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Morphology on Intuitionistic Fuzzy Soft Graphs

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Abstract- Mathematical Morphology is the study of the form and structure of objects based on set theory,lattice theory and topology.Dilation and erosion are the basic operators in Mathematical Morphology.Fuzzy Graph represents relationships that involve uncertainty.We introduce P_n-adjacency of vertices, P_n-adjacency of edges, P_n-adjacency of dilation, and P_n-adjacency of erosion on Intuitionistic Fuzzy Soft Graph(IFSG). We also present an algorithm for P_n-adjacency of dilation on IFSG.

Keywords-Dilation and erosion based on Lattice Structure, Intuitionistic Fuzzy Soft Graph,P_n-adjacency of vertices, P_n-adjacency of edges, P_n-adjacency of dilation, and P_n-adjacency of erosion on Intuitionistic Fuzzy Soft Graph(IFSG)

I. INTRODUCTION

Traditional Mathematical Morphology is a study of forms and structures based on Set theory, Lattice Theory and Topology. It is used to as a powerful tool for image analysis. The book by Jean Serra [20]"Image Analysis and Mathematical Morphology" made Mathematical Morphology popular. Works on Traditional Mathematical Morphology has been extended to many field,especially in Graph Theory[7],[13].

After introduction of Graph Theory by Euler in 1736, Kaffmann[11] put forward the first definition of Fuzzy Graph in 1973. But ,Rosenfeld[19] introduced another definition of Fuzzy Graph which is similar to the graph theoretic concepts. In 1999, Atanssove[1] introduced Intuitionistic Fuzzy Graph. Karunambigai and Parvathy[9] also did some extension to Atanassove's Intuitionistic Fuzzy Graph. Thumbakara and George[26] put forward the idea of Soft Graph. Mohita and Samanta[22] first presented the notion of Fuzzy Soft Graph. Sunitha [24] introduced the Intuitionistic Fuzzy Soft Graph. Shyla and Mathew Varkey[21] also did their work in Intuitionistic Fuzzy Soft Graph.

In this paper, we propose definitions of basic morphological operations such as dilation and erosion in Inuitionistic Fuzzy Soft Graph in section III using the notions called P_n-adjacency of vertices and P_n-adjacency of edges those we introduce in section 2.Definitions in section II make this journey to our destination smooth. In section IV, we proved that morphological operators defined in section III form an adjunction. We also give an P_n-adjacency algorithm to find P_n-adjacency dilation and P_n-adjacency erosion in IFSG in section V.

II. PRELIMINARIES

Before defining P_n-adjacency vertices and P_n-adjacency edges, we recall definitions of intuitionistic fuzzy soft graph and elementary morphological operators on a lattice.

Definition II.1

Let $G^*=\{x_1,x_2,x_3,\ldots..x_n\}$ be a non-empty set, P be a parameter set,and $A\subseteq P$, $a\in A, E\subseteq G^*\times G^*$ Let $F(G^*)$ be collection of all fuzzy subsets of G^* and $F(G^*xG^*)$ be collection of all fuzzy subsets of G^*xG^*. Also let

(1) $\mu_1,\gamma_1: A\rightarrow F(G^*)$ such that

$a\mapsto\mu_1(a)=\mu_{1a}(say)$

and $a\mapsto\gamma_1(a)=\gamma_{1a}(say)$

where $\mu_{1a}: G^*\rightarrow[0,1]$ such that $x_i\mapsto\mu_{1a}(x_i)$ and

$\gamma_{1a}: G^*\rightarrow[0,1]$ such that $x_i\mapsto\gamma_{1a}(x_i)$

(A,μ_1,γ_1) is intuitionistic fuzzy soft vertex if

$0\le\mu_{1a}+\gamma_{1a}\le 1,\ \forall x_i\in V$ and $a\in A$.

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(2) $\mu_2,\gamma_2: \quad A \to F(G^*xG^*)$ such that

a$\mapsto$ $\mu_2(a) = \mu_{2a}(say)$ and

$a \mapsto \gamma_2(a) = \mu_{2a}(say)$

where $\mu_{2a}: G^*xG^* \to [0,1]$ such that

$(x_i,x_j) \mapsto \mu_{2a}(x_i,x_j)$

$\gamma_{2a}: G^*xG^* \to [0,1]$ such that

$(x_i,x_j) \mapsto \gamma_{2a}(x_i,x_j)$

(A,μ_2,γ_2) is an intuitionistic fuzzy soft edge if

$a \in A,$

$\forall(x_i,x_j) \in E \quad and \; \forall i,j = 1,2,\ldots..n$

(1) $\mu_{2a}(x_i,x_j) \le \mu_{1a}(x_i) \wedge \mu_{1a}(x_j)$

(2) $\gamma_{2a}(x_i,x_j) \le \gamma_{1a}(x_i) \vee \gamma_{1a}(x_j)$

(3) $0 \le \mu_{2a}(x_i,x_j) + \gamma_{2a}(x_i,x_j) \le 1$

Then $A(\mu_{1a},\gamma_{1a},\mu_{2a},\gamma_{2a})$ is called intuitionistic fuzzy soft graph(IFSG) is denoted by $G_{A,G^*,E}$.

Let P be a parameter. Let A,B⊆ P, a∈ A. Let $G^i = (A,\mu^i_{1a}\gamma^i_{1a}\mu^i_{2a},\gamma^i_{2a})$ and $G^j = (A,\mu^j_{1a}\gamma^j_{1a}\mu^j_{2a},\gamma^j_{2a})$ be IFSG's. Then G^i is an intuitionistic fuzzy soft sub graph of G^j if

(1) A⊆ B

(2) $H^i(a)$ is a partial intuitionistic fuzzy sub graph of $H^j(a)$ for all a∈ A.

where $H^i(a)$ and $H^j(a)$ are the corresponding intuitionistic fuzzy graph of G^i and G^i for each a∈ A

Example II.1

Consider a simple graph G=(V,E), where V={v_1,v_2,v_3},E={(v_1,v_2),(v_2,v_3),(v_1,v_3)}

Let A={a_1,a_2,a_3} be the parameter set. Then intuitionistic fuzzy soft graph $G_{A,V,E}$.

Table 1

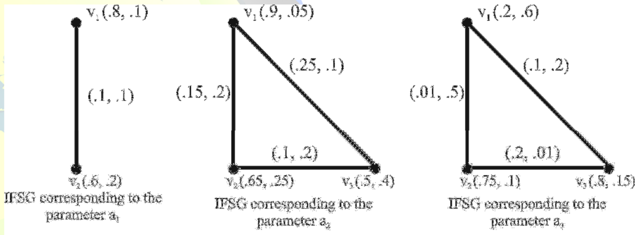
μ_{1a}	v_1	v_2	v_3
a_1	.8	.6	0
a_2	.9	.65	.5
a_3	.2	.75	.8

γ_{1a}	v_1	v_2	v_3
a_1	.1	.2	0
a_2	.05	.25	.4
a_3	.6	.1	.15

Table 2

γ_{2a}	(v_1,v_2)	(v_1,v_3)	(v_2,v_3)
a_1	0.1	0	0
a_2	0.15	0.25	0.1
a_3	0.01	0.1	0.2

γ_{2a}	(v_1,v_2)	(v_1,v_3)	(v_2,v_3)
a_1	0.1	0	0
a_2	0.2	0.1	0.2
a_3	0.5	0.2	0.01



IFSG

Fig.1

Proposition II.1

Union of two intuitionistic fuzzy soft graph is an IFSG.

Proposition II.2

Intersection of two intuitionistic fuzzy soft graph is an IFSG.

Definition II.2

Any operator δ acting on a lattice L is called dilation if it is extensive,increasing and distributes over the supremum. Any operator ϵ acting on a lattice L is called erosion if it is anti extensive, increasing and distributes over the infimum. The pair (ϵ, δ) form an adjunction if $\delta(A) \subseteq B \Leftrightarrow A \subseteq \epsilon(B)$.

ϵ and δ are dual with respect to complementation if $\overline{\in (A)}$ =δ(A).

Theorem II.1

If (ϵ, δ) is an adjunction ,then ϵ is an erosion and δ is a dilation.

Now we introduce n-path adjacency vertices(P_n-adjacency vertices), n-path adjacency edges and (P_n-adjacency edges). We also propose path adjacency dilated IFSG which includes both P_n-adjacency vertex dilation and P_n-adjacency edge dilation and path adjacency eroded IFSG which includes both P_n-adjacency vertex erosion and P_n-adjacency edge erosion.

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Throughout this paper, let P is the parameter set, A,B⊆ P, a∊A. Let $G^i = (G^*, G^\times, \mu_{1a}^i, \gamma_{1a}^i, \mu_{2a}^i, \gamma_{2a}^i)$ be an Intuitionistic Fuzzy Soft Graph(IFSG) ,where G^* is the underlying vertex set,$G^\times$ is the set of all elements in $G^* \times G^*$,μ_{1a}^i and γ_{1a}^i are the membership function and non-membership function of vertex set of IFSG and μ_{2a}^i and γ_{2a}^i are the membership function and non-membership function of edge set of IFSG. Let $\mathbb{G}$ be the set of all Intuitionistic Fuzzy Softgraphs $G^i = (G^*, G^\times, \mu_{1a}^i, \gamma_{1a}^i, \mu_{2a}^i, \gamma_{2a}^i)$ defined on $G=(G^*,G^\times)$,where each pair in $\mathbb{G}$ satisfies property of subgraph. We define a relation ⊆ on $\mathbb{G}$ as follows : Let 0 be the IFSG in $\mathbb{G}$ with all vertices and edges of membership function 0 and non- membership function 1 and let 1 be the IFSG in $\mathbb{G}$ with all vertices and edges of membership function 1 and non- membership function 0. Let ϕ be the empty set. We represent the vertices of the underlying graph by u_i and the edge between u_i and u_j by $e_{u_i-u_j}$.We represent that u_i and u_j are P_n- adjacency vertices in G as u_i P_n-adj u_j.

Definition II.3

Let u_i and u_j be two vertices in the IFSG $G^i = (G^*, G^\times, \mu_{1a}^i, \gamma_{1a}^i, \mu_{2a}^i, \gamma_{2a}^i)$∊$\mathbb{G}$. Then,$u_j$ is said to be 1-path adjacency vertex (P_1- adjacency vertex) to u_i if they are connected by at most 1 edge. Then,u_j is 1-path adjacency vertex of u_i and vice versa. Illustrated example is given in Example II.2.

Definition II.4

Let u_i and u_j be two vertices in the IFSG $G^i = (G^*, G^\times, \mu_{1a}^i, \gamma_{1a}^i, \mu_{2a}^i, \gamma_{2a}^i)$∊$\mathbb{G}$. Then,$u_j$ is said to be 2-path adjacency vertex (P_2- adjacency vertex) to u_i if they are connected by at most 2 edges. Then u_j is 2 path adjacency vertex of u_i and vice versa.Illustrated example is given in Example II.2 .

Observation II.1

In general ,Let u_i and u_j be two vertices in the IFSG $G^i = (G^*, G^\times, \mu_{1a}^i, \gamma_{1a}^i, \mu_{2a}^i, \gamma_{2a}^i)$∊$\mathbb{G}$. Then, u_j is said to be n-path adjacency vertex (P_n- adjacency vertex) to u_i if they are connected by at most n edges. Then u_j is n-path adjacency vertex of u_i and vice versa.

Definition II.5

Let $e_{u_i-u_j}$ and $e_{u_k-u_l}$ be two edges in the IFSG $G^i = (G^*, G^\times, \mu_{1a}^i, \gamma_{1a}^i, \mu_{2a}^i, \gamma_{2a}^i)$∊$\mathbb{G}$. Then,$e_{u_k-u_l}$ is said to be 1-path adjacency edge (P_1- adjacency vertex) to $e_{u_i-u_j}$ if either u_i or u_j is connected to u_k or u_l by at most 1 edge. Illustrated example is given in Example II.2 .

Definition II.6

Let $e_{u_i-u_j}$ and $e_{u_k-u_l}$ be two edges in the IFSG $G^i = (G^*, G^\times, \mu_{1a}^i, \gamma_{1a}^i, \mu_{2a}^i, \gamma_{2a}^i)$∊$\mathbb{G}$. Then,$e_{u_k-u_l}$ is said to be 2-path adjacency edge (P_2- adjacency vertex) to $e_{u_i-u_j}$ if either u_i or u_j is connected to u_k or u_l by at most 2 edges. Illustrated example is given in Example 2.2.

In general, Let $e_{u_i-u_j}$ and $e_{u_k-u_l}$ be two edges in the IFSG $G^i = (G^*, G^\times, \mu_{1a}^i, \gamma_{1a}^i, \mu_{2a}^i, \gamma_{2a}^i)$∊$\mathbb{G}$.Then, $e_{u_k-u_l}$ is said to be n-path adjacency edge (P_n- adjacency vertex) to $e_{u_i-u_j}$ if either u_i or u_j is connected to u_k or u_l by at most n edge.

Example II.2

Consider a simple graph G=(V,E), where $V=\{u_1,u_2,u_3,u_4,u_5,u_6\}$,$E=\{e_{u_1-u_2}, e_{u_2-u_3}, e_{u_3-u_4}, e_{u_4-u_5}, e_{u_4-u_6}, e_{u_1-u_4}\}$, Let $A=\{a_1,a_2\}$ be the parameter set. Then intuitionistic fuzzy soft graph $G_{A,V,E}$ is given in Table-3 and its graph is given in figure 2.

Table 3

μ_{1a}	u_1	u_2	u_3	u_4	u_5	u_6
a_1	.7	.4	.5	.4	.8	1
a_2	.5	.2	.2	.3	0	0

γ_{1a}	u_1	u_2	u_3	u_4	u_5	u_6
a_1	.3	.6	.4	.5	.1	0
a_2	.4	.4	.1	.4	0	0

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μ_{2a}	$e_{u_1-u_2}$	$e_{u_2-u_3}$	$e_{u_3-u_4}$	$e_{u_4-u_5}$	$e_{u_4-u_6}$	$e_{u_1-u_4}$
a_1	.4	.3	.2	.3	.2	.1
a_2	.2	.1	.2	0	0	.1

γ_{2a}	$e_{u_1-u_2}$	$e_{u_2-u_3}$	$e_{u_3-u_4}$	$e_{u_4-u_5}$	$e_{u_4-u_6}$	$e_{u_1-u_4}$
a_1	.4	.6	.4	.5	.2	.5
a_2	.4	.4	.4	0	0	.3

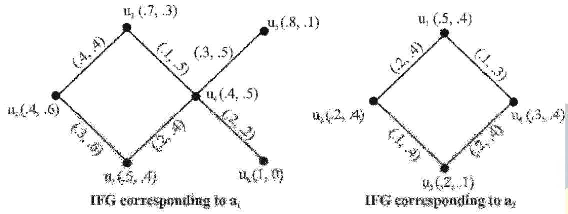

Fig.2

P_1- adjacency vertices and P_2- adjacency vertices of each vertices of IFG corresponding to a_1 are given below Table-4:

Table-4

Vertex	P_1- adjacency vertices	P_2- adjacency vertices
u_1	u_1, u_2, u_4	$u_1, u_2, u_3, u_4, u_5, u_6$
u_2	$u_1, u_2 u_3$	u_1, u_2, u_3, u_4
u_3	u_2, u_3, u_4	$u_1, u_2, u_3, u_4, u_5, u_6$
u_4	u_3, u_1, u_4, u_5, u_6	$u_1, u_2, u_3, u_4, u_5, u_6$
u_5	u_4, u_5	u_2, u_3, u_4, u_5, u_6
u_6	u_4, u_6	u_1, u_3, u_4, u_5, u_6

P_1-adjacency edges and P_2- adjacency edges of each edges of IFG corresponding to a_1 are given below Table-5:

Till now, we defined P_n-adjacency of vertices and P_n-adjacency of edges in IFSG in detail. So we reached half way to the journey of our destination. Now we are going to define the corresponding basic morphological operators in IFSG in the following section.

III. P_n-adjacency Dilated IFSG&P_n-adjacency Eroded IFSG

At first , we define P_1- adjacency dilation of each vertices and edges and then it leads to the P_n-adjacency dilated IFSG corresponding to each $a \epsilon A$ in Definition III.1.

Definition III.1

Let P is the parameter set, $A \subseteq P$, $a \epsilon A$. Let $G^i = (G^*, G^\times, \mu_{1a}^i, \gamma_{1a}^i, \mu_{2a}^i, \gamma_{2a}^i) \epsilon \mathcal{G}$ be an Intuitionistic Fuzzy Soft Graph(IFSG) ,where $G^* = \{u_1, u_2, \ldots\ldots, u_n\}$ is the underlying vertex set,$G^\times$ is the set of all elements in $G^* \times G^*$,μ_{1a}^i and γ_{1a}^i are the membership function and non-membership function of vertex set of IFSG and μ_{2a}^i and γ_{2a}^i are the membership function and non-membership function of edge set of IFSG. We define the following:

1. For all elements in $G*$, $\delta_{1a}^i : G^* \to [0,1]$ by

   $$\delta_{1a}^i(u_k) = \vee_{u_j}(\mu_{1a}^i, \gamma_{1a}^i) = (Sup_{u_j}(\mu_{1a}^i), Inf_{u_j}(\gamma_{1a}^i)) = (\delta_{\mu_{1a}^i}^i, \delta_{\gamma_{1a}^i}^i)$$

   where $u_j = u_k$ or u_j P_1-adj u_k

   Then $\delta_{1a}^i(u_k)$ is the P_1- adjacency dilation of each vertex u_k corresponding to the parameter each $a \epsilon A$ in the given IFSG.

2. For all elements in $G^\times$,

$\delta_{2a}^i : G^\times \to [0,1]$ by $\delta_{2a}^i(e_{u_i-u_j}) = \vee_{e_{u_l-u_k}}(\mu_{2a}^i, \gamma_{2a}^i)$

$= (Sup_{e_{u_l-u_k}}[\mu_{2a}^i(e_{u_l-u_k})], Inf_{e_{u_l-u_k}}[\gamma_{2a}^i(e_{u_l-u_k})])$

$= (\delta_{\mu_{2a}^i}^i, \gamma_{\mu_{2a}^i}^i)$

where $e_{u_l-u_k}$ is $e_{u_i-u_j}$ itself or $e_{u_l-u_k}$ P_n-adjacency edge to $e_{u_i-u_j}$.

Then $\delta_{2a}^i(e_{u_i-u_j})$ is the P_1-adjacency dilation of each edge $e_{u_i-u_j}$ corresponding to the parameter each $a \epsilon A$ in the given IFSG.

Thus $G_D^i = (\delta_{1a}^i, \delta_{2a}^i)$ or $\delta_G{}^i$ is called P_1- adjacency dilation in IFSG G^i corresponding to $a \epsilon A$. Illustrated example is given in Example III.1 .

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Table-4

Vertex	P_1- adjacency vertices	P_2- adjacency vertices
$e_{u_1-u_2}$	$e_{u_1-u_2}$, $e_{u_2-u_3}$, $e_{u_1-u_4}$	$e_{u_1-u_2}$, $e_{u_2-u_3}$, $e_{u_3-u_4}$, $e_{u_4-u_5}$, $e_{u_4-u_6}$, $e_{u_1-u_4}$
$e_{u_2-u_3}$	$e_{u_1-u_2}$, $e_{u_2-u_3}$, $e_{u_3-u_4}$	$e_{u_1-u_2}$, $e_{u_2-u_3}$, $e_{u_3-u_4}$, $e_{u_4-u_5}$, $e_{u_4-u_6}$, $e_{u_1-u_4}$
$e_{u_3-u_4}$	$e_{u_2-u_3}$, $e_{u_3-u_4}$, $e_{u_4-u_5}$, $e_{u_4-u_6}$, $e_{u_1-u_4}$	$e_{u_1-u_2}$, $e_{u_2-u_3}$, $e_{u_3-u_4}$, $e_{u_4-u_5}$, $e_{u_4-u_6}$, $e_{u_1-u_4}$
$e_{u_4-u_5}$	$e_{u_3-u_4}$, $e_{u_4-u_5}$, $e_{u_4-u_6}$, $e_{u_1-u_4}$	$e_{u_1-u_2}$, $e_{u_2-u_3}$, $e_{u_3-u_4}$, $e_{u_4-u_5}$, $e_{u_4-u_6}$, $e_{u_1-u_4}$
$e_{u_4-u_6}$	$e_{u_3-u_4}$, $e_{u_4-u_5}$, $e_{u_4-u_6}$, $e_{u_1-u_4}$	$e_{u_1-u_2}$, $e_{u_2-u_3}$, $e_{u_3-u_4}$, $e_{u_4-u_5}$, $e_{u_4-u_6}$, $e_{u_1-u_4}$
$e_{u_1-u_4}$	$e_{u_1-u_2}$, $e_{u_3-u_4}$, $e_{u_4-u_5}$, $e_{u_4-u_6}$, $e_{u_1-u_4}$	$e_{u_1-u_2}$, $e_{u_2-u_3}$, $e_{u_3-u_4}$, $e_{u_4-u_5}$, $e_{u_4-u_6}$, $e_{u_1-u_4}$

Observation III.1

It is obvious that we can extend the above formula to P_n-adjacency dilated IFSG corresponding to each a∊A.

Now we define P_1- adjacency erosion of each vertices and edges and then it leads to the P_n-adjacency eroded IFSG corresponding to each a∊A in following Definition III.2.

Definition III.2

Let P is the parameter set, A⊆ P, a∊A. Let $G^i = (G^*, G^{\times}, \mu^i_{1a}, \gamma^i_{1a}, \mu^i_{2a}, \gamma^i_{2a})\epsilon\mathcal{G}$ be an Intuitionistic Fuzzy Soft Graph(IFSG) ,where G^* ={u_1,u_2,……,u_n} is the underlying vertex set,$G^{\times}$ is the set of all elements in G^*×G^*,μ^i_{1a} *and* γ^i_{1a} are the membership function and non-membership function of vertex set of IFSG and aμ^i_{2a} *and* γ^i_{2a} are the membership function and non-membership function of edge set of IFSG. We define the following:

1. *For all elements in* $G*, \delta^i_{1a}: G^* \to [0,1]$ *by*

   $\epsilon^i_{1a}(u_k) = \wedge_{u_j}(\mu^i_{1a}, \gamma^i_{1a})$=$(Inf_{\,u_j}(\mu^i_{1a}), Sup_{\,u_j}(\gamma^i_{1a}))$

   where $u_j = u_k$ *or* u_j P_1-adj u_k

   Then $\in^i_{1a}(u_k)$ is the P_1- adjacency erosion of each vertex u_k corresponding to the parameter each a∊A in the given IFSG.

2. For all elements in $G^{\times}$,

   $\in^i_{2a}: G^{\times} \to [0,1]$ by)= $\in^i_{2a}(e_{u_i-u_j}\ \wedge_{e_{u_l-u_k}}(\mu^i_{2a}, \gamma^i_{2a})$

   = $(Inf_{\,e_{u_l-u_k}}[\mu^i_{2a}(e_{u_l-u_k})], Sup_{\,e_{u_l-u_k}}[\gamma^i_{2a}(e_{u_l-u_k}$)])

   where $e_{u_l-u_k}$ is $e_{u_i-u_j}$ itself or $e_{u_l-u_k}$ P_n-adjacency edge to $e_{u_i\ u_j}$ .Then $\in^i_{2a}(e_{u_i-u_j})$ is the P_1-adjacency erosion of each edge $e_{u_i-u_j}$ corresponding to the parameter each a∊A in the given IFSG.

Thus G^i_E=($\in^i_{1a}$,$\in^i_{2a}$) is called P_1-adjacency eroded IFSG corresponding to a∊A.Illustrated example is given in ExampleIII.1 .

Observation III.2

It is obvious that we can extend the above formula to P_n-adjacency eroded IFSG corresponding to each a∊A.

Example III.1

Given below are the P_1-adjacency dilated IFSG corresponding to each a_1 ∊A and P_1-adjacency eroded IFSG corresponding to a_1∊A using corresponding formulae in definition 3.1 and definition III.2 for P_1-adjacency dilation for each vertices and P_1-adjacency erosion for each edges in Intuitionistic Fuzzy Soft Graph corresponding to the parameter a_1 ∊A in figure-2 in the above example II.2.

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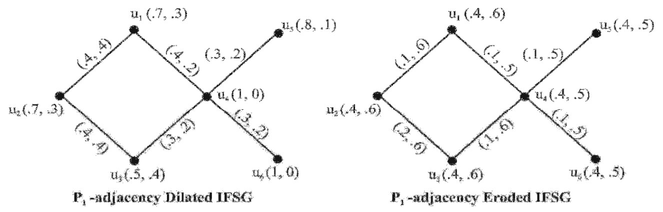
Fig.3



Observation III.3

In the similar manner ,we can find out the P_1-adjacency dilated IFSG corresponding to each $a_2 \epsilon A$ and P_1-adjacency eroded IFSG corresponding to $a_2 \epsilon A$ of the IFSG corresponding to $a_2 \in A$ in the given above example II.2.

Observation III.4

Further, it easy to find out the P_2-adjacency dilated IFSG and P_2-adjacencyeroded IFSG corresponding to each parameters a_1 and a_2 in the given IFSG in example II.2.

Now we have to prove that the above proposed P_n-adjacency dilation and P_n-adjacency erosion in definition III.1 and definition III.2 is morphological operators. So we define a lattice on the set of all intuitionistic fuzzy soft sub graphs and adjunction between the above defined operators in the following section IV.

IV. P_n-ADJACENCY DILATION AND P_nADJACENCY EROSION AS MORPHOLOGICAL OPERATORS

Definition IV.1

We define the partial order ⊑ on $\mathbb{G}$ as $G^1 \sqsubseteq G^2 \Leftrightarrow G^1$ is an intuitionistic fuzzy soft sub graph of G^2. It is obvious that this relation is reflexive ,anti-symmetric and transitive.This leads us to the following:

Proposition IV.1

($\mathbb{G}$, $\sqsubseteq$) is a poset.

Supremum and infimum of two intuitionistic fuzzy soft sub graphs in $\mathbb{G}$ are defined as follws:-

Definition IV4.2

For all $G^1, G^2 \epsilon \mathbb{G}$, we define

$G^1 \vee G^2$

$= G^1 \cup G^2 = (G^*, G^\times, \mu_{1a}^1 \vee \mu_{1a}^2, \gamma_{1a}^1 \wedge \gamma_{1a}^2, \mu_{2a}^1 \vee \mu_{2a}^2, \gamma_{2a}^1 \wedge \gamma_{2a}^2)$

$G^1 \wedge G^2$

$= G^1 \cap G^2 = (G^*, G^\times, \mu_{1a}^1 \wedge \mu_{1a}^2, \gamma_{1a}^1 \vee \gamma_{1a}^2, \mu_{2a}^1 \wedge \mu_{2a}^2, \gamma_{2a}^1 \vee \gamma_{2a}^2)$

The following proposition will prove that union (intersection)of finite collection of intuitionistic fuzzy soft sub graphs in $\mathbb{G}$ is the supremum (infimum) of this collection.

Proposition IV.2

Let £=$(G^1, G^2, \ldots\ldots G^n)$ be a family of elements of $\mathbb{G}$.

Then Sup £=$G^1 \vee G^2 \vee \ldots \vee G^n$ and Inf £ $= G^1 \wedge G^2 \wedge \ldots \wedge G^n$

Proof

Let X= $G^1 \vee G^2 \vee \ldots \vee G^n$

$= G^1 \cup G^2 \cup \ldots \cup G^n$

$(G^*, G^\times, \vee_{i=1}^n \mu_{1a}^i, \vee_{i=1}^n \gamma_{1a}^i, \vee_{i=1}^n \mu_{2a}^i, \vee_{i=1}^n \gamma_{2a}^i)$

For corresponding vertices and edges of

$G^1, G^2, \ldots\ldots G^n$,

$\mu_{1a}^i \leq \vee_{i=1}^n \mu_{1a}^i$, $\gamma_{1a}^i \leq \vee_{i=1}^n \gamma_{1a}^i$,

$\mu_{2a}^i \leq \vee_{i=1}^n \mu_{2a}^i$, $\gamma_{2a}^i \leq \vee_{i=1}^n \gamma_{2a}^i$

By definition, $G^i \sqsubseteq X$ $\forall$ i=1,2,….n

Assume that $G^i \sqsubseteq Y$ $\forall$ i=1,2,….n where Y = $(G^*, G^\times, \mu_{1a}^y, \gamma_{1a}^y, \mu_{2a}^y, \gamma_{2a}^y)$

$\Rightarrow \mu_{1a}^i \leq \mu_{1a}^y, \gamma_{1a}^i \leq \gamma_{1a}^y, \mu_{2a}^i \leq \mu_{2a}^y$ and $\gamma_{2a}^i \leq \gamma_{2a}^y$ $\forall$ i=1,2,….n

$\Rightarrow \vee_{i=1}^n \mu_{1a}^i \leq \mu_{1a}^y$, $\vee_{i=1}^n \gamma_{1a}^i \leq \gamma_{1a}^y$, $\vee_{i=1}^n \mu_{2a}^i \leq \mu_{2a}^y$, $\vee_{i=1}^n \gamma_{2a}^i \leq \gamma_{2a}^y$

for corresponding vertices and edges of $G^1, G^2, \ldots\ldots G^n$

$\Rightarrow \cup_{i=1}^n G^i \sqsubseteq Y$

$\Rightarrow X \sqsubseteq Y$

Since it is true for all IFSG Y , we can conclude that Sup £=$G^1 \vee G^2 \vee \ldots \vee G^n$

Similarly we can prove that Inf £ $= G^1 \wedge G^2 \wedge \ldots \wedge G^n$ ■

Theorem IV.1

($\mathbb{G}$, $\wedge$, $\vee$,0,1) is a complete lattice.

Proof

Proof follows from the Proposition II.1,II.2 ,III.1 and III..2 ■

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Now we prove P_n-adjacency dilated IFSG and P_n-adjacency eroded IFSG are again IFSG in the following theorem IV.2 and IV.3 .

Theroem IV.2

$(G^*, G^\times, \delta^i_{\mu^i_{1a}}, \delta^i_{\gamma^i_{1a}}, \delta^i_{\mu^i_{2a}}, \delta^i_{\gamma^i_{2a}}) \in \mathcal{G}$.

Proof

It is enough to prove that

$0 \le \delta^i_{\mu^i_{1a}}(u_i) + \delta^i_{\gamma^i_{1a}}(u_i) \le 1$ ……………………..(a)

$\delta^i_{\mu^i_{2a}}(e_{u_i-u_j}) \le \delta^i_{\mu^i_{1a}}(u_i) \wedge \delta^i_{\mu^i_{1a}}(u_j)$ …………..(b)

$\gamma^i_{\mu^i_{2a}}(e_{u_i-u_j}) \le \delta^i_{\gamma^i_{1a}}(u_i) \vee \delta^i_{\gamma^i_{1a}}(u_j)$ ……………(c)

$0 \le \delta^i_{\mu^i_{2a}}(e_{u_i-u_j}) + \delta^i_{\mu^i_{2a}}(e_{u_i-u_j}) \le 1$ ………..(d)

Case 1

If possible let, $\delta^i_{\mu^i_{1a}}(u_i) + \delta^i_{\gamma^i_{1a}}(u_i) > 1$ ……………(e)

By definition of dilation, $\delta^i_{\mu^i_{1a}}(u_i)$ is the supremum and $\delta^i_{\gamma^i_{1a}}(u_i)$ is the infimum. Then one of the P_n- adjacency vertices to u_i must have membership function as $\delta^i_{\mu^i_{1a}}(u_i)$,where the non- membership function is greater than or equal to $\delta^i_{\gamma^i_{1a}}(u_i)$.

Hence by our assumption (e), the sum of membership function and non-membership function of vertex u_i must be greater than 1in the given IFSG.

As sum of membership function and non-membership function should be in between 0 and 1,this contradicts the fact that the given graph is IFSG.

Since membership function and non-membership function of each vertices are greater than zero,$0 \le \delta^i_{\mu^i_{1a}}(u_i) + \delta^i_{\gamma^i_{1a}}(u_i)$

This proves (a).

The same argument used in the proof of (a) proves (d).

Case 2

If possible let, (1)

$\delta^i_{\mu^i_{2a}}(e_{u_i-u_j}) > \delta^i_{\mu^i_{1a}}(u_i) \wedge \delta^i_{\mu^i_{1a}}(u_j)$…………(f)(2)

(3)

By definition of dilation, $\delta^i_{\mu^i_{2a}}(e_{u_i-u_j})$ is the supremum.

The membership functions $\mu^i_{1a}(u_i)$ and $\mu^i_{1a}(u_j)$ of vertices u_i and u_j in the given IFSG should be greater than or equal to the membership of the edge in the IFSG whose membership function is $\delta^i_{\mu^i_{2a}}(e_{u_i-u_j})$.

The membership function of the vertices u_i and u_j and the edge $e_{u_i-u_j}$ in the P_n-adjacency dilated graph are the supremums of membership functions of the corresponding P_n-adjacency vertices and P_n-adjacency edges.

Hence the assumption (f) will occur only when the membership functions $\mu^i_{1a}(u_i)$ and $\mu^i_{1a}(u_j)$ of vertices u_i and u_j in the given IFSG are less than the membership function of the edge in the IFSG whose membership function is $\delta^i_{\mu^i_{2a}}(e_{u_i-u_j})$.

This leads to a contradiction to the fact that given graph is IFSG.

This proves (b).

The same argument used in the proof of (b) for non-membership functions proves (d). ■

Theorem IV.3

$(G^*, G^\times, \in^i_{\mu^i_{1a}}, \in^i_{\gamma^i_{1a}}, \in^i_{\mu^i_{2a}}, \in^i_{\gamma^i_{2a}}) \in \mathcal{G}$.

Proof

Proof is obvious from the proof of the above Theorem . ■

Remarks

From the definitions,it is clear that $G^i \subseteq G^i_D$or $G^i \subseteq \delta_{G^i}$.Hence δ_{G^i} is extensive.

Similarly ,$G^i_E \subseteq G^i$ or $\epsilon_{G^i} \subseteq G^i$.Hence ϵ_{G^i} is anti-extensive.

The following theorem proves the operations δ_{G^i} and ϵ_{G^i} are increasing.

Theorem IV.4

Let $G^i = (G^*, G^\times, \in^i_{\mu^i_{1a}}, \in^i_{\gamma^i_{1a}}, \in^i_{\mu^i_{2a}}, \in^i_{\gamma^i_{2a}}) \in \mathcal{G}$, i=1,2.Then

$G^1 \Box G^2 \Rightarrow G^1_D \Box G^2_D$

$G^1 \Box G^2 \Rightarrow G^1_E \Box G^2_E$

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Proof:

(1) Let u_i be any vertex. Let A be the parameter set.

Suppose G^1□ G^2 ,then for any aϵA ,

$\mu^1_{1a}(u_i) \leq \mu^2_{1a}(u_i)$ *and* $\gamma^1_{1a}(u_i) \geq \gamma^2_{1a}(u_i)$

If possible let $G^1_D \not\subseteq G^2_D$,then either $\delta^1_{\mu^1_{1a}}(u_i) \succ \delta^2_{\mu^2_{1a}}(u_i)$ or $\gamma^1_{\mu^1_{1a}}(u_i) \geq \gamma^2_{\mu^2_{1a}}(u_i)$

At first assume $\delta^1_{\mu^1_{1a}}(u_i) \succ \delta^2_{\mu^2_{1a}}(u_i)$.

Then ∃ a P_n-adjacency vertex u_k of u_i in G^1 whose membership function is $\delta^1_{\mu^1_{1a}}(u_i)$.

Since $\delta^2_{\mu^2_{1a}}(u_i)$ is the supremum of membership function of P_n-adjacency vertices of u_i,

$\mu^1_{1a}(u_k) = \delta^1_{\mu^1_{1a}}(u_i) \succ \delta^2_{\mu^2_{1a}}(u_i) \succ \mu^2_{1a}(u_k)$

$\Rightarrow \mu^1_{1a}(u_k) \succ \mu^2_{1a}(u_k)$,which is a contradiction to our assumption G^1□ G^2 .

∴ $G^1_D \subseteq G^2_D$

(2) Similarly we can prove that the operator ϵ_{G^i} is increasing. ■

Now we are going to prove the operator δ_{G^i} is distributive with respect to union and ϵ_{G^i} is distributive with respect to intersection.

Theorem IV.5

Let $G^i = (G^*, G^\times, \epsilon^i_{\mu^i_{1a}}, \epsilon^i_{\gamma^i_{1a}}, \epsilon^i_{\mu^i_{2a}}, \epsilon^i_{\gamma^i_{2a}})$ ϵ₲, i=1,2.Then

1. $\delta_{G^1 \cup G^2} = \delta_{G^1} \cup \delta_{G^2}$
2. $\epsilon_{G^1 \cap G^2} = \epsilon_{G^1} \cap \epsilon_{G^2}$

Proof: Let $V_1 \subseteq G^*$ and $E_1 \subseteq G^\times$ be vertex set and edge set of IFS subgroups of G^1 and $V_2 \subseteq G^*$ and $E_2 \subseteq G^\times$ be vertex set and edge set of IFS subgroups of G^2 in ₲.

Let A and B be parameter set and A□*B*

Suppose $G^1_{A,V_1,E_1} \subseteq G^2_{B,V_2,E_2}$

(1) By definition of union of IFSG's ,the possible cases are

a) aϵ B\A and $v_i \epsilon V_2 \setminus V_1$
b) aϵ B\A and $v_i \epsilon V_1 \cap V_2$
c) aϵ B∩A and $v_i \epsilon V_2 \setminus V_1$
d) aϵ B∩A and $v_i \epsilon V_1 \cap V_2$

Since $V_1 \leq V_2$ and A□B *,all membership functions and non membership functions of vertices and edges of* $G^1 \cup G^2$ *in* cases (a),(b) and (c) will be corresponding membership and non membership functions of vertices and edges of G^2.

In the case of (d), by definition of union of 2 IFSG's G^1 *and* G^2 and since $V_1 \subseteq V_2$ and A□B, the membership and non membership functions of vertices and edges of $G^1 \cup G^2$ will be corresponding to membership and non membership functions of vertices and edges in G^2.

∴ In all cases , $G^1 \cup G^2$ will be G^2.

∴ $\delta_{G^1 \cup G^2} = \delta_{G^2}$ (1)

By definition of IFS sub graph, $G^1 \cup G^2 \Rightarrow \delta_{G^1} \subseteq \delta_{G^2}$

∴ $\delta_{G^1 \cup G^2} = \delta_{G^2}$ (2)

From (1) and (2), $\delta_{G^1 \cup G^2} = \delta_{G^1} \cup \delta_{G^2}$

(2) Let $V_3 = V_1 \cap V_2$ and $E_3 = E_1 \cap E_2$ and C=$A \cap B$

By definition of intersection of IFSG's, V_3 is the set all vertices and E_3 is the set of all edges in $G^1 \cap G^2$.

Since $G^1 \subseteq G^2 \Rightarrow G^1 \cap G^2 = G^1$, $\epsilon_{G^1 \cap G^2} = \epsilon_{G^1}$ (3)

Since $G^1 \subseteq G^2 \Rightarrow \epsilon_{G^1} \subseteq \epsilon_{G^2} \Rightarrow \epsilon_{G^1 \cap G^2} = \epsilon_{G^1}$ (4)

From (1) and (2), $\epsilon_{G^1 \cap G^2} = \epsilon_{G^1} \cap \epsilon_{G^2}$ ■

Observation

We can extend the Theorem IV.5 to finite number of IFSG's.

The following theorem proves an adjunction between the proposed operators P_n-adjacency dilation and P_n-adjacency erosion.

Theorem IV.6

Let $G^i = (G^*, G^\times, \mu^i_{1a}, \gamma^i_{1a}, \mu^i_{2a}, \gamma^i_{2a})$ϵ₲ ,i=1,2 be an Intuitionistic Fuzzy Soft Graphs(IFSG). Then $\delta_{G^i} \subseteq G^i \Leftrightarrow G^i \subseteq \epsilon_{G^i}$.

Proof:

Case1

Consider, for $u_i$in G^* ,

$\delta_{G^1} \subseteq G^2 \Leftrightarrow \delta^1_{\mu^1_{1a}}(u_i) \leq \mu^2_{1a}(u_i)and\delta^1_{\gamma^1_{1a}}(u_i) \geq \gamma^2_{1a}(u_i)$

$\Leftrightarrow \vee_{u_j}\mu^1_{1a}(u_j) \leq \mu^2_{1a}(u_i)and\vee_{u_j}\gamma^1_{1a}(u_j) \geq \gamma^2_{1a}(u_i)$

⇔ where $u_j = u_i or u_j$ P_1-adj u_i

$\mu^1_{1a}(u_j) \leq \mu^2_{1a}(u_i)and\gamma^1_{1a}(u_j) \geq \gamma^2_{1a}(u_i) \forall u_j$ and where $u_j = u_i or u_j$ P_1-adj u_i

⇔

$\mu^1_{1a}(u_i) \leq \wedge_{u_j}\mu^2_{1a}(u_j)and\gamma^1_{1a}(u_i) \geq \wedge_{u_j}\gamma^2_{1a}(u_j)$ where $u_j = u_i or u_j$ P_1-adj u_i

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$\Leftrightarrow\ \mu^1_{1a}(u_i)\ \leq\ \in^2_{\mu^2_{1a}}(u_i)$ and

$\gamma^1_{1a}(u_i) \geq \in^2_{\gamma^2_{1a}}(u_i)$

$\Leftrightarrow G^1 \subseteq \in_{G^2}$

Case 2

For edge $e_{u_i-u_j}$

$\delta_{G^1} \subseteq G^2 \Leftrightarrow \delta^1_{\mu^1_{2a}}\left(e_{u_i-u_j}\right) \leq \mu^2_{2a}\left(e_{u_i-u_j}\right)$ and

$\delta^1_{\gamma^1_{2a}}(u_i) \geq \gamma^2_{2a}(e_{u_i-u_j}) \Leftrightarrow$

$\vee_{e_{u_l-k}} \mu^1_{2a}\left(e_{u_l-k}\right) \leq \mu^2_{2a}\left(e_{u_i-u_j}\right)$ and

$\vee_{e_{u_l-k}} \gamma^1_{2a}\left(e_{u_l-u_k}\right) \geq \gamma^2_{2a}(e_{u_i-u_j})$

where $e_{u_l-u_k}$ is $e_{u_i-u_j}$ itself or $e_{u_l-u_k}$ P_n-adjacency edge to $e_{u_i-u_j}$

$\Leftrightarrow \mu^1_{2a}\left(e_{u_l-k}\right) \leq \mu^2_{2a}\left(e_{u_i-u_j}\right)$ and

$\gamma^1_{2a}\left(e_{u_l-u_k}\right) \geq \gamma^2_{2a}\left(e_{u_i-u_j}\right) \forall e_{u_i-u_j}$ and

where $e_{u_l-u_k}$ is $e_{u_i-u_j}$ itself or $e_{u_l-u_k}$ P_n- adjacency edge to $e_{u_i-u_j}$

$\Leftrightarrow$

$\mu^1_{2a}\left(e_{u_i-u_j}\right) \leq \wedge_{e_{u_l-u_k}} \mu^2_{2a}(e_{u_l-u_k})$ and

$\gamma^1_{2a}\left(e_{u_i-u_j}\right) \geq \wedge_{e_{u_l-u_k}} \gamma^2_{2a}\left(e_{u_l-u_k}\right)$

where $e_{u_l-u_k}$ is $e_{u_i-u_j}$ itself or $e_{u_l-u_k}$ P_n-adjacency edge to $e_{u_i-u_j}$

$\Leftrightarrow\ \mu^1_{2a}\left(e_{u_i-u_j}\right) \leq \in^2_{\mu^2_{2a}}(e_{u_i-u_j})$ and

$\gamma^1_{2a}(u_i) \geq \in^2_{\gamma^2_{2a}}(e_{u_i-u_j})$

$\Leftrightarrow\ G^1 \subseteq \in_{G^2}$

Hence the result is proved.

Observation

The pair of operators $(\in_{G^i}, \delta_{G^i})$ form an intuitionistic fuzzy soft adjunction.

Proposition IV.3

If i∈I and n > i, then P_n-adjacency dilation IFSG and $P_{n\pm i}$-adjacency dilation IFSG are isomorphic if and only if the corresponding vertices and edges have same membership and non-membership functions.

Proposition IV.4

If i∈I and n > i, then P_n-adjacency erosion IFSG and $P_{n\pm i}$-adjacency erosion IFSG are isomorphic if and only if the corresponding vertices and edges have same membership and non-membership functions.

V. P_n-ADJACENCY ALGORITHM

The path adjacency concept in Morphology can apply in the field of Medical Imaging. This helps to identify the region of interest. We propose an algorithm for P_n-adjacency dilation in the following.

Step 1. Convert the image into graph structure with vertex and edge.

Step 2. Perform Intuitionistic soft fuzzification of graph structure in step 1.

Step 3. Use the two formulae given in definition 3.1 to get P_n -adjacency Dilation on the IFSG in step 2.

Step4. Compare the obtainedmembership and non-membership degrees of P_n-adjacency Dilation in IFSG in step 3withIFSG having threshold membership and non-membership degrees.

Step 5. This graph generates a particular area of interest in the graph.

VI. CONCLUSION

In this paper, we have introduced the path adjacency vertex,path adjacency edge, P_n-adjacency Dilation, P_n-adjacency Erosion, P_n-adjacency Dilated IFSG, and P_n-adjacency Eroded IFSG. The algorithm presented in this paper is applied to the other areas of knowledge.

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