in E_1,(v_1,v_2)\in E_2\}$ if,

i) $(\rho_1*\rho_2)(u_1,v_1)=\min(\rho_1(u_1),\rho_2(v_1))$ ii) $(\chi_1*\chi_2)(u_1v_1,u_2v_2)=\min(\chi_1(u_1u_2),\chi_2(v_1v_2))$

E. Definition 2.5

Let $G_1=(V_1,E_1)$ and $G_2=(V_2,E_2)$ be two graphs. The Strong product of G_1 and G_2 is a graph $G_1\otimes G_2=(V,E)$ with $V=V_1\times V_2$ and $E=\{((u_1,v_1),(u_2,v_2))\,|\,(u_1,u_2)\in E_1,(v_1,v_2)\in E_2\}$ if

i) $(\rho_1\otimes\rho_2)(u_1,v_1)=\min(\rho_1(u_1),\rho_2(v_1))$ ii) $(\chi_1\otimes\chi_2)(u_1v_1,u_2v_2)=\min(\chi_1(u_1u_2),\chi_2(v_1v_2))$

III. OPERATIONS ON COMPLEX INTUITIONISTIC FUZZY GRAPH

A. Definition 3.1

A Complex intutionistic fuzzy graph is the form $G=(V,\rho,E,\chi)$, where $V=(u,v,u_1,v_1)$ such that $\rho_1:V\to[0,1]$ and $\rho_2:V\to[0,1]$,denotes the degree of membership and non-membership of the element $u,v\in V$, respectively and $E\subseteq V\times V$ where $\chi_1:V\times V\to[0,1]$ and $\chi_2:V\times V\to[0,1]$ are such that

i) $0\le\rho_1(u)+\rho_2(v)\le 1,\ \forall u,v\in V$ ii) $\chi_1(u,u_1)\le\min(\rho_1(u),\rho_1(u_1))$ iii) $\chi_2(v,v_1)\le\max(\rho_2(v),\rho_2(v_1))$, $\forall u,u_1,v,v_1\in V$

Example 3.1

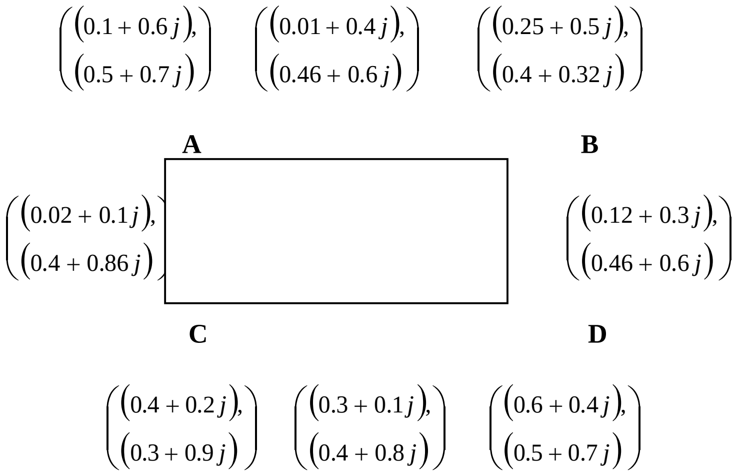

Fig.3.1.Complex intuitionistic fuzzy graph

i) $0 \le \rho_1(a) + \rho_2(a) \le 1 \quad \forall a \in V$

$0 \le (0.1 + 0.6j) + (0.5 + 0.7j) \le 1$

$0 \le (0.6 + 1.3j) \le 1$

ii) $\chi_1(a,b) \le \min(\rho_1(a), \rho_1(b)) \quad \forall a,b \in V$

$\le \min((0.1 + 0.6j), (0.25 + 0.5j))$

$\le (0.1 + 0.5j)$

$\chi_1(a,b) = (0.01 + 0.4j)$

iii) $\chi_2(a,b) \le \max(\rho_2(a), \rho_2(b)) \quad \forall a,b \in V$

$\le \max((0.5 + 0.7j), (0.4 + 0.32j))$

$\le (0.5 + 0.7j)$

$\chi_2(a,b) = (0.46 + 0.6j)$

B. *Definition 3.2*

A Complex intutionistic fuzzy graph is the form $G = (V, \rho, E, \chi)$, where $V = (a, b, a_1, b_1)$ such that $\rho_1 : V \to [0,1]$ and $\rho_2 : V \to [0,1]$,denotes the degree of membership and non-membership of the element $a, b, a_1, b_1 \in V$, respectively and $E \subseteq V \times V$

where $\chi_1 : V \times V \to [0,1]$ and $\chi_2 : V \times V \to [0,1]$ are said to be Complete if

i) $|\chi_1(a,b)| = \min(|\rho_1(a)|, |\rho_1(b)|) \quad \forall a,b \in V$ ii) $|\chi_2(a,b)| = \max(|\rho_2(a)|, |\rho_2(b)|) \quad \forall a,b \in V$

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Example 3.2

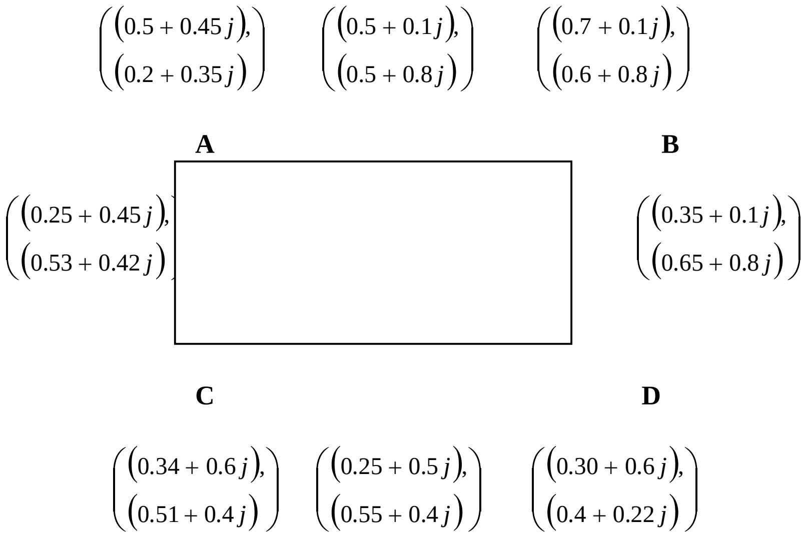

Fig.3.2.Complete Complex intuitionistic fuzzy graph

C. Definition 3.3

The direct product of two complex intuitionistic fuzzy graph of the form $G_1 = (V_1, E_1)$ and $G_2 = (V_2, E_2)$ is the crisp graph of the $G_1 : (\rho_1, \chi_1)$ and $G_2 : (\rho_2, \chi_2)$ is defined to be complex intuitionistic fuzzy graph $G_1 \Pi G_2 : (\rho_1 \Pi \rho_2, \chi_1 \Pi \chi_2)$ here ρ', χ' are denote the degree of membership function and ρ'', χ'' are denote the degree of non membership function if,

i) $(\rho_1' \Pi \rho_2')(u_1, v_1) = \min(|\rho_1'(u_1)|, |\rho_2'(v_1)|)$ ii) $(\rho_1'' \Pi \rho_2'')(u_1, v_1) = \max(|\rho_1''(u_1)|, |\rho_2''(v_1)|)$

iii) $(\chi_1' \Pi \chi_2')(u_1v_1, u_2v_2) = \min(|\chi_1'(u_1u_2)|, |\chi_2'(v_1v_2)|)$ iv) $(\chi_1'' \Pi \chi_2'')(u_1v_1, u_2v_2) = \max(|\chi_1''(u_1u_2)|, |\chi_2''(v_1v_2)|)$

D. Definition 3.4

The semi strong product of two complex intuitionistic fuzzy graph of the form $G_1 = (V_1, E_1)$ and $G_2 = (V_2, E_2)$ is the crisp graph of the $G_1 : (\rho_1, \chi_1)$ and $G_2 : (\rho_2, \chi_2)$ is defined to be complex intuitionistic fuzzy graph $G_1 * G_2 : (\rho_1 * \rho_2, \chi_1 * \chi_2)$ here ρ', χ' are denote the degree of membership function and ρ'', χ'' are denote the degree of non membership function if,

i) $(\rho_1' * \rho_2')(u_1, v_1) = \min(|\rho_1'(u_1)|, |\rho_2'(v_1)|)$ ii) $(\rho_1'' * \rho_2'')(u_1, v_1) = \max(|\rho_1''(u_1)|, |\rho_2''(v_1)|)$

iii) $(\chi_1' * \chi_2')((u_1, v_1), (u_2, v_2)) = \min(|\chi_1'(u_1u_2)|, |\chi_2'(v_1v_2)|)$

iv) $(\chi_1'' * \chi_2'')((u_1, v_1), (u_2, v_2)) = \max(|\chi_1''(u_1u_2)|, |\chi_2''(v_1v_2)|)$

E. Definition 3.5

The strong product of two complex intuitionistic fuzzy graph of the form $G_1 = (V_1, E_1)$ and $G_2 = (V_2, E_2)$ is the crisp graph of the $G_1 : (\rho_1, \chi_1)$ and $G_2 : (\rho_2, \chi_2)$ is defined to be complex intuitionistic fuzzy graph $G_1 \otimes G_2 : (\rho_1 \otimes \rho_2, \chi_1 \otimes \chi_2)$ here ρ', χ' are denote the degree of membership function and ρ'', χ'' are denote the degree of non membership function if,

i) $\left(\rho_1' \otimes \rho_2'\right)(u_1, v_1) = \min\left(\left|\rho_1'(u_1)\right|, \left|\rho_2'(v_1)\right|\right)$

ii) $\left(\rho_1'' \otimes \rho_2''\right)(u_1, v_1) = \max\left(\left|\rho_1''(u_1)\right|, \left|\rho_2''(v_1)\right|\right)$

iii) $\left(\chi_1' \otimes \chi_2'\right)\left((u_1, v_1), (u_2, v_2)\right) = \min\left(\left|\chi_1'(u_1 u_2)\right|, \left|\chi_2'(v_1 v_2)\right|\right)$

iv) $\left(\chi_1'' \otimes \chi_2''\right)\left((u_1, v_1), (u_2, v_2)\right) = \max\left(\left|\chi_1''(u_1 u_2)\right|, \left|\chi_2''(v_1 v_2)\right|\right)$

F. Definition 3.6

The Density of a complex intuitionistic fuzzy graph is $G:(V,E)$ is defined by,

i) $D_{\chi_1'}(G) = 2\left(\dfrac{\sum_{u_1,v_1\in V}\left|\chi_1'(u_1,v_1)\right|}{\sum_{u_1,v_1\in V}\min\left(\left|\rho_1'(u_1)\right|, \left|\rho_1'(v_1)\right|\right)}\right)$ ii) $D_{\chi_1''}(G) = 2\left(\dfrac{\sum_{u_1,v_1\in V}\left|\chi_1''(u_1,v_1)\right|}{\sum_{u_1,v_1\in V}\max\left(\left|\rho_1''(u_1)\right|, \left|\rho_1''(v_1)\right|\right)}\right)$

G is balanced if $D(H) \le D(G)$ for all complex intuitionistic fuzzy non empty subgraph H of G.

G. Theorem 3.3

Direct product of two complete complex intuitionistic fuzzy graph is also a complete complex intuitionistic fuzzy graph.

Proof:

Let $G_1 = (V_1, E_1)$ be the crisp graph $G_1 : (\rho_1, \chi_1)$ and $G_2 = (V_2, E_2)$ be the crisp graph $G_2 : (\rho_2, \chi_2)$ of two complete complex intuitionistic fuzzy graph then,

$$\begin{aligned}
\left(\chi_1' \Pi \chi_2'\right)(u_1 v_1, u_2 v_2) &= \min\left(\left|\chi_1'(u_1 u_2)\right|, \left|\chi_2'(v_1 v_2)\right|\right)\\
&= \min\left(\left|\rho_1'(u_1)\right|, \left|\rho_1'(u_2)\right|, \left|\rho_2'(v_1)\right|, \left|\rho_2'(v_2)\right|\right)\\
&= \min\left(\left|\rho_1'(u_1)\right|, \left|\rho_2'(v_1)\right|, \left|\rho_1'(u_2)\right|, \left|\rho_2'(v_2)\right|\right)\\
&= \min\left(\left|\rho_1'(u_1)\right|, \left|\rho_2'(v_1)\right|\right)\min\left(\left|\rho_1'(u_2)\right|, \left|\rho_2'(v_2)\right|\right)\\
&= \min\left(\rho_1' \Pi \rho_2'\right)(u_1, v_1)\min\left(\rho_1' \Pi \rho_2'\right)(u_2, v_2)
\end{aligned}$$

$$\left(\chi_1' \Pi \chi_2'\right)(u_1 v_1, u_2 v_2) = \min\left(\rho_1' \Pi \rho_2'\right)(u_1, v_1)\min\left(\rho_1' \Pi \rho_2'\right)(u_2, v_2)$$

$$\left(\chi_1'' \Pi \chi_2''\right)(u_1 v_1, u_2 v_2) = \max\left(\left|\chi_1''(u_1 u_2)\right|, \left|\chi_2''(v_1 v_2)\right|\right)$$

$$\left(\chi_1'' \Pi \chi_2''\right)(u_1 v_1, u_2 v_2) = \max\left(\rho_1'' \Pi \rho_2''\right)(u_1, v_1)\max\left(\rho_1'' \Pi \rho_2''\right)(u_2, v_2)$$

$\therefore$ Hence, $G_1 \Pi G_2$ is a complete complex intuitionistic fuzzy graph.

H. Theorem 3.4

Semi strong product of two complete complex intuitionistic fuzzy graph is also a complete complex intuitionistic fuzzy graph

I. Theorem 3.5

Strong product of two complete complex intuitionistic fuzzy graph is also a complete complex intuitionistic fuzzy graph

J. Theorem 3.6

Any complete complex intuitionistic fuzzy graph is balanced.

Proof:

Let G be a complete complex intuitionistic fuzzy graph, then

$$D_{\chi_1'}(G) = 2\left(\frac{\Sigma_{u_1,v_1 \in V}\left|\chi_1'(u_1,v_1)\right|}{\Sigma_{u_1,v_1 \in V}\min\left(\left|\rho_1'(u_1)\right|,\left|\rho_1'(v_1)\right|\right)}\right)$$

$$D_{\chi_1'}(G) = 2\left(\frac{\Sigma_{u_1,v_1 \in V}\left|\chi_1'(u_1,v_1)\right|}{\Sigma_{u_1,v_1 \in V}\left|\chi_1'(u_1,v_1)\right|}\right)$$

Since G is complete complex intuitionistic fuzzy graph.

$$D_{\chi_1'}(G) = 2$$

If H is a non empty complex intuitionistic fuzzy subgraph of G, then

$$D_{\chi_1'}(H) = 2\left(\frac{\Sigma_{u_1,v_1 \in V(H)}\left|\chi_1'(u_1,v_1)\right|}{\Sigma_{u_1,v_1 \in V(H)}\min\left(\left|\rho_1'(u_1)\right|,\left|\rho_1'(v_1)\right|\right)}\right)$$

$$D_{\chi_1'}(H) = 2\left(\frac{\Sigma_{u_1,v_1 \in V(H)}\left|\chi_1'(u_1,v_1)\right|}{\Sigma_{u_1,v_1 \in V(H)}\left|\chi_1'(u_1,v_1)\right|}\right)$$

$$D_{\chi_1'}(H) = 2$$

$$\therefore D_{\chi_1'}(H) = D_{\chi_1'}(G)$$

Similarly,

$$\therefore D_{\chi_1''}(H) = D_{\chi_1''}(G)$$

∴ Thus, G is balanced.

IV. CONCLUSION

In this paper, we present the complex intuitionistic fuzzy graph. Also we define the complete complex intuitionistic fuzzy graph with example. It is useful to understand the condition of complex intuitionistic fuzzy graph. we used different types of products like Direct product, Semi strong product and Strong product. Here the density and balanced of complex intuitionistic fuzzy graph are discussed in this paper. The complex intuitionistic fuzzy graph is useful for real life applications. We are committed to managing other maintainable improvement objectives for a better world.

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