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AN ELEMENTARY INTRODUCTION TO INTUITIONISTIC FUZZY SOFT GRAPH

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Abstract: Many fields deal with uncertain data. Classical mathematical tools are unable to solve uncertain data in many situations. There are several theories viz. theory of probability, theory of evidence, fuzzy set, intuitionistic fuzzy set, vague set for dealing uncertainties but they have their own difficulties. The reason for difficulties is inadequacy of parameterization tools of the theories. The concept of fuzzy soft set theory is one of the recent topics developed for dealing the uncertainties. The parameterization tools of soft set theory enhances the flexibility of its application. In this paper we introduce the concept of intuitionistic fuzzy soft graph, strong intuitionistic fuzzy soft graph, union and intersection of intuitionistic fuzzy soft graph.

Keywords: intuitionistic fuzzy soft graph; strong intuitionistic fuzzy soft graph; union and intersection of intuitionistic fuzzy soft graph.

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I. INTRODUCTION

The concept of fuzzy soft set theory was developed to deal with uncertainties in real life situation. A number of real life problems in engineering, medical sciences etc., involves imprecise data and their solution involves the application of principles based on uncertainty and imprecision. Such uncertainties can be dealt with fuzzy set theory developed by Zadeh[29] and soft set theory introduced by Molodstov[16]. The operations of soft sets was developed by Maji et al[14]. The theoretical study of soft sets has been studied in detail by Ali et al[2], Cagman & Enginoglu [6][7], Cagman et al [8][9], Herawan & Deris[11], Kovkov et al[12], Maji et al[13][15], Molodtsov [17][18], Molodtsov et al [19], Pei & Miao [22], Yang [28], Xiao et al [25][26], Xu et al [27].

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Rosenfield[24] introduced the concept of fuzzy graph. The notion of intuitionistic fuzzy set as a generalization of fuzzy set was introduced by Atanassov[3] which had a wider application in many fields. Later the concept of intuitionistic fuzzy graph was persuaded by Atanassov[4]. Akram et al[20] has introduced the concept of strong intuitionistic fuzzy graph, intuitionistic fuzzy hypergraph and intuitionistic fuzzy trees. Thambakara and George[23] discussed the notion of soft graph. Akram et al[21] extended their work in the field of fuzzy soft graph. Samanta et al[5] has also introduced fuzzy soft graph and their operations using the notion of fuzzy soft set in fuzzy graph. In this paper, we introduce the basic notion of intuitionistic fuzzy soft graph and their certain operations.

II. PRELIMINARIES

Definition 2.1[1]: Let U be an initial universe set and E be the set of parameters. Let $P(U)$ denotes the power set of U. A pair (F, E) is called a soft set over U where F is a mapping given by $F : E \rightarrow P(U)$.

Definition 2.2 [15]: Let U be an initial universe set and E be the set of parameters. Let $A \subset E$. A pair (F, A) is called fuzzy soft set over U where F is a mapping given by $F : A \rightarrow I^U$, where I^U denotes the collection of all fuzzy subsets of U.

Definition 2.3 [10]: Let U be an initial universe set and E be the set of parameters. Let IF^U denotes the collection of all intuitionistic fuzzy subsets of U. Let $A \subset E$. A pair (F, A) is called intuitionistic fuzzy soft set over U, where F is a mapping given by $F : A \rightarrow IF^U$.

Definition 2.4 [10]: Intersection of two intuitionistic fuzzy soft sets (F, A) and (G, B) over a common universe U is the intuitionistic fuzzy soft set (H, C) where $C = A \cap B$ and $\forall e \in C$, $H(e) = F(e) \cap G(e)$. We write$(F, A) \tilde{\cap} (G, B) = (H, C)$.

Definition 2.5 [10]: Union of two intuitionistic fuzzy soft sets (F, A) and (G, B) over a common universe U is the intuitionistic fuzzy soft set (H, C) where $C = A \cup B$ and $\forall e \in C$,

$$H(e) = F(e), \text{ if } e \in A - B$$
$$= G(e), \text{ if } e \in B - A$$
$$= F(e) \cup G(e), \text{ if } e \in A \cap B$$

We write $(F, A) \tilde{\cup} (G, B) = (H, C)$.

Definition 2.6 [10]: For two intuitionistic fuzzy soft sets (F, A) and (G, B) over a common universe U, we say that (F, A) is an intuitionistic fuzzy soft subset of (G, B) if

(i) $A \subset B$ and

(ii) $\forall e \in A, F(e)$ is an intuitionistic fuzzy subset of $G(e)$.

We write $(F, A) \tilde{\subseteq} (G, B)$.

Definition 2.7 [24]: A fuzzy graph $G = (\sigma, \mu)$ is a pair of functions $\sigma : V \rightarrow [0,1]$ and $\mu : V \, x \, V \rightarrow [0,1]$, where for all $u, v \in V$, we have $\mu(u, v) \leq \sigma(u) \wedge \sigma(v)$.

Definition 2.8 [4]: An Intuitionistic fuzzy graph is of the form $G = < V, E >$ where

(i) $V = \{v1, v2, \ldots, vn\}$ such that $\mu_1 : V \rightarrow [0,1]$and $\gamma_1 : V \rightarrow [0,1]$ denote the degree of membership and non-membership of the element $v_i \in V$, respectively, and $0 \leq \mu_1(vi) + \gamma_1(vi) \leq 1$ for every $vi \in V, (i = 1,2, \ldots \ldots . n)$,

(ii) $E \subseteq V \, x \, V$ where $\mu_2 : VxV \rightarrow [0,1]$ and $\gamma_2 : VxV \rightarrow [0,1]$ are such that

$$\mu_2(vi, vj) \leq min\,[\mu_1(vi), \mu_1(vj)] \; and \; \gamma_2(vi, vj) \leq max\,[\gamma_1(vi), \gamma_1(vj)]$$

and $0 \leq \mu_2(vi, vj) + \gamma_2(vi, vj) \leq 1$ for every $(vi, vj) \in E, (i, j = 1,2, \ldots \ldots . n)$

Definition 2.9 [20]: An intuitionistic fuzzy graph $G = (A, B)$ is called strong intuitionistic fuzzy graph if

$\mu_B(x, y) = min\big((\mu_A(x), (\mu_A(y))\big)$ and $\gamma_B(x, y) = min\big((\gamma_A(x), (\gamma_A(y))\big) \forall xy \in B$.

Definition 2.10 [21]: The order of a fuzzy soft graph is

$$Ord(\tilde{G}) = \sum_{e_i \in A} \left(\sum_{a \in V} \tilde{F}(e_i)(a) \right)$$

Definition 2.11 [21]: The size of a fuzzy soft graph is

$$Siz(\tilde{G}) = \sum_{e_i \in A} \left(\sum_{ab \in E} \tilde{K}(e_i)(ab) \right)$$

Definition 2.12 [21]: A fuzzy soft graph $\tilde{G}$ is a strong fuzzy soft graph if $\widetilde{H}(e)$ is a strong fuzzy soft graph for all $e \in A$. That is,

$$\widetilde{K}(e)(ab) = min\{\tilde{F}(e)(a), \tilde{F}(e)(b)\}\ \forall ab \in E$$

Definition 2.13 [21]: A fuzzy soft graph $\tilde{G}$ is a complete fuzzy soft graph if $\widetilde{H}(e)$ is a complete fuzzy soft graph for all $e \in A$. That is,

$$\widetilde{K}(e)(ab) = min\{\tilde{F}(e)(a), \tilde{F}(e)(b)\}\ \forall a, b \in V$$

III. MAIN RESULTS

Definition 3.1: An intuitionistic fuzzy soft graph $\tilde{G} = \left(G^*, \tilde{F}_{\mu,\gamma}, \widetilde{K}_{\rho,\tau}, A\right)$ is such that

(i) $G^* = (V, E)$ is a simple graph

(ii) A is a nonempty set of parameters

(iii) $\left(\tilde{F}_{\mu,\gamma}, A\right)$ is a intuitionistic fuzzy soft set over V

(iv) $\left(\widetilde{K}_{\rho,\tau}, A\right)$ is a intuitionistic fuzzy soft set over E

(v) $\left(\tilde{F}_{\mu,\gamma}, \widetilde{K}_{\rho,\tau}\right)$ is a intuitionistic fuzzy (sub)graph of G^* for all $a \in A$. That is

$\widetilde{K}_\rho(a)(xy) \leq min\left\{\tilde{F}_\mu(a)(x), \tilde{F}_\mu(a)(y)\right\}$ and

$\widetilde{K}_\tau(a)(xy) \leq max\left\{\tilde{F}_\gamma(a)(x), \tilde{F}_\gamma(a)(y)\right\} \forall a \in A\ ;\ x, y \in V$

The intuitionistic fuzzy soft graph $\left(\tilde{F}_{\mu,\gamma}(a), \widetilde{K}_{\rho,\tau}(a)\right)$ is denoted by $\widetilde{H}_{\beta,\delta}(a)$.

Example 3.1:

Consider a simple graph $G^* = (V, E) \ni V = \{a_1, a_2, a_3\}$ and $E = \{a_1a_2, a_2a_3, a_1a_3\}$

Let $A = \{e_1, e_2, e_3\}$ be a parameter set and $\left(\tilde{F}_{\mu,\gamma}, A\right)$ be a intuitionistic fuzzy soft set over V with intuitionistic fuzzy approximate function $\tilde{F}_{\mu,\gamma} :\ A \rightarrow\ IF^V$

Consider $\tilde{F}_{\mu,\gamma}(e_1) = \{a_1/(0.2,0.7), a_2/(0.6,0.3), a_3/(0.8,0.2)\}$

$$\tilde{F}_{\mu,\gamma}(e_2) = \{a_1/(0.1,0.9), a_2/(0.3,0.7), a_3/(0.7,0.3)\}$$

$$\tilde{F}_{\mu,\gamma}(e_3) = \{a_1/(0.4,0.5), a_2/(0.5,0.4), a_3/(0.9,0.1)\}$$

Let $\left(\widetilde{K}_{\rho\tau}, A\right)$ be a intuitionistic fuzzy soft set over E with

$$\widetilde{K}_{\rho,\tau}(e_1) = \{a_1a_2/(0.1,0.7), a_2a_3/(0.5,0.2), a_1a_3/(0.1,0.7)\}$$

$$\widetilde{K}_{\rho,\tau}(e_2) = \{a_1a_2/(0.1,0.8), a_2a_3/(0.2,0.6), a_1a_3/(0.1,0.8)\}$$

$$\widetilde{K}_{\rho,\tau}(e_3) = \{a_1a_2/(0.4,0.5), a_2a_3/(0.4,0.3), a_1a_3/(0.3,0.4)\}$$

Thus $\widetilde{H}_{\beta,\delta}(e_1) = \left(\tilde{F}_{\mu,\gamma}(e_1), \widetilde{K}_{\rho,\tau}(e_1)\right)$, $\widetilde{H}_{\beta,\delta}(e_2) = \left(\tilde{F}_{\mu,\gamma}(e_2), \widetilde{K}_{\rho,\tau}(e_2)\right)$, $\widetilde{H}_{\beta,\delta}(e_3) = \left(\tilde{F}_{\mu,\gamma}(e_3), \widetilde{K}_{\rho,\tau}(e_3)\right)$ are intuitionistic fuzzy soft subgraph and $\tilde{G} = \left(G^*, \tilde{F}_{\mu,\gamma}, \widetilde{K}_{\rho,\tau}, A\right)$ is a intuitionistic fuzzy soft graph.

Definition 3.2: The order of a intuitionistic fuzzy soft graph is

$$Ord(\tilde{G}) = \sum_{e_i \in A}\left(\sum_{a \in V} \tilde{F}_{\mu,\gamma}(e_i)(a)\right)$$

Example 3.2:

Consider a simple graph $G^* = (V, E) \ni V = \{a_1, a_2, a_3, a_4, a_5\}$ and $E = \{a_1a_2, a_2a_3, a_3a_4, a_4a_5, a_5a_1, a_2a_5\}$

Let $A = \{e_1, e_3, e_5\}$ be a parameter set and $\left(\tilde{F}_{\mu,\gamma}, A\right)$ be a intuitionistic fuzzy soft set over V with intuitionistic fuzzy approximate function $\tilde{F}_{\mu,\gamma} : A \to IF^V$

Consider $\tilde{F}_{\mu,\gamma}(e_1) = \{a_1/(0.5,0.4), a_2/(0.7,0.3), a_3/(0,0.9), a_4/(0,0.8), a_5/(0.4,0.6)\}$

$$\tilde{F}_{\mu,\gamma}(e_3) = \{a_1/(0,0.9), a_2/(0.9,0.1), a_3/(0.8,0.2), a_4/(0.6,0.3), a_5/(0,0.9)\}$$

$$\tilde{F}_{\mu,\gamma}(e_5) = \{a_1/(0.1,0.9), a_2/(0.5,0.4), a_3/(0,0.9), a_4/(0.7,0.3), a_5/(0.8,0.1)\}$$

Let $\left(\widetilde{K}_{\rho\tau}, A\right)$ be a intuitionistic fuzzy soft set over E with

$$\widetilde{K}_{\rho,\tau}(e_1) = \{a_1a_2/(0.4,0.4), a_2a_3/(0,0.8), a_3a_4/(0,0.8), a_4a_5/(0,0.7), a_5a_1/(0.3,0.5), a_2a_5/(0.4,0.5)\}$$

$$\widetilde{K}_{\rho,\tau}(e_3) = \{a_1a_2/(0,0.8), a_2a_3/(0.6,0.2), a_3a_4/(0.5,0.2), a_4a_5/(0,0.8), a_5a_1/(0,0.8), a_2a_5/(0,0.8)\}$$

$$\widetilde{K}_{\rho,\tau}(e_5) = \{a_1a_2/(0.1,0.8), a_2a_3/(0,0.9), a_3a_4/(0,0.8), a_4a_5/(0.6,0.2), a_5a_1/(0.1,0.8), a_2a_5/(0.4,0.4)\}$$

Hence

$$Ord(\tilde{G}) = \sum_{e_1,e_2,e_3 \in A}\left(\tilde{F}_{\mu,\gamma}(e_i)(a_1) + \tilde{F}_{\mu,\gamma}(e_i)(a_2) + \tilde{F}_{\mu,\gamma}(e_i)(a_3) + \tilde{F}_{\mu,\gamma}(e_i)(a_4) + \tilde{F}_{\mu,\gamma}(e_i)(a_5)\right)$$

=(6.0,8.0)

Definition 3.3: The size of a intuitionistic fuzzy soft graph is

$$Siz(\tilde{G}) = \sum_{e_i \in A} \left(\sum_{ab \in E} \widetilde{K}_{\rho,\tau}(e_i)(ab) \right)$$

Example 3.3:

Considering the above example we determine the size of the graph as

$$Siz(\tilde{G}) = \sum_{e_1,e_2,e_3 \in A} \Big(\widetilde{K}_{\rho,\tau}(e_i)(a_1a_2) + \widetilde{K}_{\rho,\tau}(e_i)(a_2a_3) + \widetilde{K}_{\rho,\tau}(e_i)(a_3a_4) + \widetilde{K}_{\rho,\tau}(e_i)(a_4a_5)$$
$$+ \widetilde{K}_{\rho,\tau}(e_i)(a_5a_1) + \widetilde{K}_{\rho,\tau}(e_i)(a_2a_5) \Big)$$

= (3.6,11.2)

Definition 3.4: A intuitionistic fuzzy soft graph $\tilde{G}$is a strong intuitionistic fuzzy soft graph if $\widetilde{H}_{\beta,\delta}(e)$ is a strong intuitionistic fuzzy soft graph $\forall e \in A$ i.e.,

$$\widetilde{K}_{\rho}(e)(a\,b) = min\left(\tilde{F}_{\mu}(e)(a), \tilde{F}_{\mu}(e)(b)\right)$$

$$\widetilde{K}_{\tau}(e)(a\,b) = max\left(\tilde{F}_{\gamma}(e)(a), \tilde{F}_{\gamma}(e)(b)\right) \; \forall (a,b) \in E$$

Example 3.4:

Consider a simple graph $G^* = (V,E) \ni V = \{a_1, a_2, a_3, a_4\}$ and $E = \{a_1a_2, a_2a_3, a_3a_4, a_4a_1\}$ Let $A = \{e_1, e_2\}$ be a parameter set and $(\tilde{F}_{\mu,\gamma}, A)$ be a intuitionistic fuzzy soft set over V with intuitionistic fuzzy approximate function $\tilde{F}_{\mu,\gamma} : A \to IF^V$

$$\widetilde{F}_{\mu,\gamma}(e_1) = \{a_1/(0.5,0.4), a_2/(0.3,0.7), a_3/(0.2,0.8), a_4/(0.9,0)\}$$

$$\tilde{F}_{\mu,\gamma}(e_2) = \{a_1/(0.7,0.3), a_2/(0.5,0.4), a_3/(0.1,0.9), a_4/(0.8,0.2)\}$$

Let $(\widetilde{K}_{\rho,\tau}, A)$ be a intuitionistic fuzzy soft set over E such that

$$\widetilde{K}_{\rho,\tau}(e_1) = \{a_1a_2/(0.3,0.7), a_2a_3/(0.2,0.8), a_3a_4/(0.2,0.8), a_4a_1/(0.5,0.4)\}$$

$$\widetilde{K}_{\rho,\tau}(e_2) = \{a_1a_2/(0.5,0.4), a_2a_3/(0.1,0.9), a_3a_4/(0.1,0.9), a_4a_1/(0.7,0.3)\}$$

Here $\widetilde{H}_{\beta,\delta}(e_1) = \left(\tilde{F}_{\mu,\gamma}(e_1), \widetilde{K}_{\rho,\tau}(e_1)\right)$, $\widetilde{H}_{\beta,\delta}(e_2) = \left(\tilde{F}_{\mu,\gamma}(e_2), \widetilde{K}_{\rho,\tau}(e_2)\right)$ are strong intuitionistic fuzzy soft graph.

Definition 3.5: A intuitionistic fuzzy soft graph $\tilde{G}$is a complete intuitionistic fuzzy soft graph if $\widetilde{H}_{\beta,\delta}(e)$ is a complete intuitionistic fuzzy soft graph $\forall e \in A$ i.e.,

$$\widetilde{K}_{\rho}(e)(a\,b) = min\left(\tilde{F}_{\mu}(e)(a), \tilde{F}_{\mu}(e)(b)\right)$$

$$\widetilde{K}_{\tau}(e)(a\,b) = max\left(\tilde{F}_{\gamma}(e)(a), \tilde{F}_{\gamma}(e)(b)\right)\ \forall a, b \in V$$

Example 3.5:

Consider a simple graph $G^* = (V, E) \ni V = \{a_1, a_2, a_3, a_4\}$ and $E = \{a_1a_2, a_2a_3, a_3a_4, a_4a_1, a_1a_3, a_2a_4\}$

Let $A = \{e_1, e_2\}$ be a parameter set and $\left(\tilde{F}_{\mu,\gamma}, A\right)$ be a intuitionistic fuzzy soft set over V with intuitionistic fuzzy approximate function $\tilde{F}_{\mu,\gamma} :\ A\ \rightarrow\ IF^V$

$$\widetilde{F}_{\mu,\gamma}(e_1) = \{a_1/(0.5,0.4), a_2/(0.3,0.7), a_3/(0.2,0.8), a_4/(0.9,0.1)\}$$

$$\tilde{F}_{\mu,\gamma}(e_2) = \{a_1/(0.4,0.5), a_2/(0.3,0.7), a_3/(0.2,0.7), a_4/(0.7,0.3)\}$$

Then $(\widetilde{K}_{\rho,\tau}, A)$ be a intuitionistic fuzzy soft set over E such that

$\widetilde{K}_{\rho,\tau}(e_1)$
$= \{a_1a_2/(0.3,0.7), a_2a_3/(0.2,0.8), a_3a_4/(0.2,0.8), a_4a_1/(0.5,0.4), a_1a_3/(0.2,0.8), a_2a_4/(0.3,0.7)\}$

$\widetilde{K}_{\rho,\tau}(e_2) =$
$\{a_1a_2/(0.3,0.7), a_2a_3/(0.2,0.7), a_3a_4/(0.2,0.7), a_4a_1/(0.4,0.5), a_1a_3/(0.2,0.7), a_2a_4/(0.3,0.7)\}$.

Here $\widetilde{H}_{\beta,\delta}(e_1) = \left(\tilde{F}_{\mu,\gamma}(e_1), \widetilde{K}_{\rho,\tau}(e_1)\right)$, $\widetilde{H}_{\beta,\delta}(e_2) = \left(\tilde{F}_{\mu,\gamma}(e_2), \widetilde{K}_{\rho,\tau}(e_2)\right)$ are complete intuitionistic fuzzy soft graph.

Definition 3.6: Let $V_1, V_2 \subset V$, $E_1, E_2 \subset E\ and\ A, B$ are the subsets of the parameter set. Then the union of two intuitionistic fuzzy soft graph $\tilde{G}^1_{A,V_1} = \left(\widetilde{F}^1_{\mu,\gamma}(e_i), \widetilde{K}^1_{\rho,\tau}(e_i)\right)\ and\ \tilde{G}^2_{B,V_2} = \left(\widetilde{F}^2_{\mu,\gamma}(e_i), \widetilde{K}^2_{\rho,\tau}(e_i)\right)$ is defined to be $\tilde{G}^3_{C,V_3} = \left(\widetilde{F}^3_{\mu,\gamma}(e_i), \widetilde{K}^3_{\rho,\tau}(e_i)\right)$ where $e_i \in C = A \cup B, V_3 = V_1 \cup V_2$ and

$$\left(\widetilde{F}^3_{\mu}(e)(x_i),\ \widetilde{F}^3_{\gamma}(e)(x_i)\right) = \left(\widetilde{F}^1_{\mu}(e)(x_i),\ \widetilde{F}^1_{\gamma}(e)(x_i)\right)\ \forall e \in A\backslash B\ and\ x_i \in V_1 \setminus V_2$$

$$= (0,1)\forall e \in A \setminus B and\ x_i \in V_2 \setminus V_1$$

$$= \left(\widetilde{F}^1_{\mu}(e)(x_i),\ \widetilde{F}^1_{\gamma}(e)(x_i)\right)\ \forall e \in A\backslash B\ and\ x_i \in V_1 \cap V_2$$

$$= \left(\widetilde{F}^2_{\mu}(e)(x_i),\ \widetilde{F}^2_{\gamma}(e)(x_i)\right)\ \forall e \in B\backslash A\ and\ x_i \in V_2 \setminus V_1$$

$$= (0,1)\forall e \in B \setminus A\ and\ x_i \in V_1 \cap V_2$$

$$= \left(\widetilde{F}^2_{\mu}(e)(x_i),\ \widetilde{F}^2_{\gamma}(e)(x_i)\right)\ \forall e \in B\backslash A\ and\ x_i \in V_1 \cap V_2$$

$$= \left(max\left(\widetilde{F}_\mu^1(e)(x_i), \widetilde{F}_\mu^2(e)(x_i) \right), min\left(\widetilde{F}_\gamma^1(e)(x_i), \widetilde{F}_\gamma^2(e)(x_i) \right) \right) \forall e \in A \cap B, x_i \in V_1 \cap V_2$$

$$= \left(\widetilde{F}_\mu^1(e)(x_i), \widetilde{F}_\gamma^1(e)(x_i) \right) \forall e \in A \cap B , x_i \in V_1 \setminus V_2$$

$$= \left(\widetilde{F}_\mu^2(e)(x_i), \widetilde{F}_\gamma^2(e)(x_i) \right) \forall e \in A \cap B , x_i \in V_2 \setminus V_1$$

and $\left(\widetilde{K}_\rho^3(e)(x_i, x_j), \widetilde{K}_\tau^3(e)(x_i, x_j) \right) = \left(\widetilde{K}_\rho^1(e)(x_i, x_j), \widetilde{K}_\tau^1(e)(x_i, x_j) \right)$

$$if\ e \in A \setminus B\ and\ (x_i, x_j) \in (V_1 X V_1) \setminus (V_2 X V_2)$$

$$= (0,1) \forall e \in A \setminus B\ and\ (x_i, x_j) \in (V_2 X V_2) \setminus (V_1 X V_1)$$

$$= \left(\widetilde{K}_\rho^1(e)(x_i, x_j), \widetilde{K}_\tau^1(e)(x_i, x_j) \right)\ if\ e \in A \setminus B\ and\ (x_i, x_j) \in (V_1 X V_1) \cap (V_2 X V_2)$$

$$= \left(\widetilde{K}_\rho^2(e)(x_i, x_j), \widetilde{K}_\tau^2(e)(x_i, x_j) \right)\ if\ e \in B \setminus A\ and\ (x_i, x_j) \in (V_2 X V_2) \setminus (V_1 X V_1)$$

$$= (0,1) \forall e \in B \setminus A\ and\ (x_i, x_j) \in (V_1 X V_1) \setminus (V_2 X V_2)$$

$$= \left(\widetilde{K}_\rho^2(e)(x_i, x_j), \widetilde{K}_\tau^2(e)(x_i, x_j) \right)\ if\ e \in B \setminus A\ and\ (x_i, x_j) \in (V_1 X V_1) \cap (V_2 X V_2)$$

$$= \left(max\left(\widetilde{K}_\rho^1(e)(x_i, x_j), \widetilde{K}_\rho^2(e)(x_i, x_j) \right), min\left(\widetilde{K}_\tau^1(e)(x_i, x_j), \widetilde{K}_\tau^2(e)(x_i, x_j) \right) \right)\ if\ e \in A \cap B, (x_i, x_j) \in (V_1 X V_1) \cap (V_2 X V_2)$$

$$= \left(\widetilde{K}_\rho^1(e)(x_i, x_j), \widetilde{K}_\tau^1(e)(x_i, x_j) \right)\ if\ e \in A \cap B\ and\ (x_i, x_j) \in (V_1 X V_1) \setminus (V_2 X V_2)$$

$$= \left(\widetilde{K}_\rho^2(e)(x_i, x_j), \widetilde{K}_\tau^2(e)(x_i, x_j) \right)\ if\ e \in A \cap B\ and\ (x_i, x_j) \in (V_2 X V_2) \setminus (V_1 X V_1)$$

Example 3.6:

Consider a simple graph $G^* = (V, E) \ni V = \{a_1, a_2, a_3, a_4, a_5, a_6\}$ and $E = \{a_1a_2, a_2a_3, a_3a_4, a_2a_5, a_5a_6\}$

Let $A = \{e_1, e_2, e_3\}$ and $B = \{e_2, e_3, e_4\}$ be the subsets of the parameter set and $V_1 = \{a_1, a_2, a_3, a_4\} \subset V$ and$V_2 = \{a_1, a_2, a_5, a_6\} \subset V; E_1 = \{a_1a_2, a_2a_3, a_3a_4\}, E_2 = \{a_1a_2, a_2a_5, a_5a_6\}$. $\left(\widetilde{F}_{\mu,\gamma}^1, A\right), \left(\widetilde{F}_{\mu,\gamma}^2, B\right)$ be a intuitionistic fuzzy soft set over V with intuitionistic fuzzy approximate function $\widetilde{F}_{\mu,\gamma}^1 :\ A \to IF^{V_1}$ and $\widetilde{F}_{\mu,\gamma}^2 :\ B \to IF^{V_2}$

$$\widetilde{F}_{\mu,\gamma}^1(e_1) = \{a_1/(0.1,0.8), a_2/(0.5,0.4), a_3/(0.8,0.2), a_4/(0.2,0.7)\}$$

$$\widetilde{F}_{\mu,\gamma}^1(e_2) = \{a_1/(0.8,0.1), a_2/(0.2,0.8), a_3/(0.3,0.6), a_4/(0.9,0.1)\}$$

$$\widetilde{F}_{\mu,\gamma}^1(e_3) = \{a_1/(0.3,0.6), a_2/(0.7,0.2), a_3/(0.7,0.2), a_4/(0,0.6)\}$$

and

$$\widetilde{F}_{\mu,\gamma}^2(e_2) = \{a_1/(0.2,0.7), a_2/(0.3,0.6), a_3/(0.8,0.1), a_4/(0.7,0.3)\}$$

$$\widetilde{F}^2_{\mu,\gamma}(e_3) = \{a_1/(0.6,0.3), a_2/(0.4,0.6), a_3/(0.5,0.4), a_4/(0,0.7)\}$$

$$\widetilde{F}^2_{\mu,\gamma}(e_4) = \{a_1/(0,0.6), a_2/(0.7,0.2), a_3/(0.5,0.4), a_4/(0.4,0.6)\}$$

Then $(\widetilde{K}^1_{\rho,\tau}(e_1), A)$ and $(\widetilde{K}^2_{\rho,\tau}(e_2), B)$ are intuitionistic fuzzy soft set over E such that

$$\widetilde{K}^1_{\rho,\tau}(e_1) = \{a_1a_2/(0.1,0.7), a_2a_3/(0.4,0.4), a_3a_4/(0.1,0.6)\}$$

$$\widetilde{K}^1_{\rho,\tau}(e_2) = \{a_1a_2/(0.2,0.8), a_2a_3/(0.2,0.7), a_3a_4/(0.2,0.5)\}$$

$$\widetilde{K}^1_{\rho,\tau}(e_3) = \{a_1a_2/(0.2,0.6), a_2a_3/(0.5,0.2), a_3a_4/(0,0.6)\}$$

and

$$\widetilde{K}^2_{\rho,\tau}(e_2) = \{a_1a_2/(0.2,0.5), a_2a_5/(0.2,0.7), a_5a_6/(0.6,0.2)\}$$

$$\widetilde{K}^2_{\rho,\tau}(e_3) = \{a_1a_2/(0.4,0.6), a_2a_5/(0.3,0.5), a_5a_6/(0,0.7)\}$$

$$\widetilde{K}^2_{\rho,\tau}(e_4) = \{a_1a_2/(0,0.6), a_2a_5/(0.4,0.3), a_5a_6/(0.3,0.5)\}$$

Then the union of two intuitionistic fuzzy soft graph is $\tilde{G}^3_{C,V_3} = \left(\widetilde{F}^3_{\mu,\gamma}(e_i), \widetilde{K}^3_{\rho,\tau}(e_i)\right)$ such that

$$\widetilde{F}^3_{\mu,\gamma}(e_1) = \{a_1/(0.1,0.8), a_2/(0.5,0.4), a_3/(0.8,0.2), a_4/(0.2,0.7), a_5/(0,1), a_6/(0,1)\}$$

$$\widetilde{F}^3_{\mu,\gamma}(e_2) = \{a_1/(0.8,0.1), a_2/(0.3,0.6), a_3/(0.3,0.6), a_4/(0.9,0.1), a_5/(0.8,0), a_6/(0.7,0.3)\}$$

$$\widetilde{F}^3_{\mu,\gamma}(e_3) = \{a_1/(0.6,0.3), a_2/(0.7,0.2), a_3/(0.7,0.2), a_4/(0,0.6), a_5/(0.5,0.4), a_6/(0,0.7)\}$$

$$\widetilde{F}^3_{\mu,\gamma}(e_4) = \{a_1/(0,0.6), a_2/(0.7,0.2), a_3/(0,1), a_4/(0,1), a_5/(0.5,0.4), a_6/(0.4,0.6)\}$$

and $\widetilde{K}_{\rho,\tau}(e_1) = \{a_1a_2/(0.1,0.7), a_2a_3/(0.4,0.4), a_3a_4/(0.1,0.6), a_2a_5/(0,1), a_5a_6/(0,1)\}$

$$\widetilde{K}_{\rho,\tau}(e_2) = \{a_1a_2/(0.2,0.7), a_2a_3/(0.2,0.7), a_3a_4/(0.2,0.5), a_2a_5/(0.2,0.5), a_5a_6/(0.6,0.2)\}$$

$$\widetilde{K}_{\rho,\tau}(e_3) = \{a_1a_2/(0.4,0.6), a_2a_3/(0.5,0.2), a_3a_4/(0,0.6), a_2a_5/(0.3,0.5), a_5a_6/(0,0.7)\}$$

$$\widetilde{K}_{\rho,\tau}(e_4) = \{a_1a_2/(0,0.6), a_2a_3/(0,1), a_3a_4/(0,1), a_2a_5/(0.4,0.3), a_5a_6/(0.3,0.5)\}$$

Definition 3.7: Let $V_1, V_2 \subset V$, $E_1, E_2 \subset E$ and A, B are the subsets of the parameter set. Then the intersection of two intuitionistic fuzzy soft graph $\tilde{G}^1_{A,V_1} = \left(\widetilde{F}^1_{\mu,\gamma}(e_i), \widetilde{K}^1_{\rho,\tau}(e_i)\right)$ and $\tilde{G}^2_{B,V_2} = \left(\widetilde{F}^2_{\mu,\gamma}(e_i), \widetilde{K}^2_{\rho,\tau}(e_i)\right)$ is defined to be $\tilde{G}^3_{C,V_3} = \left(\widetilde{F}^3_{\mu,\gamma}(e_i), \widetilde{K}^3_{\rho,\tau}(e_i)\right)$ where $e_i \in C = A \cap B, V_3 = V_1 \cap V_2$ and $\left(\widetilde{F}^3_{\mu}(e)(x_i), \widetilde{F}^3_{\gamma}(e)(x_i)\right) =$

$$\left(min\left(\widetilde{F}^1_{\mu}(e)(x_i), \widetilde{F}^2_{\mu}(e)(x_i)\right), max\left(\widetilde{F}^1_{\gamma}(e)(x_i), \widetilde{F}^2_{\gamma}(e)(x_i)\right)\right) \forall e \in C, x_i \in V_3$$

$$\left(\widetilde{K}_{\rho}^{3}(e)(x_i,x_j),\ \widetilde{K}_{\tau}^{3}(e)(x_i,x_j)\right)$$
$$=\left(min\left(\widetilde{K}_{\rho}^{1}(e)(x_i,x_j),\ \widetilde{K}_{\rho}^{2}(e)(x_i,x_j)\right), max\left(\widetilde{K}_{\tau}^{1}(e)(x_i,x_j),\ \widetilde{K}_{\tau}^{2}(e)(x_i,x_j)\right)\right)\forall e\in C,$$
$$(x_i,x_j)\in V_3$$

Example 3.7:

Consider a simple graph $G^*=(V,E)\ni V=\{a_1,a_2,a_3,a_4\}$ and $E=\{a_1a_2,a_1a_3,a_2a_3,a_2a_4,a_3a_4\}$

Let $A=\{e_1,e_2\}$ and $B=\{e_2,e_3\}$ be the subsets of the parameter set and $V_1=\{a_1,a_2,a_3\}\subset V$ and $V_2=\{a_2,a_3,a_4\}\subset V; E_1=\{a_1a_2,a_1a_3,a_2a_3\}, E_2=\{a_2a_3,a_2a_4,a_3a_4\}$. $(\widetilde{F}_{\mu,\gamma}^{1},A),(\widetilde{F}_{\mu,\gamma}^{2},B)$ be a intuitionistic fuzzy soft set over V with intuitionistic fuzzy approximate function $\widetilde{F}_{\mu,\gamma}^{1}: A\rightarrow IF^{V_1}$ and $\widetilde{F}_{\mu,\gamma}^{2}: B\rightarrow IF^{V_2}$

$$\widetilde{F}_{\mu,\gamma}^{1}(e_1)=\{a_1/(0.2,0.8),a_2/(0.4,0.5),a_3/(0.6,0.3)\}$$
$$\widetilde{F}_{\mu,\gamma}^{1}(e_2)=\{a_1/(0.3,0.6),a_2/(0.9,0.1),a_3/(0.6,0.4)\}$$
$$and\ \widetilde{F}_{\mu,\gamma}^{2}(e_2)=\{a_2/(0.3,0.7),a_3/(0.5,0.4),a_4/(0.4,0.5)\}$$
$$\widetilde{F}_{\mu,\gamma}^{2}(e_2)=\{a_2/(0.1,0.9),a_3/(0.4,0.5),a_4/(0.7,0.2)\}$$

Then $(\widetilde{K}_{\rho,\tau}^{1}(e_1),A)$ and $(\widetilde{K}_{\rho,\tau}^{2}(e_2),B)$ are intuitionistic fuzzy soft set over E such that

$$\widetilde{K}_{\rho,\tau}^{1}(e_1)=\{a_1a_2/(0.2,0.8),a_1a_3/(0.2,0.7),a_2a_3/(0.4,0.5)\}$$
$$\widetilde{K}_{\rho,\tau}^{1}(e_2)=\{a_1a_2/(0.3,0.6),a_1a_3/(0.2,0.5),a_2a_3/(0.5,0.3)\}$$

and

$$\widetilde{K}_{\rho,\tau}^{2}(e_2)=\{a_2a_3/(0.3,0.7),a_2a_4/(0.2,0.6),a_3a_4/(0.4,0.4)\}$$
$$\widetilde{K}_{\rho,\tau}^{2}(e_3)=\{a_2a_3/(0.1,0.8),a_2a_4/(0.1,0.8),a_3a_4/(0.3,0.4)\}$$

Then the intersection of two intuitionistic fuzzy soft graph is $\tilde{G}_{C,V_3}^{3}=\left(\widetilde{F}_{\mu,\gamma}^{3}(e_i),\widetilde{K}_{\rho,\tau}^{3}(e_i)\right)$ such that

$$\widetilde{F}_{\mu,\gamma}^{3}(e_2)=\{a_2/(0.3,0.7),a_3/(0.5,0.4)\}$$
$$\widetilde{K}_{\rho,\tau}^{3}(e_2)=\{a_2a_3/(0.3,0.7)\}$$

Proposition 3.1:

Let $\tilde{G}_{C,V_3}^{3}$ be the union of the intuitionistic fuzzy soft graph $\tilde{G}_{A,V_1}^{1}$ *and* $\tilde{G}_{B,V_2}^{2}$. Then $\tilde{G}_{C,V_3}^{3}=\tilde{G}_{A,V_1}^{1}\ \tilde{\cup}\ \tilde{G}_{B,V_2}^{2}$ is a intuitionistic fuzzy soft graph.

Proof:

If $e \in A\backslash B\ and\ (x_i, x_j) \in (V_1XV_1) \setminus (V_2XV_2)\ or\ (x_i, x_j) \in (V_1XV_1) \cap (V_2XV_2)$ then by definition(3.6) it follows that $\left(\widetilde{K}_\rho^3(e)(x_i, x_j), \widetilde{K}_\tau^3(e)(x_i, x_j)\right) = \left(\widetilde{K}_\rho^1(e)(x_i, x_j), \widetilde{K}_\tau^1(e)(x_i, x_j)\right)$

$$\leq \left(min\left(\widetilde{F}_\mu^1(e)(x_i), \widetilde{F}_\mu^1(e)(x_j)\right), max\left(\widetilde{F}_\gamma^1(e)(x_i), \widetilde{F}_\gamma^1(e)(x_j)\right)\right)$$

$$= \left(min\left(\widetilde{F}_\mu^3(e)(x_i), \widetilde{F}_\mu^3(e)(x_j)\right), max\left(\widetilde{F}_\gamma^3(e)(x_i), \widetilde{F}_\gamma^3(e)(x_j)\right)\right)$$

If $e \in A \setminus Band\ (x_i, x_j) \in (V_2XV_2) \setminus (V_1XV_1)$ then we know that

$$\left(\widetilde{K}_\rho^3(e)(x_i, x_j), \widetilde{K}_\tau^3(e)(x_i, x_j)\right) = (0,1)$$

$$\leq \left(min\left(\widetilde{F}_\mu^3(e)(x_i), \widetilde{F}_\mu^3(e)(x_j)\right), max\left(\widetilde{F}_\gamma^3(e)(x_i), \widetilde{F}_\gamma^3(e)(x_j)\right)\right)$$

Similarly $if\ e \in B\backslash A\ and\ (x_i, x_j) \in (V_2XV_2) \setminus (V_1XV_1)\ or\ (x_i, x_j) \in (V_1XV_1) \cap (V_2XV_2)$ then

$$\left(\widetilde{K}_\rho^3(e)(x_i, x_j), \widetilde{K}_\tau^3(e)(x_i, x_j)\right) = \left(\widetilde{K}_\rho^2(e)(x_i, x_j), \widetilde{K}_\tau^2(e)(x_i, x_j)\right)$$

$$\leq \left(min\left(\widetilde{F}_\mu^3(e)(x_i), \widetilde{F}_\mu^3(e)(x_j)\right), max\left(\widetilde{F}_\gamma^3(e)(x_i), \widetilde{F}_\gamma^3(e)(x_j)\right)\right)$$

Now let us consider the case when $e \in A \cap B\ and\ (x_i, x_j) \in (V_1XV_1) \cap (V_2XV_2)$

$$\left(\widetilde{K}_\rho^3(e)(x_i, x_j), \widetilde{K}_\tau^3(e)(x_i, x_j)\right)$$

$$= \left(max\left(\widetilde{K}_\rho^1(e)(x_i, x_j), \widetilde{K}_\rho^2(e)(x_i, x_j)\right), min\left(\widetilde{K}_\tau^1(e)(x_i, x_j), \widetilde{K}_\tau^2(e)(x_i, x_j)\right)\right)$$

$$\leq \{max\left(min\left(\widetilde{F}_\mu^1(e)(x_i), \widetilde{F}_\mu^1(e)(x_j)\right), min\left(\widetilde{F}_\mu^2(e)(x_i), \widetilde{F}_\mu^2(e)(x_j)\right)\right),$$

$$min\left(max\left(\widetilde{F}_\gamma^1(e)(x_i), \widetilde{F}_\gamma^2(e)(x_j)\right), max\left(\widetilde{F}_\gamma^1(e)(x_i), \widetilde{F}_\gamma^2(e)(x_j)\right)\right)\}$$

$$\leq \{max\left(min\left(\widetilde{F}_\mu^1(e)(x_i), \widetilde{F}_\mu^2(e)(x_i)\right), min\left(\widetilde{F}_\mu^1(e)(x_j), \widetilde{F}_\mu^2(e)(x_j)\right)\right),$$

$$min\left(max\left(\widetilde{F}_\gamma^1(e)(x_i), \widetilde{F}_\gamma^2(e)(x_i)\right), max\left(\widetilde{F}_\gamma^1(e)(x_j), \widetilde{F}_\gamma^2(e)(x_j)\right)\right)\}$$

$$\leq \{min\left(max\left(\widetilde{F}_\mu^1(e)(x_i), \widetilde{F}_\mu^2(e)(x_i)\right), max\left(\widetilde{F}_\mu^1(e)(x_j), \widetilde{F}_\mu^2(e)(x_j)\right)\right),$$

$$max\left(min\left(\widetilde{F}_\gamma^1(e)(x_i), \widetilde{F}_\gamma^2(e)(x_i)\right), min\left(\widetilde{F}_\gamma^1(e)(x_j), \widetilde{F}_\gamma^2(e)(x_j)\right)\right)\}$$

$$= \left(min\left(\widetilde{F}_\mu^3(e)(x_i), \widetilde{F}_\mu^3(e)(x_j)\right), max\left(\widetilde{F}_\gamma^3(e)(x_i), \widetilde{F}_\gamma^3(e)(x_j)\right)\right)$$

Similarly we can prove that $if\ e \in A \cap B\ and\ \left(x_i, x_j\right) \in (V_1XV_1) \setminus (V_2XV_2)\ or\ \left(x_i, x_j\right) \in (V_2XV_2) \setminus (V_1XV_1)$,

$$\left(\widetilde{K}_\rho^3(e)\left(x_i, x_j\right), \widetilde{K}_\tau^3(e)\left(x_i, x_j\right)\right)$$
$$\leq \left(min\left(\widetilde{F}_\mu^3(e)(x_i), \widetilde{F}_\mu^3(e)\left(x_j\right)\right), max\left(\widetilde{F}_\gamma^3(e)(x_i), \widetilde{F}_\gamma^3(e)\left(x_j\right)\right)\right)$$

Hence $\tilde{G}_{C,V_3}^3 = \tilde{G}_{A,V_1}^1\ \widetilde{\cup}\ \tilde{G}_{B,V_2}^2$ is a intuitionistic fuzzy soft graph.

Proposition 3.2:

If $\tilde{G}_{C,V_3}^3$ is the union of two intuitionistic fuzzy soft graph $\tilde{G}_{A,V_1}^1\ and\ \tilde{G}_{B,V_2}^2$ then both $\tilde{G}_{A,V_1}^1\ and\ \tilde{G}_{B,V_2}^2$ are intuitionistic fuzzy soft subgraph of $\tilde{G}_{C,V_3}^3$.

Proposition 3.3:

Let $\tilde{G}_{C,V_3}^3$ be the intersection of the intuitionistic fuzzy soft graph $\tilde{G}_{A,V_1}^1\ and\ \tilde{G}_{B,V_2}^2$. Then $\tilde{G}_{C,V_3}^3 = \tilde{G}_{A,V_1}^1\ \widetilde{\cap}\ \tilde{G}_{B,V_2}^2$ is a intuitionistic fuzzy soft graph.

Proof:

Let $x_i, x_j \in V_3\ and\ e \in C$. Then we have $\left(\widetilde{K}_\rho^3(e)\left(x_i, x_j\right), \widetilde{K}_\tau^3(e)\left(x_i, x_j\right)\right)$

$$\left(min\left(\widetilde{K}_\rho^1(e)\left(x_i, x_j\right), \widetilde{K}_\rho^2(e)\left(x_i, x_j\right)\right), max\left(\widetilde{K}_\tau^1(e)\left(x_i, x_j\right), \widetilde{K}_\tau^2(e)\left(x_i, x_j\right)\right)\right)$$
$$\leq \{min\left(min\left(\widetilde{F}_\mu^1(e)(x_i), \widetilde{F}_\mu^1(e)\left(x_j\right)\right), min\left(\widetilde{F}_\mu^2(e)(x_i), \widetilde{F}_\mu^2(e)\left(x_j\right)\right)\right),$$
$$max\left(max\left(\widetilde{F}_\gamma^1(e)(x_i), \widetilde{F}_\gamma^1(e)\left(x_j\right)\right), max\left(\widetilde{F}_\gamma^2(e)(x_i), \widetilde{F}_\gamma^2(e)\left(x_j\right)\right)\right)\}$$
$$= \{min\left(min\left(\widetilde{F}_\mu^1(e)(x_i), \widetilde{F}_\mu^2(e)(x_i)\right), min\left(\widetilde{F}_\mu^1(e)\left(x_j\right), \widetilde{F}_\mu^2(e)\left(x_j\right)\right)\right),$$
$$max\left(max\left(\widetilde{F}_\gamma^1(e)(x_i), \widetilde{F}_\gamma^2(e)(x_i)\right), max\left(\widetilde{F}_\gamma^1(e)\left(x_j\right), \widetilde{F}_\gamma^2(e)\left(x_j\right)\right)\right)\}$$
$$= \left(min\left(\widetilde{F}_\mu^3(e)(x_i), \widetilde{F}_\mu^3(e)\left(x_j\right)\right), max\left(\widetilde{F}_\gamma^3(e)(x_i), \widetilde{F}_\gamma^3(e)\left(x_j\right)\right)\right)$$

Hence $\tilde{G}_{C,V_3}^3 = \tilde{G}_{A,V_1}^1\ \widetilde{\cap}\ \tilde{G}_{B,V_2}^2$ is a intuitionistic fuzzy soft graph.

Proposition 3.4:

If $\tilde{G}_{C,V_3}^3$ is the intersection of two intuitionistic fuzzy soft graph $\tilde{G}_{A,V_1}^1\ and\ \tilde{G}_{B,V_2}^2$ then $\tilde{G}_{C,V_3}^3$ is a intuitionistic fuzzy soft subgraph of both $\tilde{G}_{A,V_1}^1\ and\ \tilde{G}_{B,V_2}^2$.

IV. CONCLUSION

The basic notions of intuitionistic fuzzy soft graph, order, size, strong intuitionistic fuzzy soft graph,union and intersection of them has been explained with illustration which has wider application in the field of engineering and medicine. Using this concept we can extend our work in determining regular intuitionistic fuzzy soft graph.

Conflict of Interests

The authors declare that there is no conflict of interests.

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