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A STUDY ON NORMAL INTUITIONISTIC MULTI-FUZZY BG-IDEALS OF BG-ALGEBRA

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1.Introduction:

The notion of a fuzzy subset was initially introduced by Zadeh[13] in 1965, for representing uncertainity.The idea of Intuitionistic fuzzy set was first published by Atanassov [2], as a generalization of the notion of the fuzzy set.In 2000, S.Sabu and T.V.Ramakrishnan [10] proposed the theory of multi-fuzzy sets in terms of multi-dimensional membership function and investigated some properties of multi –level fuzziness.Theory of multi-fuzzy set is an extension of theory of fuzzy sets.

Y.Imai and K.Iseki introduced two classes of abstract algebras:BCK algebras and BCI-algebras[4].It is shown that the BCK-algebras is a proper subclass of the class of BCI-algebras.C.B.Kim and H.S.Kim[5] introduced the notion of a BG-algebra which is generalization of B-algebras.With these ideas, fuzzy subalgebras of BG-algebra were developed by S.S.Ahn and H.D.Lee[1].R.Muthuraj and S.Devi[6,7,8] introduced the concept of multi –fuzzy subalgebra and intuitionistic multi-fuzzy subalgebras in BG-algebra in 2016.Also in 2017 they also introduced intuitionistic multi-fuzzy ideals in BG-algebra.In this paper,we define a new algebraic structure of normal intuitionistic multi-fuzzy ideals in BG-algebra and discuss some of their related properties.Also we investigate the properties of Cartesian product of intuitionistic multi fuzzy BG-ideals.

2.Preliminaries

Definition:2.1

A BG-algebra is a non-empty set X with a constant 0 and a binary operation '*' satisfying the following axioms

(i) $x * x = 0$

(ii) $x * 0 = x$

(iii)$(x * y) * (0 * y) = x \ \forall\, x, y\, \epsilon X$.

Definition:2.2

Let X be a non-empty set.An intuitionistic fuzzy set (IFS) A in X is a set of the form $A = \{(x, \mu_A(x), \gamma_A(x)): x\epsilon X\}$, where $\mu_A: X \to [0,1]$ and $\gamma_A: X \to [0,1]$ define the degree of membership and the degree of non-membership of the element $x\epsilon X$ respectively, with
$0 \leq \mu_A(x) + \gamma_A(x) \leq 1$.

Definition:2.3

Let X be a non-empty set. An intuitionistic multi fuzzy set A in X is a set of the form $A = \{(x, \mu_A(x), \gamma_A(x)): x\epsilon X\}$, where $\mu_A(x) = \big(\mu_A(x), \mu_A(x), \dots, \mu_A(x)\big)$,

$\gamma_A(x) = \big(\gamma_A(x), \gamma_A(x), \dots, \gamma_A(x)\big)$, and each $\mu_A: X \to [0,1]$, $\gamma_A: X \to [0,1]$ with

$0 \leq \mu_A + \gamma_A \leq 1, x\epsilon X$ Here $\mu_1(x) \geq \mu_2(x) \geq \dots \geq \mu_n(x), x\epsilon X$.

Definition:2.4

Let $A = \{(x, \mu_A(x), \gamma_A(x): x\epsilon X\}$ and $B = \{(x, \mu_B(x), \gamma_B(x): x\epsilon X\}$ be any two intuitionistic multi fuzzy sets having the same dimension of X.Then

(i) $A \subseteq B$ if and only if, $\mu_A(x) \leq \mu_B(x), \gamma_A(x) \leq \gamma_B(x)$, for all $x\epsilon X$.

(ii) $A = B$ if and only if, $\mu_A(x) = \mu_B(x), \gamma_A(x) = \gamma_B(x)$, for all $x\epsilon X$.

(iii)$A \cap B = \{(x, \mu_{A\cap B}(x), \gamma_{A\cap B}(x): x\epsilon X\}$

where $\mu_{A\cap B}(x) = min\{\mu_A(x), \mu_B(x)\}$

$= (min\{\mu_{iA}(x), \mu_{iB}(x)\})_{i=n}^{n}$

And where $\gamma_{A\cap B}(x) = max\{\gamma_A(x), \gamma_B(x)\}$

$= (max\{\gamma_{iA}(x), \gamma_{iB}(x)\})_{i=n}^{n}$

(iv) $A \cup B = \{(x, \mu_{A\cup B}(x), \gamma_{A\cup B}(x): x\epsilon X\}$

where $\mu_{A\cup B}(x) = max\{\mu_A(x), \mu_B(x)\}$

$= (max\{\mu_{iA}(x), \mu_{iB}(x)\})_{i=n}^{n}$

And where $\gamma_{A\cup B}(x) = min\{\gamma_A(x), \gamma_B(x)\}$

$= (min\{\gamma_{iA}(x), \gamma_{iB}(x)\})_{i=n}^{n}$

Definition:2.5

An intuitionistic multi fuzzy subset $A = \{(x, \mu_A(x), \gamma_A(x): x\epsilon X\}$ in X is called an intuitionistic multi fuzzy subalgebra of X if it satisfies

(i) $\mu_A(x * y) \geq min\{\mu_A(x), \mu_A(y)\}$

(ii) $\gamma_A(x * y) \leq max\{\gamma_A(x), \gamma_A(y)\}$ $\forall$ $x, y\epsilon X$.

Definition:2.6

Let A be a multi fuzzy set in X.Then A is called a multi fuzzy BG-Ideal in X if it satisfies the following condition

(i) $A(0) \geq A(x)$

(ii) $A(x) \geq min\{A(x,y), A(y)\}$

(ii) $A(x * y) \geq min\{A(x), A(y)\}$ $\forall x, y$ ϵX

Definition:2.7

Let $A = (\mu_A, \gamma_A)$ be a multi fuzzy BG-Ideal in X.Then A is called a intuitionistic multi fuzzy BG-Ideal in X if it satisfies the following condition

(i) $\mu_A(0) \geq \mu_A(x)$

(ii) $\mu_A(x) \geq \min\{\mu_A(x*y), \mu_A(y)\}$

(iii) $\mu_A(x*y) \geq \min\{\mu_A(x), \mu_A(y)\}$

(iv) $\gamma_A(0) \leq \gamma_A(x)$

(v) $\gamma_A(x) \leq \max\{\gamma_A(x*y), \gamma_A(y)\}$

(vi) $\gamma_A(x*y) \leq \max\{\mu_A(x), \mu_A(y)\}$ $\forall x, y \epsilon X$.

3.Normal Intuitionistic Multi-Fuzzy BG-Ideal of BG-algebra

Definition:3.1

An intuitionistic multi fuzzy BG-Ideal (μ_A, γ_A) in X is called normal, if there exist $x\epsilon X$ such that $\mu_A(x) = 1_n = \gamma_A(x)$ .where $1_n = (1,1,\dots,n\ times)$

Lemma:3.2

An intuitionistic multi fuzzy BG-Ideal (μ_A, γ_A) in X is normal if and only if

$\mu_A(0) = \gamma_A(0) = 1_n$.

Theorem:3.3

Let $(\mu_A, \gamma_A) = A$ be a intuitionistic multi fuzzy set in a BG-algebra X. Then $A^+(x) = A(x) + 1_n - A(0)$ $\forall$ $x\epsilon X$ is a intuitionistic normal multi fuzzy BG-Ideal of X which contain A.

Proof:

Let $x, y \in X$

$$\begin{aligned}
{\mu_A}^+(x) &= \mu_A(x) + 1 - \mu_A(0) \\
&\leq \mu_A(0) + 1 - \mu_A(0) \\
&= {\mu_A}^+(0)
\end{aligned}$$

$$\begin{aligned}
min\{{\mu_A}^+(x*y), {\mu_A}^+(y)\} &= min\{\mu_A(x*y) + 1 - \mu_A(0), \mu_A(y) + 1 - \mu_A(0)\} \\
&= min\{\mu_A(x*y), \mu_A(y)\} + 1 - \mu_A(0) \\
&\leq \mu_A(x) + 1 - \mu_A(0) \\
&= {\mu_A}^+(x)
\end{aligned}$$

$$\begin{aligned}
min\{{\mu_A}^+(x), {\mu_A}^+(y)\} &= min\{\mu_A(x) + 1 - \mu_A(0), \mu_A(y) + 1 - \mu_A(0)\} \\
&= min\{\mu_A(x), \mu_A(y)\} + 1 - \mu_A(0) \\
&\leq \mu_A(x*y) + 1 - \mu_A(0) \\
&= {\mu_A}^+(x*y)
\end{aligned}$$

Clearly this can be proved for maximum condition also

Therefore, ${\gamma_A}^+(x) \geq {\gamma_A}^+(0)$

$max\{{\gamma_A}^+(x * y), {\gamma_A}^+(y)\} \geq {\gamma_A}^+(x)$

$max\{{\gamma_A}^+(x), {\gamma_A}^+(y)\} \geq {\gamma_A}^+(x * y)$

Hence $(\mu_A, \gamma_A)^+ = A^+$ is a intuitionistic normal multi fuzzy BG-Ideal of X.

Clearly $A \subseteq A^+$

Thus (μ_A^+, γ_A^+) is a intuitionistic normal multi fuzzy BG-Ideal which contain (μ_A, γ_A).

Corollary 3.4

If there is an element $x \epsilon X$ such that(${\mu_A}^+(x), {\gamma_A}^+(x)) = (0,0)$ then $(\mu_A(x), \gamma_A(x)) = (0,0)$

Proof:

Since $A \subseteq A^+$ then $A(x) = 0$

That is, $\mu_A(x) = 0$

Similarly, $\gamma_A(x) = 0$

Corollary 3.5

(i) If (μ_A, γ_A) itself is normal then $\mu_A = \mu_A^+, \gamma_A = \gamma_A^+$.

(ii) If μ_A is a intuitionistic multi fuzzy BG-Ideal in X then $(\mu_A^+)^+ = \mu_A^+$, Also γ_A is a intuitionistic multi fuzzy BG-Ideal in X then $(\gamma_A^+)^+ = \gamma_A^+$.

Theorem:3.6

Let μ_A be a intuitionistic multi fuzzy BG-Ideal in X.If there exist a intuitionistic multi fuzzy BG-Ideal γ_A of X such that $\gamma_A^+ \subseteq \mu_A$.then μ_A is normal.

Proof:

Since γ_A be a intuitionistic fuzzy BG-Ideal in X.

γ_A^+ is a normal intuitionistic multi fuzzy BG-Ideal of X.

Then

$\gamma_A^+(0) = 1_n$

This implies $\gamma_A^+(0) = 1$

$\gamma_A^+(0) \subseteq \mu_A$

Implies $\gamma_A(x) \leq \mu_A(x) \forall , x \epsilon X$

$1 = \gamma_A^+(0) \leq \mu_A(0)$

Thus $1_n = \gamma_A^+(0) \leq \mu_A^+(0)$

Hence μ_A is normal.

Theorem 3.7

Let (μ_A, γ_A) be a intuitionistic multi fuzzy BG-Ideal and let $f: [0, A(0)] \to [0,1]$ be an increasing function.Then a multi fuzzy set $\mu_A^f: X \to [0,1]$ by $\mu_A^f(x) = f\big(\mu_A(x)\big)\forall\ x\epsilon X$ is a intuitionistic fuzzy BG-Ideal in X. Also if $f\big(\mu_A(0)\big) = 1_n$ then (μ_A^f, γ_A^f) is normal.

Proof:

Since f is an increasing function

$$\mu_A^f(0) = f(\mu_A(0))$$
$$\geq f(\mu_A(x))$$
$$= \mu_A^f(x)$$

We have $\mu_A^f(x) = f(\mu_A(x))$

$$\geq f(\min\{\mu_A(x * y), \mu_A(y)\}$$
$$= \min\{f(\mu_A(x * y), \mu_A(y))\}$$
$$= \min\{(\mu_A^f(x * y), \mu_A^f(y)\}$$

And $\mu_A^f(x * y) = f(\mu_A(x * y))$

$$\geq f(\min\{\mu_A(x), \{\mu_A(y))$$
$$= \min\{f\big(\mu_A(x), f(\mu_A(y)\big)\}$$
$$= \min\{(\mu_A^f(x), \mu_A^f(y)\}$$

Similarly, $\gamma_A^f(0) \leq \gamma_A^f(x)$

$$\gamma_A^f(x) \leq \max\{(\gamma_A^f(x * y), \mu_A^f(y)\}$$
$$\gamma_A^f(x * y) \leq \max\{(\gamma_A^f(x), \gamma_A^f(y)\}$$

This implies (μ_A^f, γ_A^f) is a intuitionistic multi fuzzy BG-Ideal in X.

If $f\big(\mu_A(0)\big) = f\big(\gamma_A(0)\big) = 1_n$

$$\mu_A^f(x) = \gamma_A^f(x) = 1_n$$

Therefore, (μ_A^f, γ_A^f) is normal.

4.Cartesian product of Intuitionistic Multi fuzzy BG-Ideals

In this section,the Cartesian product of intuitionistic multi fuzzy BG-Ideals of BG-algebra is defined and its properties are discussed.

Definition:4.1

Let μ_A and μ_B be two membership function and γ_A and γ_B be two nonmembership function of each $x\epsilon X$.Then $\mu_{A\times B}(x, y)$ is membership function and $\gamma_{A\times B}(x, y)$ is non membership function of each element $(x, y)\epsilon X \times X$ to the set $A \times B$ and defined by,

$$\mu_{A\times B}(x,y) = min\{\mu_{A\times B}(x), \mu_{A\times B}(y)\}$$

$$\gamma_{A\times B}(x,y) = max\{\gamma_{A\times B}(x), \gamma_{A\times B}(y)\}$$

Theorem 4.2

Let $A = (\mu_A, \gamma_A)$ and $B = (\mu_B, \gamma_B)$ are two intuitionistic multi fuzzy BG-Ideals of X, then $A \times B = (\mu_{A\times B}, \gamma_{A\times B})$ also a intuitionistic multi fuzzy BG-Ideals of $X \times X$.

Soln:

(i)

$$\mu_{A\times B}(0,0) = min\{\mu_A(0), \mu_B(0)\}$$
$$\geq min\{\mu_A(x), \mu_B(x)\}$$
$$= \mu_{A\times B}(x,x)$$
$$\mu_{A\times B}(0,0) \geq \mu_{A\times B}(x,x)$$

(ii) $\mu_{A\times B}(x,x) = min\{\mu_A(x), \mu_B(x)\}$

$$\geq min\{min\{\mu_A(x*y), \mu_A(y)\}, min\{\mu_B(x*y), \mu_B(y)\}\}$$
$$= min\{min\{\mu_A(x*y), \mu_B(x*y)\}, min\{\mu_A(y), \mu_B(y)\}\}$$
$$\geq \min\{\mu_{A\times B}(x*y), \mu_{A\times B}(y)\}$$

(iii) $\mu_{A\times B}(x,y) = min\{\mu_{A\times B}(x), \mu_{A\times B}(y)\}$

$$\geq min\{min\{\mu_A(x), \mu_B(x)\}, min\{\mu_A(y), \mu_B(y)\}\}$$
$$= \min\{\mu_{A\times B}(x), \mu_{A\times B}(y)\}$$

Similarly,

(iv) $\gamma_{A\times B}(0,0) \leq \gamma_{A\times B}(x,x)$

(v) $\gamma_{A\times B}(x,x) \leq \max\{\gamma_{A\times B}(x*y), \gamma_{A\times B}(y)\}$

(vi) $\gamma_{A\times B}(x,y) \leq \max\{\gamma_{A\times B}(x), \gamma_{A\times B}(y)\}$

Hence $A \times B = (\mu_{A\times B}, \gamma_{A\times B})$ is a intuitionistic multi fuzzy BG-Ideals of $X \times X$.

Theorem 4.3

Let $A = (\mu_A, \gamma_A)$ and $B = (\mu_B, \gamma_B)$ are two intuitionistic multi fuzzy set in a BG-algebra of X such that $A \times B = (\mu_{A\times B}, \gamma_{A\times B})$ is a intuitionistic multi fuzzy BG-Ideals of $X \times X$.
Then (i) Either $\mu_{A\times B}(0) \geq \mu_{A\times B}(x)$ or $\gamma_{A\times B}(0) \geq \gamma_{A\times B}(x)$

(ii) If $\mu_{A\times B}(0) \geq \mu_{A\times B}(x)$.Then either $\gamma_{A\times B}(0) \geq \gamma_{A\times B}(x)$ or $\gamma_{A\times B}(0) \geq \gamma_{A\times B}(x)$

(iii) $\gamma_{A\times B}(0) \geq \gamma_{A\times B}(x)$.Then either $\mu_{A\times B}(0) \geq \mu_{A\times B}(x)$ or $\mu_{A\times B}(0) \geq \gamma_{A\times B}(x)$
Proof:

Let $\mu_{A\times B}(0) < \mu_{A\times B}(x)$ and $\gamma_A(0) < \gamma_A(x)$

Then $\mu_{(A\times B)i}(0) < \mu_{(A\times B)i}(x)$ and $\gamma_{(A\times B)i}(0) < \gamma_{(A\times B)i}(x)\ \forall\ i = 1,2,\dots,n$

$$\mu_{A\times B}(x,x) = min\{\mu_A(x),\mu_B(x)\}$$
$$\geq min\{\mu_A(0),\mu_B(0)\}$$
$$\geq \mu_{A\times B}(0,0)$$

Which is a contradiction that $\mu_{A\times B}$ is a intuitionistic multi fuzzy BG-Ideals of $X\times X$.

Therefore either $\mu_{A\times B}(0) \geq \mu_{A\times B}(x)$ or $\gamma_{A\times B}(0) \geq \gamma_{A\times B}(x)$

Let $\gamma_{A\times B}(0) < \mu_{A\times B}(x)$ and $\gamma_{A\times B}(0) < \gamma_{A\times B}(x)$.then $\gamma_{(A\times B)i}(0) < \mu_{(A\times B)i}(x)$ and$\gamma_{(A\times B)i}(0) < \gamma_{(A\times B)i}(x)\ \forall\ i = 1,2,\dots,n$

$$\mu_{A\times B}(0,0) = min\{\mu_A(0),\mu_B(0)\}$$
$$\geq min\{\mu_A(x),\mu_B(x)\}$$
$$\geq min\{\gamma_A(0),\gamma_B(0)\}$$
$$= \gamma_{A\times B}(0,0)$$
$$\mu_{A\times B}(x,x) = min\{\mu_A(x),\mu_B(x)\}$$
$$\geq min\{\mu_A(0),\mu_B(0)\}$$
$$\geq min\{\gamma_A(0),\gamma_B(0)\}$$
$$= \gamma_{A\times B}(0,0)$$

This implies that $\mu_{A\times B}(x,x) \geq \mu_{A\times B}(0,0)$

Which is a contradiction that $A\times B$ is a intuitionistic multi fuzzy BG-Ideals of $X\times X$.

Therefore either $\mu_{A\times B}(x) \geq \mu_{A\times B}(x)$

Then either $\gamma_{A\times B}(0) \geq \mu_{A\times B}(x)$ or $\gamma_{A\times B}(0) \geq \gamma_{A\times B}(x)$

The Third proof is similar to second proof.

Theorem 4.4

If $A\times B = \mu_A \times \gamma_A$ is a intuitionistic multi fuzzy BG-Ideals of $X\times X$, then μ_A or γ_A is a intuitionistic multi fuzzy BG-Ideals of X.

Proof:

To Prove that γ_A is a intuitionistic multi fuzzy BG-Ideals of X.

By the above thrm

(i) Either $\mu_A(0) \geq \mu_A(x)$ or $\gamma_A(0) \geq \gamma_A(x)$

Assume that $\gamma_A(0) \geq \gamma_A(x)$

Also from the above thrm

(iii) Either $\mu_A(0) \geq \mu_A(x)$ or $\mu_A(0) \geq \gamma_A(x)$, Then $\mu_A(0) \geq \gamma_A(x)$

$(\mu_A \times \gamma_A)(0,x) = min\{\mu_A(0), \gamma_A(x)\}$

$= \gamma_A(x)$

$= (\mu_A \times \gamma_A)(0,x)$

$\geq min\{(\mu_A \times \gamma_A\big((0,x) * (0,y)\big), (\mu_A \times \gamma_A)(0,y)\}$

$= min\{\mu_A \times \gamma_A\big((0,0), (x * y)\big), \mu_A \times \gamma_A(0,y)\}$

$=min\{\mu_A(x * y), \gamma_A(y)\}$

Also $\gamma_A(x * y) = (\mu_A \times \gamma_A)(0, x * y)$

$= (\mu_A \times \gamma_A)(0 * 0, x * y)$

$= (\mu_A \times \gamma_A)(0 * x, 0 * y)$

$= min\{(\mu_A \times \gamma_A)(0 * x), (\mu_A \times \gamma_A)(0 * y)\}$

$= min\{\gamma_A(x), \gamma_A(y)\}$

Hence γ_A is a intuitionistic multi fuzzy BG-Ideals of X.

To Prove that μ_A is a intuitionistic multi-fuzzy BG-Ideals of X.

By the above thrm

(i) Either $\mu_A(0) \geq \mu_A(x)$ or $\gamma_A(0) \geq \gamma_A(x)$

Assume that $\mu_A(0) \geq \mu_A(x)$

Also from the above thrm

(iii) Either $\gamma_A(0) \geq \mu_A(x)$ or $\gamma_A(0) \geq \gamma_A(x)$,

If $\gamma_A(0) \geq \mu_A(x)$ then $\gamma_A(0) \geq \mu_A(x)$

$(\mu_A \times \gamma_B)(0,0) = min\{\mu_A(0), \gamma_B(0)\}$

$= \mu_A(0)$

$\mu_A(x) = (\mu_A \times \gamma_A)(x, 0)$

$\geq min\{(\mu_A \times \gamma_A)\big((x, 0) * (y, 0)\big), (\mu_A \times \gamma_A)(y, 0)\}$

$= min\{(\mu_A \times \gamma_A)\big((x * y), (0,0)\big), (\mu_A \times \gamma_A)(y, 0)\}$

$=min\{\mu_A(x * y), \mu_A(y)\}$

Also $\mu_A(x * y) = (\mu_A \times \gamma_A)(x * y, 0)$

$= (\mu_A \times \gamma_A)(x * y, 0)$

$= (\mu_A \times \gamma_A)(x * y, 0 * 0)$

$= min\{(\mu_A \times \gamma_A)(x, 0), (\mu_A \times \gamma_A)(y, 0)\}$

$$= min\{\mu_A(x), \mu_A(y)\}$$

Hence μ_A is a intuitionistic multi-fuzzy BG-Ideals of X.

Clearly, this can be proved for maximal condition also

Hence the result proved

Theorem 4.5 Let $A = (\mu_A, \gamma_A)$ and $B = (\mu_B, \gamma_B)$ are two normal intuitionistic multi fuzzy BG-Ideal of X such that $A \times B = (\mu_{A\times B}, \gamma_{A\times B})$ is a normal intuitionistic multi-fuzzy BG-Ideals of $X \times X$.

Proof:

Let (μ_A, γ_A) and (μ_B, γ_B) are two normal intuitionistic multi fuzzy BG-Ideal of X.

To Prove: $A \times B$ is a normal intuitionistic multi-fuzzy BG-Ideals of $X \times X$.

We Know that $\mu_A(0) = 1_n = 1,1, \dots, n\ times$

$$\mu_B(0) = \gamma_A(0) = \gamma_B(0) = 1_n = 1,1, \dots, n\ times$$

$$\mu_{A\times B}(0) = 1 = \gamma_{A\times B}$$

$$\mu_{A\times B}(0,0) = min\{\mu_A(0), \mu_B(0)\}$$

$$= \min\{1,1\}$$

$$= 1_n(1,1, \dots, n\ times)$$

$$\gamma_{A\times B}(0,0) = max\{\gamma_A(0), \gamma_B(0)\}$$

$$= max\{1,1\}$$

$$= 1_n(1,1, \dots, n\ times)$$

Hence $A \times B$ is a normal intuitionistic multi-fuzzy BG-Ideals of $X \times X$.

5.Conclusion

In this paper the normal intuitionistic multi-fuzzy BG-ideal of BG-algebra and also the cartesian product of intuitionistic multi fuzzy BG-ideals of BG-algebra is defined and its properties are discussed.

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