

Intuitionistic Q-Fuzzy Normal Subgroups

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ABSTRACT: In this paper, we introduce the concept of intuitionistic Q-fuzzy normal group and discussed some of its properties

KEYWORDS: Fuzzy set, , fuzzy subgroup, ,Q-fuzzy subgroup , intuitionistic Q- fuzzy subgroups , Q-fuzzy normal subgroup,Q-fuzzy normalizer , intuitionistic Q- fuzzy normal subgroups, intuitionistic Q- fuzzy normalizer subgroups, intuitionistic Q- fuzzy left and right cosets

I. INTRODUCTION

After the introduction of the concept of fuzzy sets by L.A.Zadeh [6], researchers were conducted the generalizations of the notion of fuzzy sets, A. Rosenfeld [7] introduced the concept of fuzzy group and the idea of “intuitionistic fuzzy set” was first published by K.T. Atanassov [5]. S..Also T. Priya, T.Ramachandran, K.T. Nagalakshmi” *On Q-Fuzzy Normal Subgroups*” [3]..A.Solairaju and R. Nagarajan [1,2] introduce and define a new algebraic structure of Q-fuzzy normal subgroups and Q-fuzzy left and right cosets. Choudhury.F.P. and Chakraborty.A.B. and Khare.S.S,[4] *A note on fuzzy subgroups and Homomorphism Journal of mathematical analysis and applications* In this chapter we introduce the concept of intuitionistic Q-fuzzy normal subgroups and some properties are proved

II. PRELIMINARIES

2.1. Definition:Fuzzy Set

Let X be a non-empty set. A **fuzzy set** μ on X is a mapping $\mu : X \rightarrow [0,1]$ and is defined as

$$\mu = \{x \in X / (x, \mu(x))\}$$

2.2. Definition:Fuzzy Level Subset

Let μ be a fuzzy subset of a set X . For $t \in [0,1]$, $\mu_t = \{x \in X / \mu(x) \geq t\}$ is called a **level fuzzy subset** of μ

2.3. Definition: Fuzzy Multiset (FMS)

Let X be a non-empty set. A **Fuzzy Multiset (FMS)** A drawn from X is characterized by a function ‘Count membership’ of A denoted by CM_A such that $CM_A : X \rightarrow Q$ where Q is the set of all crisp finiteset drawn from the unit interval $[0,1]$.Then for any $x \in X$, the value $CM_A(x)$ is a crisp multiset drawn from

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$[0,1]$. For each $x \in X$, the membership sequence is defined as the decreasingly ordered sequence of elements in $CM_A(x)$. It is denoted by $(\mu_{A_1}(x), \mu_{A_2}(x), \dots, \mu_{A_k}(x))$ where

Example:2.3

Let $X = \{x, y, z, w\}$ be a universal non empty set. For each $x \in X$, we can write a Fuzzy Multi set as follows

$$A = \{ \langle x, (0.8, 0.7, 0.7, 0.6) \rangle, \langle y, (0.8, 0.5, 0.2) \rangle, \langle z, (1, 0.5, 0.5) \rangle \} \text{ Where}$$

$$CM_{A(x)} = (0.8, 0.7, 0.7, 0.6) \text{ with } 0.8 \geq 0.7 \geq 0.7 \geq 0.6$$

2.4. Definition: Q-Fuzzy set

A mapping $\mu : M \times Q \rightarrow [0,1]$, where M and Q are arbitrary non-empty sets is called

Q-fuzzy set of M and is denoted by $A_Q = \{ [(x, q), \mu(x, q)] / x \in M, q \in Q \}$

Example:2.4

Let $M = \{m_1, m_2, m_3, m_4, m_5\}$ and $Q = \{p, q, r\}$ be any two arbitrary non-empty sets, then

$$A_Q = \{ [(m_1, p), 0.3], [(m_1, q), 0.6], [(m_1, r), 0.4], [(m_2, p), 0.3],$$

$$[(m_2, q), 0.3], [(m_2, r), 0.6], [(m_3, r), 0.4], [(m_4, p), 0.3] \}$$

2.5. Definition: Intuitionistic Fuzzy set (IFS)

Let X be a non empty set. An Intuitionistic Fuzzy set A on X is an object having the form

$$A = \{ \langle x, \mu_A(x), \gamma_A(x) \rangle / x \in X \}, \text{ where } \mu_A : X \rightarrow [0,1] \text{ \& } \gamma_A : X \rightarrow [0,1] \text{ are the degree of membership and non-membership functions respectively with } 0 \leq \mu_A(x) + \gamma_A(x) \leq 1$$

2.6. Definition: Intuitionistic Q-Fuzzy set (IQFS)

Let X and Q are arbitrary non-empty sets. An Intuitionistic Q-Fuzzy Set (IQFS in short) A is an object having

the form $A = \{ \langle (x, q), \mu_A(x, q), \gamma_A(x, q) \rangle : x \in X, q \in Q \}$ where the functions

$\mu_A : X \times Q \rightarrow [0,1]$ and $\gamma_A : X \times Q \rightarrow [0,1]$ denote the degree of membership and non-membership of each

element $(x, q) \in X \times Q$ to the set A respectively, and for all $x \in X$ and

$$q \in Q, \quad 0 \leq \mu_A(x, q) + \gamma_A(x, q) \leq 1$$

2.9. Definition:

Let G be a group. A fuzzy subset A of G is said to be a fuzzy subgroup of G if

$$(i). A(xy) \geq \min \{ A(x), A(y) \}$$

$$(ii). A(x^{-1}) \geq A(x) \quad \forall x, y \in G$$

2.7. Definition:

Let G be a group. A fuzzy subset μ of G is said to be a **normal fuzzy subgroup** of G if

$$(i). \mu(xy x^{-1}) = \mu(y) \text{ or } \mu(xy) = \mu(yx)$$

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2.8. Definition:

A Q -fuzzy set μ is called a Q -fuzzy subgroup of a group G if

- (i). $\mu(xy, q) \geq \min \{ \mu(x, q), \mu(y, q) \}$
- (ii). $\mu(x^{-1}, q) \geq \mu(x, q) \quad \forall x, y \in G, q \in Q$

2.9. Definition:

Let μ be a Q -fuzzy subgroup of a group G . For $t \in [0, 1]$, we define the level subset of μ is the set

$$\mu^t = \{ x \in G, q \in Q / \mu(x, q) \geq t \}$$

2.10. Definition:

Let μ be a multi Q -fuzzy subgroup of a group G . For $t \in [0, 1]$, we define the multi level subset of μ is the set

$$\mu_i^t = \{ x \in G, q \in Q / \mu_i(x, q) \geq t \}$$

2.11. Definition: Intuitionistic Q- Fuzzy Level subsets

Let $A = \{ \langle (x, q), \mu_A(x, q), \gamma_A(x, q) \rangle : x \in X, q \in Q \}$ be a IQFS on X . Then for $\alpha, \beta \in [0, 1]$, the set $A^{[\alpha, \beta]} = \{ x \in X, q \in Q / \mu_A(x, q) \geq \alpha \text{ and } \gamma_A(x, q) \leq \beta \}$ is called the (α, β) -level subsets of A .

Theorem:3.1

Let G be a group and A be a Intuitionistic Q -fuzzy subset of G . Then A is a Intuitionistic Q -fuzzy subgroup of a group G iff the Intuitionistic (α, β) -level subsets $A^{[\alpha, \beta]} \quad \alpha, \beta \in [0, 1]$, are subgroups of G

Proof:

Let A be a Intuitionistic Q -fuzzy subgroup of G and the (α, β) -level subset

$$A^{[\alpha, \beta]} = \{ x \in X, q \in Q / \mu_A(x, q) \geq \alpha \text{ and } \gamma_A(x, q) \leq \beta \}.$$

Let $x, y \in A^{[\alpha, \beta]}$. Then $\mu_A(x, q) \geq \alpha$ and $\gamma_A(x, q) \leq \beta$

$$\begin{aligned} \text{Now, } \mu_A(xy^{-1}, q) &\geq \min \{ \mu_A(x, q), \mu_A(y^{-1}, q) \} \\ &= \min \{ \mu_A(x, q), \mu_A(y, q) \} \\ &= \min \{ \alpha, \alpha \} = \alpha \end{aligned}$$

Hence $\mu_A(xy^{-1}, q) \geq \alpha$.

$$\begin{aligned} \text{Similarly, } \gamma_A(xy^{-1}, q) &\leq \text{Max} \{ \gamma_A(x, q), \gamma_A(y^{-1}, q) \} \\ &= \text{Max} \{ \gamma_A(x, q), \gamma_A(y, q) \} \\ &= \text{Max} \{ \beta, \beta \} = \beta \end{aligned}$$

Hence $\gamma_A(xy^{-1}, q) \leq \beta$.

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This implies $xy^{-1} \in A^{[\alpha, \beta]}$.

Thus $A^{[\alpha, \beta]}$ is a subgroup of G .

Conversely, let us assume that $A^{[\alpha, \beta]}$ is a subgroup of G

Let $x, y \in A^{[\alpha, \beta]}$. Then $\mu_A(x, q) \geq \alpha$ and $\gamma_A(x, q) \leq \beta$

Also, $\mu_A(xy^{-1}, q) \geq \alpha = \min \{ \alpha, \alpha \}$

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

$\mu_A(xy^{-1}, q) \geq \min \{ \mu_A(x, q), \mu_A(y, q) \}$

Also, $\gamma_A(xy^{-1}, q) \leq \beta = \text{Max} \{ \beta, \beta \}$

$= \text{Max} \{ \gamma_A(x, q), \gamma_A(y, q) \}$

$\gamma_A(xy^{-1}, q) \leq \text{Max} \{ \gamma_A(x, q), \gamma_A(y, q) \}$

Hence A is a Intuitionistic Q -fuzzy subgroup of G

2.12. Definition:

Let G be a group and A be a Intuitionistic Q -fuzzy subgroup of a group G . Let

$N(A) = \{ a \in G / \mu_A(axa^{-1}, q) = \mu_A(x, q), \gamma_A(axa^{-1}, q) = \gamma_A(x, q) \forall x \in G, q \in Q \}$. Then $N(A)$ is called the Intuitionistic Q -fuzzy normalizer of A

Theorem: 3.2

Let G be a group and A be a Intuitionistic Q -fuzzy subset of G . Then A is a Intuitionistic Q -fuzzy normal subgroup of G iff the level subsets $A^{[\alpha, \beta]}, \alpha, \beta \in [0, 1]$ is a subgroup of G

Proof:

Let A be a Intuitionistic Q -fuzzy normal subgroup of G and the level subsets $A^{[\alpha, \beta]}, \alpha, \beta \in [0, 1]$, is a subgroup of G . Let $x \in G$ and $a \in A^{[\alpha, \beta]}$, then $\mu_A(a, q) \geq \alpha$. Now $\mu_A(xax^{-1}, q) = \mu_A(a, q) \geq \alpha$

Since A a Intuitionistic Q -fuzzy normal subgroup of G

That is, $\mu_A(xax^{-1}, q) \geq \alpha$

$\Rightarrow xax^{-1} \in A^{[\alpha, \beta]}$

Similarly, $\gamma_A(xax^{-1}, q) = \gamma_A(a, q) \leq \beta$

Since A a Intuitionistic Q -fuzzy normal subgroup of G

That is, $\gamma_A(xax^{-1}, q) \leq \beta$

$\Rightarrow xax^{-1} \in A^{[\alpha, \beta]}$

Hence $A^{[\alpha, \beta]}$ is a normal subgroup of G

Theorem: 3.3

Let A be a Intuitionistic Q -fuzzy normal subgroup of a group G . Then

(i). $N(A)$ is a subgroup of a group G .

(ii). A is a Intuitionistic Q -fuzzy normal subgroup of a group G iff $N(A) = G$.

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(iii). A is a Intuitionistic Q -fuzzy normal subgroup of a group $N(A)$.

Proof:

Let $a, b \in N(A) \Rightarrow \mu_A(xax^{-1}, q) \geq \alpha, \mu_A(xbx^{-1}, q) \geq \alpha$, for all $x \in G, q \in Q$. Now,

$$\begin{aligned} \mu_A(abx(ab)^{-1}, q) &= \mu_A(abxb^{-1}a^{-1}, q) \Rightarrow \\ &= \mu_A(bxb^{-1}, q) = \mu_A(x, q). \end{aligned}$$

Thus $\mu_A(abx(ab)^{-1}, q) = \mu_A(x, q)$

Let $a, b \in N(A) \Rightarrow \gamma_A(xax^{-1}, q) \leq \beta, \gamma_A(xbx^{-1}, q) \leq \beta$, for all $x \in G, q \in Q$.

Now, $\gamma_A(abx(ab)^{-1}, q) = \gamma_A(abxb^{-1}a^{-1}, q) \Rightarrow$
 $= \gamma_A(bxb^{-1}, q) = \gamma_A(x, q)$.

Thus $\gamma_A(abx(ab)^{-1}, q) = \gamma_A(x, q)$

This implies $ab \in N(\lambda)$

That is $N(A)$ is a subgroup of a group G

(ii). From (i). $N(A) \subseteq G$, A is a Intuitionistic Q -fuzzy normal subgroup of a group G .

Let $a \in G \Rightarrow \mu_A(axa^{-1}, q) = \mu_A(x, q) \Rightarrow a \in N(A)$.

$$\gamma_A(axa^{-1}, q) = \gamma_A(x, q) \Rightarrow a \in N(A)$$

Hence $N(A) = G$. Conversely let $N(A) = G$.

Clearly $\mu_A(axa^{-1}, q) = \mu_A(x, q)$, and $\gamma_A(axa^{-1}, q) = \gamma_A(x, q) \quad \forall a, x \in G, q \in Q$

Hence A is a Intuitionistic Q -fuzzy normal subgroup of group G .

From (2), A is a Intuitionistic Q -fuzzy normal subgroup of a group $N(A)$

Theorem: 3.4

If A is a Intuitionistic Q -fuzzy subgroup of a group G . Then $g\mu_A g^{-1}$ & $g\gamma_A g^{-1}$ are also a Intuitionistic Q -fuzzy subgroups of a group G for all $g \in G$ and $q \in Q$.

Proof:

Let A is an Intuitionistic Q -fuzzy subgroup of a group G

Then (i). $(g\mu_A g^{-1})(xy, q) = \mu_A(g^{-1}(xy)g, q)$
 $= \mu_A(g^{-1}(xgg^{-1}y)g, q)$
 $= \mu_A((g^{-1}xg)(g^{-1}yg), q)$
 $\geq \text{Min} \{ \mu_A(g^{-1}xg, q), \mu_A(g^{-1}yg, q) \}$

for all $\forall x, y \in G$ and $q \in Q$

Similarly, $(g\gamma_A g^{-1})(xy, q) = \gamma_A(g^{-1}(xy)g, q)$
 $= \gamma_A(g^{-1}(xgg^{-1}y)g, q)$
 $= \gamma_A((g^{-1}xg)(g^{-1}yg), q)$
 $\leq \text{Max} \{ \gamma_A(g^{-1}xg, q), \gamma_A(g^{-1}yg, q) \}$

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for all $\forall x, y \in G$ and $q \in Q$

$$\begin{aligned} \text{(ii). } (g\mu_A g^{-1})(x, q) &= \mu_A(g^{-1}xg, q) \\ &= \mu_A\left(\left(g^{-1}xg\right)^{-1}, q\right) \\ &= \mu_A\left(g^{-1}x^{-1}g, q\right) \\ &= g\mu_A g^{-1}\left(x^{-1}, q\right) \end{aligned}$$

Similarly, $(g\gamma_A g^{-1})(x, q) = \gamma_A(g^{-1}xg, q)$

$$\begin{aligned} &= \gamma_A\left(\left(g^{-1}xg\right)^{-1}, q\right) \\ &= \gamma_A\left(g^{-1}x^{-1}g, q\right) \\ &= g\gamma_A g^{-1}\left(x^{-1}, q\right) \end{aligned}$$

for all $\forall x, y \in G$ and $q \in Q$.

Hence $g\mu_A g^{-1}$ & $g\gamma_A g^{-1}$ are also a Intuitionistic Q -fuzzy subgroups of a group G .

Theorem:3.5:

Let A and B be two Intuitionistic Q -fuzzy subgroup of a group G . Then $A \cap B$ is also an Intuitionistic Q -fuzzy subgroup of a group G

Proof:

Let A and B be two Intuitionistic Q -fuzzy subgroups of a group G

$$\begin{aligned} \text{(i). } (A \cap B)(xy^{-1}, q) &= \text{Min}\left\{\mu_A(xy^{-1}, q), \mu_B(xy^{-1}, q)\right\} \\ &\geq \text{Min}\left\{\min\{\mu_A(x, q), \mu_A(y, q)\}, \min\{\mu_B(x, q), \mu_B(y, q)\}\right\} \\ &\geq \text{Min}\left\{\min\{\mu_A(x, q), \mu_B(x, q)\}, \min\{\mu_A(y, q), \mu_B(y, q)\}\right\} \\ &= \text{Min}\left\{(A \cap B)(x, q), (A \cap B)(y, q)\right\} \end{aligned}$$

Thus $(A \cap B)(xy^{-1}, q) \geq \text{Min}\left\{(A \cap B)(x, q), (A \cap B)(y, q)\right\}$

$$\begin{aligned} \text{Similarly, } (A \cap B)(xy^{-1}, q) &= \text{Max}\left\{\gamma_A(xy^{-1}, q), \gamma_B(xy^{-1}, q)\right\} \\ &\leq \text{Max}\left\{\max\{\gamma_A(x, q), \gamma_A(y, q)\}, \max\{\gamma_B(x, q), \gamma_B(y, q)\}\right\} \\ &\leq \text{Max}\left\{\max\{\gamma_A(x, q), \gamma_B(x, q)\}, \max\{\gamma_A(y, q), \gamma_B(y, q)\}\right\} \\ &= \text{Max}\left\{(A \cap B)(x, q), (A \cap B)(y, q)\right\} \end{aligned}$$

Thus $(A \cap B)(xy^{-1}, q) \leq \text{Max}\left\{(A \cap B)(x, q), (A \cap B)(y, q)\right\}$

$$\begin{aligned} \text{(ii). } (A \cap B)(x, q) &= \text{Min}\left\{\mu_A(x, q), \mu_B(x, q)\right\} = \text{Min}\left\{\mu_A(x^{-1}, q), \mu_B(x^{-1}, q)\right\} \\ &= \text{Min}\left\{(A \cap B)(x^{-1}, q)\right\}. \end{aligned}$$

$$\begin{aligned} (A \cap B)(x, q) &= \text{Max}\left\{\gamma_A(x, q), \gamma_B(x, q)\right\} = \text{Max}\left\{\gamma_A(x^{-1}, q), \gamma_B(x^{-1}, q)\right\} \\ &= \text{Max}\left\{(A \cap B)(x^{-1}, q)\right\} \end{aligned}$$

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Hence $A \cap B$ is also an Intuitionistic Q -fuzzy subgroup of a group G

Theorem: 3.6

The intersection of any two Intuitionistic Q -fuzzy normal subgroup of a group G is also a Intuitionistic Q -fuzzy normal subgroup of a group G .

Proof:

Let A and B be two Intuitionistic Q -fuzzy normal subgroup of a group G

According to previous theorem, $A \cap B$ is also a Intuitionistic Q -fuzzy subgroup of a group G

Now we have to prove that $A \cap B$ is a normal subgroup

Now $\forall x, y \in G$ and $q \in Q$ we have

$$\begin{aligned} (A \cap B)(xyx^{-1}, q) &= \min\{\mu_A(xyx^{-1}, q), \mu_B(xyx^{-1}, q)\} \\ &= \min\{\mu_A(y, q), \mu_B(y, q)\} \\ &= (A \cap B)(y, q) \end{aligned}$$

Similarly, $\forall x, y \in G$ and $q \in Q$ we have

$$\begin{aligned} (A \cap B)(xyx^{-1}, q) &= \text{Max}\{\gamma_A(xyx^{-1}, q), \gamma_B(xyx^{-1}, q)\} \\ &= \text{Max}\{\gamma_A(y, q), \gamma_B(y, q)\} \\ &= (A \cap B)(y, q) \end{aligned}$$

Hence $A \cap B$ is a Intuitionistic Q -fuzzy normal subgroup of a group G

3.7. Definition:

The mapping $f : G \times Q \rightarrow H \times Q$ is said to be a group Intuitionistic Q -fuzzy homomorphism if

- (i). $f : G \rightarrow H$ is a group homomorphism
- (ii). $f(xy, q) = (f(x)f(y), q) \quad \forall x, y \in G, q \in Q$

Theorem: 3.7

Let $f : G \times Q \rightarrow H \times Q$ be Intuitionistic Q -fuzzy group homomorphism

- (i). If A is a Intuitionistic Q -fuzzy normal subgroup of a group H , then $f'(A)$ is a Intuitionistic Q -fuzzy normal subgroup of a group G ,
- (ii). If f is an epimorphism and A is a Intuitionistic Q -fuzzy normal subgroup of a group G , then $f(A)$ is a Intuitionistic Q -fuzzy normal subgroup of a group H

Proof:

Let $f : G \times Q \rightarrow H \times Q$ be a group Intuitionistic Q -fuzzy homomorphism and let A be a Intuitionistic Q -fuzzy normal subgroup of a group H .

$$\begin{aligned} \text{Now, for all } x, y \in G, q \in Q \text{ we have } f'(\mu_A)(xyx^{-1}, q) &= \mu_A(f(xyx^{-1}, q)) \\ &= \mu_A\left(f(x)f(y)(f(x))^{-1}, q\right) \\ &= \mu_A(f(y), q) \end{aligned}$$

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$$= f'(\mu_A)(y, q)$$

$$\text{Similarly, } f'(\gamma_A)(xyx^{-1}, q) = \gamma_A(f(xyx^{-1}, q))$$

$$= \gamma_A\left(f(x)f(y)(f(x))^{-1}, q\right)$$

$$= \mu_A(f(y), q)$$

$$= f'(\gamma_A)(y, q)$$

Hence $f'(A)$ is a Intuitionistic Q -fuzzy normal subgroup of a group G ,

(ii). Let A be a Intuitionistic Q -fuzzy normal subgroup of a group G , then $f(A)$ is a Intuitionistic Q -fuzzy subgroup of a group H

Now, for all $u, v \in H$ we have

$$f(\mu_A)(uvu^{-1}, q) = \sup_{f(\mu_A)=uvu^{-1}} \mu_A(y, q) = \sup_{f(x)=u; f(y)=v} \mu_A(y, q)$$

$$= \sup_{f(y)=v} \mu_A(y, q) = f(\mu_A)(v, q) \text{ since } f \text{ is an epimorphism}$$

$$f(\gamma_A)(uvu^{-1}, q) = \inf_{f(\gamma_A)=uvu^{-1}} \gamma_A(y, q) = \inf_{f(x)=u; f(y)=v} \gamma_A(y, q)$$

$$= \inf_{f(y)=v} \gamma_A(y, q) = f(\gamma_A)(v, q) \text{ since } f \text{ is an epimorphism}$$

Hence $f(\mu_A, \gamma_A)$ is a Intuitionistic Q -fuzzy normal subgroup of a group H .

III. CONCLUSION

In this article we have discussed Intuitionistic Q -fuzzy normal subgroups, n -generated Q -fuzzy Normalizer and Intuitionistic Q -fuzzy subgroups under homomorphism. Interestingly, it has been observed that Q -fuzzy concept adds another dimension to the defined fuzzy normal subgroups. This concept can further be extended for new results

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