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# Characterization of Quotient Multi-Fuzzy Subgroup

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Abstract: In this paper we define a new algebraic structure of quotient multi-fuzzy subgroup f a group and some of its properties under homomorphism and anti-homomorphism are investigated. The purpose of this study is to implement the fuzzy set theory and group theory in multi-fuzzy set. Characterization of quotient multi-fuzzy subgroup of a group is given. Mathematics Subject Classification20N25, 03E72, 08A72, 03F55, 06F35, 03G25, 08A05, 08A30. Key Words: Fuzzy set, multi-fuzzy set, fuzzy subgroup, multi-fuzzy subgroup, multi-fuzzy coset

# I. INTRODUCTION

L.A.Zadeh [9] introduced the theory of fuzzy set in 1965. Rosenfeld [6] introduced fuzzy subgroups in 1971. P.S.Das[2] studied the inter-relationship between the fuzzy subgroup and its level subgroups in 1981. Mukharjee and Bhattacharya [4] proposed the concept of normal fuzzy subgroups and fuzzy cosets in 1984. S.Sabu and T.V.Ramakrishnan[7, 8] proposed the theory of multi-fuzzy set in terms of multi-dimensional membership functions and investigated some properties of multi-level fuzziness in 2010 and 2011. R.Muthuraj and S.Balamurugan[5] proposed the inter-relationship between the multi-fuzzy subgroup and its level subgroups in 2013.Several researchers N.Ajmal [1], Kumar I.J., Saxena P.K., and Yadav P. [3], etc., are developed the concept of fuzzy normal subgroup and fuzzy quotient group.In this paper we define a new algebraic structure of multi-fuzzy quotient group of a group and also establish some of its related properties.

#### **II. PRELIMINARIES**

In this section, we site the fundamental definitions that will be used in the sequel.

A. Definition2.1

Let X be any non-empty set. A fuzzy subset  $\mu$  of X is  $\mu : X \rightarrow [0,1]$ .

## B. Definition2.2

Let Xbe a non-empty set. A multi-fuzzy set Ain Xis defined as a set of ordered sequences:  $A = \{ (x, \mu_1(x), \mu_2(x), ..., \mu_i(x), ..$ 

## C. Remark 2.3

- 1) If the sequences of the membership functions have only k-terms (finite number of terms), then k is called the dimension of A
- 2) The multi-fuzzy membership function  $\mu_A$  is a function from X to  $[0, 1]^k$  such that for all x in X,  $\mu_A(x) = (\mu_1(x), \mu_2(x), ..., \mu_k(x))$
- 3) For the sake of simplicity, we denote the multi-fuzzy set A= {  $(x,\mu_1(x), \mu_2(x), ..., \mu_k(x))$ :  $x \in X$ } as A= $(\mu_1, \mu_2, ..., \mu_k)$ .

## D. Definition 2.4

Let k be a positive integer and let Aand Bbe two multi-fuzzy subsets of a non-empty set X, where  $A = (\mu_1, \mu_2, ..., \mu_k)$  and  $B = (\nu_1, \nu_2, ..., \nu_k)$ , then we have the following relations and operations:

- *I*)  $A \subseteq B$  if and only if  $\mu_i \le \nu_i$ , for all i = 1, 2, ..., k;
- 2) A= Bif and only if  $\mu_i = \nu_i$ , for all i = 1, 2, ..., k;
- 3)  $A \cup B = (\mu_1 \cup \nu_1, ..., \mu_k \cup \nu_k) = \{(x, max(\mu_1(x), \nu_1(x)), ..., max(\mu_k(x), \nu_k(x))) : x \in X\};$
- 4)  $A \cap B = (\mu_1 \cap \nu_1, ..., \mu_k \cap \nu_k) = \{(x, \min(\mu_1(x), \nu_1(x)), ..., \min(\mu_k(x), \nu_k(x))) : x \in X\};$

## E. Definition 2.5

Let  $A = (\mu_1, \mu_2, ..., \mu_k)$  be a multi-fuzzy subset of X having dimension k and let  $\mu_i$ 'be the fuzzy complement of the ordinary fuzzy set  $\mu_i$  for each i = 1, 2, ..., k. The complement f a multi-fuzzy set A is a multi-fuzzy set  $A^C = (\mu_1', \mu_2', ..., \mu_k')$  where each  $\mu_i' = 1 - \mu_i$  for i=1,2,...,k. That is,  $A^C = \{(x,1-\mu_1(x),...,1-\mu_k(x)): x \in X\}$ .

# F. Definition 2.6

Let  $\mu$  be a fuzzy set on a group G. Then  $\mu$  is said to be a fuzzy subgroup of G if

- 1)  $\mu(xy) \ge \min \{\mu(x), \mu(y)\}$  and
- 2)  $\mu(x^{-1}) = \mu(x)$ .

# G. Definition 2.7

A multi-fuzzy set A of a group G is called a multi-fuzzy subgroup of G iffor allx,  $y \in G$ ,

- 1)  $A(xy) \ge \min \{A(x), A(y)\}$  and
- 2)  $A(x^{-1}) = A(x)$ .

## H. Definition 2.8

Let A be a multi-fuzzy subgroup of a group G. For any  $a \in G$ , define  $(aA)(x) = A(a^{-1}x)$  for all  $x \in G$  is called a multi-fuzzy coset of a multi-fuzzy subgroup Aof the group G determined by the element  $a \in G$ .

I. Remark 2.9

If a = e in G, then the multi-fuzzy cosetaA = A, where A is a multi-fuzzy subgroup of group G.

# III. PROPERTIES OF MULTI-FUZZY QUOTIENT GROUP A OF AGROUP G DETERMINED BY A AND K

In this section, we discuss some of the properties of multi-fuzzy quotient group A of a group G determined by A and K.

A. Theorem 3.1

Let A be a normal multi-fuzzy subgroup of a group G with identity e. Let

 $K = \{ x \in G / A(x) = A(e) \}.$  Consider

 $\overline{\mathbf{A}} = (\overline{\mathbf{A}}_1, \overline{\mathbf{A}}_2, \overline{\mathbf{A}}_3, ..., \overline{\mathbf{A}}_k)$  which is defined by

$$\overline{A}(xK) = \underset{k \in K}{sur} A(xk)$$
, for all  $x \in G$ , where each  $\overline{A}_i : G/K \to [0,1]$ . Then

- 1) K is a normal subgroup of G
- 2) The multi-fuzzy set A is well-defined
- 3) A is a multi-fuzzy subgroup of  $G_{K}$ .
- 4) *Proof:* Given A is a normal multi-fuzzy subgroup of G and
- a)  $K = \{ x \in G / A(x) = A(e) \}$ . Let  $x \in G$  and  $y \in K$ . Then A(y) = A(e).

Since A is a normal multi-fuzzy subgroup of G,  $A(xyx^{-1}) = A(y) = A(e)$ . Hence,  $xyx^{-1} \in K$ . Hence,  $K = \{x \in G / A(x) = A(e)\}$  is a normal subgroup of G.

b) Consider  $\overline{A} = (\overline{A_1}, \overline{A_2}, \overline{A_3}, ..., \overline{A_k})$  which is defined by  $\overline{A}(xK) = \sup_{k \in K} A(xk)$ , for all  $x \in G$ , where each  $\overline{A_i} : G_K \to K$ 

[0,1].

Let xK = yK for some x,  $y \in G$ . Thenxy<sup>-1</sup>  $\in K$ . That is,  $A(xy^{-1}) = A(e)$ . That is,  $\overline{A}(xK) = \overline{A}(yK)$ . Hence, the map  $\overline{A}$  is well-defined. Now,  $\overline{A}(xKyK) = \overline{A}(xyK)$ 

$$= \underset{k \in K}{\overset{\textbf{Sup}}{\text{sup}}} A(xyk) \text{, for all } x, y \in G.$$

$$\geq \underset{k_1, k_2 \in K}{\overset{\textbf{Sup}}{\text{sup}}} \{ \min\{(A(xk_1), A(yk_2)\} \} \text{.}$$

$$\geq \min\{\underset{k_1 \in K}{\overset{\textbf{Sup}}{\text{sup}}} A(xk_1), \underset{k_2 \in K}{\overset{\textbf{Sup}}{\text{sup}}} A(yk_2) \}.$$

$$\geq \min\{\overline{A}(xK), \overline{A}(yK) \}.$$

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$$\equiv \overline{A}(xK), \overline{A}(yK) \}.$$

$$\equiv \overline{A}(xK), \overline{A}(yK) \}.$$

$$\equiv \underset{k \in K}{\overset{\textbf{Sup}}{\text{sup}}} A(x^{-1}k), \text{ for all } x \in G.$$

$$\equiv \underset{k \in K}{\overset{\textbf{Sup}}{\text{sup}}} A(xk), \text{ for all } x \in G.$$

$$\equiv \overline{A}(xK).$$

$$\equiv \overline{A}(xK).$$
Hence,  $\overline{A}$  is a multi-fuzzy subgroup of  $\underset{K \in K}{\overset{\textbf{G}}{\text{sup}}}.$ 

#### B. Definition 3.2

Let A be a normal multi-fuzzy subgroup of a group G with the identity element 'e'. Let  $K = \{x \in G / A(x) = A(e)\}$ . Consider  $\overline{A} = (\overline{A}_1, \overline{A}_2, \overline{A}_3, ..., \overline{A}_k)$  which is defined by  $\overline{A}(xK) = \sup_{k \in K} A(xk)$ , for all  $x \in G$  where each  $\overline{A}_i : G/_K \to [0,1]$ . Then the multi-fuzzy subgroup  $\overline{A}$  of  $G/_K$  is called a multi-fuzzy quotient group or quotient multi-fuzzy subgroup of A by K.

- C. Remarks3.3
- 1)  $\overline{A}$  is not a normal multi-fuzzy quotient group of G/K, Since,  $\overline{A}(xKyK) \neq \overline{A}(yKxK)$ .
- 2) Consider  $\overline{A} = (\overline{A_1}, \overline{A_2}, \overline{A_3}, ..., \overline{A_k})$  which is defined by  $\overline{A}(xK) = A(x)$ , for all  $x \in G$ , where each  $\overline{A_i} : G/K \to [0,1]$ . Then  $\overline{A}$  is a normal multi-fuzzy quotient group of G/K.
- D. Theorem3.4

 $\overline{A} = (\overline{A}_{1}, \overline{A}_{2}, \overline{A}_{3}, ..., \overline{A}_{k}) \text{ is a multi-fuzzy quotient group of a group } G'_{K} \text{ iff each } \overline{A}_{i}, i = 1, 2, ..., k, \text{ is a fuzzy quotient group of a group } G'_{K}.$   $I) \quad Proof: \text{ Let } \overline{A} = (\overline{A}_{1}, \overline{A}_{2}, \overline{A}_{3}, ..., \overline{A}_{k}) \text{ be a multi-fuzzy quotient group of a group } G'_{K}. \text{ Then,}$   $\Leftrightarrow \overline{A}(xyK) \ge \min\{\overline{A}(xK), \overline{A}(yK)\} \text{ and } \overline{A}(x^{-1}K) = \overline{A}(xK).$ 

 $\Leftrightarrow \overline{A}_{i}(xyK) \geq \min\{\overline{A}_{i}(xK), \overline{A}_{i}(yK)\} \text{ and } \overline{A}_{i}(x^{-1}K) = \overline{A}_{i}(xK), \text{ for all } i = 1, 2, ..., k. \\ \Leftrightarrow \overline{A}_{i}, i = 1, 2, ..., k \text{ , is a fuzzy quotient group of a group } G/K.$ 

#### E. Remark3.5

If  $\overline{A} = (\overline{A}_1, \overline{A}_2, \overline{A}_3, ..., \overline{A}_k)$  is not a multi-fuzzy quotient group of a group  $G_K$ , then there is at least one  $\overline{A}_i$ , i=1,2,...,k, is not a fuzzy quotient group of a group  $G_K$ .

F. Theorem 3.6

If  $\overline{A}$  is a multi-fuzzy quotient group of a group G/K, then  $\overline{A}(xK) \le \overline{A}(eK)$ , for all  $x \in G$ , where e is the identity element of G.

1) Proof: Let the element  $x \in G$ , where e is the identity element of G.

Now, 
$$A(eK) = A(xx^{-1}K)$$
  
 $\geq \min\{\overline{A}(xK), \overline{A}(x^{-1}K)\}$   
 $= \overline{A}(xK).$ 

Therefore,  $\overline{A}(eK) \ge \overline{A}(xK)$ , for all  $x \in G$ .

G. Theorem3.7

 $\overline{A}$  is a multi-fuzzy quotient group of a group  ${G\!\!\!\!/}_K$   $\quad$  if and only if

 $\overline{A} (xKy^{-1}K) \geq \min\{ \overline{A} (xK), \overline{A} (yK) \}, \text{ for all } x \text{ and } y \text{ in } G.$ 

1) Proof: Assume that  $\overline{A}$  is a multi-fuzzy quotient group of a group  $G_{K}^{\prime}$ .

We have	, $\overline{\mathbf{A}}(\mathbf{x}\mathbf{K}\mathbf{y}^{-1}\mathbf{K})$	$\geq \min\{\overline{A}(xK), \overline{A}(y^{-1}K)\}\$
		$\geq \min\{\overline{A}(\mathbf{x}\mathbf{K}), \overline{A}(\mathbf{y}\mathbf{K})\}$
Therefore,	$\overline{A}(xKy^{-1}K)$	$\geq \min\{\overline{A}(xK), \overline{A}(yK)\}, \text{ for all } x \text{ and } y \text{ in } G.$
Conversely, if $\overline{A}$ (xKy <sup>-1</sup> K)		$\geq \min\{\overline{A}(xK), \overline{A}(yK)\}, \text{ then }$
	$\overline{\mathbf{A}}$ (x <sup>-1</sup> K)	$=\overline{\mathbf{A}}(\mathbf{ex}^{-1}\mathbf{K})$
		$\geq \min\{\overline{A}(eK), \overline{A}(xK)\}$
		$=\overline{\mathbf{A}}(\mathbf{x}\mathbf{K}).$
Therefore,	$\overline{A}(x^{-1}K)$	$\geq \overline{A}$ (xK), for all x in G.
Hence,	$\overline{\mathbf{A}}$ ((x <sup>-1</sup> ) <sup>-1</sup> K)	$\geq \overline{A}(x^{-1}K) \text{ and } \overline{A}(xK) \geq \overline{A}(x^{-1}K).$
herefore,	$\overline{A}(x^{-1}K)$	$=\overline{\mathbf{A}}(\mathbf{x}\mathbf{K}),$ for all x in G.
Now, replace	y by y <sup>-1</sup> , then	
	$\overline{\mathbf{A}}$ (xyK)	$= \overline{\mathbf{A}} \left( \mathbf{x} (\mathbf{y}^{-1})^{-1} \mathbf{K} \right)$
		$\geq \min\{\overline{A}(xK), \overline{A}(y^{-1}K)\}$
	$\overline{\mathbf{A}}$ (xyK)	$\geq \min\{\overline{A}(xK), \overline{A}(y^{-1}K)\}, \text{ for all } x \text{ and } y \text{ in } G.$

Hence,  $\overline{A}$  is a multi-fuzzy quotient group of a group  $\frac{G}{K}$ .

H. Theorem 3.8

If  $\overline{A}$  and  $\overline{B}$  are two multi-fuzzy quotient groups of a group  $G_{K}$ , then  $\overline{A} \cap \overline{B}$  is a multi-fuzzy quotient group of  $G_{K}$ . *1) Proof:* It is trivial.

## I. Remark 3.9

The intersection of a family of multi-fuzzy quotient groups of a group  $G_{K}$ , is a multi-fuzzy quotient group of a group

# IV. PROPERTIES OF MULTI-FUZZY QUOTIENT GROUP A DETERMINED BY A AND K UNDER HOMOMORPHISM AND ANTI-HOMOMORPHISM

In this section, we discuss some of the properties of multi-fuzzy quotient group of a group G/K determined by A and K under homomorphism and anti-homomorphism.

## A. Theorem 4.1

Let G and G' be any two groups. Let f:  $G \to G'$  be a homomorphism and onto. Let  $\overline{A}$  be a multi-fuzzy quotient group of G/K. Then  $f(\overline{A})$  is a multi-fuzzy quotient group of  $G'_{K'}$ , if  $\overline{A}$  has sup property and  $\overline{A}$  is f-invariant and  $f(\overline{A}) = \overline{f(A)}$ . 1) Proof: Let  $\overline{A}$  be a multi-fuzzy quotient group of  $G_{K}$ .  $f(\overline{A})(f(x)f(y)K) = (f(\overline{A}))(f(xy)K)$  $=\overline{A}_{(xvK)}$  $\geq \min\{\overline{A}(xK), \overline{A}(yK)\}$  $= \min\{ (f(\overline{A}))(f(x)K), (f(\overline{A})(f(y)K)) \}$  $\geq \min_{\underline{A}} \{ (f(\overline{A}))(f(x)K), (f(\overline{A})(f(y)K)) \}.$  $f(\overline{A})(f(x)f(y)K)$  $f(\overline{A})([f(x)]^{-1}K)$  $= f(\overline{A})[f(x^{-1})K]$  $=\overline{\mathbf{A}}(\mathbf{x}^{-1}\mathbf{K})$  $=\overline{A}(xK)$  $= f(\overline{A})[f(x)K]$  $f(\overline{A})([f(x)]^{-1}K) = f(\overline{A})[f(x)K].$ Hence,  $f(\overline{A})$  is amulti-fuzzy quotient group of  $\mathbf{G'_K'}$ .  $= \sup_{k \in K} f(A)(yk)$ , for all  $y \in G'$ . Also,  $\overline{f(A)}$  (yK) =  $\sup_{k \in K} f(A)(f(x)k)$ , f is onto and  $x \in G$ .  $= \sup_{k \in K} A(xk), \text{ for all } x \in G$  $=\overline{A}(xK)$  $= f(\overline{A})(f(x)K)$  $= f(\overline{A})(yK).$  $\overline{f(A)}$  (yK)  $= f(\overline{A})(yK).$ Hence.

# B. Theorem 4.2

Let G and G' be any two groups. Let f:  $G \to G'$  be a homomorphism. Let  $\overline{B}$  be a multi-fuzzy quotient group of  $G'_{K'}$ . Then  $f^{-1}(\overline{B})$ 

) is a multi-fuzzy quotient group of  $G_{K}$  and  $f^{-1}(\overline{B}) = \overline{f^{-1}(B)}$ .

1) Proof: Let  $\overline{B}$  be a multi-fuzzy quotient group of  $G'_{K'}$ . For all x, y in G,

 $f^{-1}(\overline{B})(xyK) = \overline{B}(f(xy)K)$ 

$$= \overline{B} (f(x)f(y)K)$$

$$\geq \min \{\overline{B} (f(x)K), \overline{B} (f(y)K)\}$$

$$\geq \min \{\overline{f}^{-1}(\overline{B})(xK), f^{-1}(\overline{B})(yK)\}, f^{-1}(\overline{B})(yK)\}, f^{-1}(\overline{B})(yK)\}, f^{-1}(\overline{B})(xK), f^{-1}(\overline{B})(yK)\}, f^{-1}(\overline{B})(xK), f^{-1}(\overline{B})(yK)\}, f^{-1}(\overline{B})(xK), f^{-1}(\overline{B})($$

# C. Theorem 4.3

Let G and G' be any two groups. Let  $f: G \to G'$  be an anti-homomorphism and onto. Let  $\overline{A}$  be a multi-fuzzy quotient group of  $G'_{K'}$ . Then  $f(\overline{A})$  is a multi-fuzzy quotient group of  $G'_{K'}$ , if  $\overline{A}$  has sup property and  $\overline{A}$  is f-invariant and  $f(\overline{A}) = \overline{f(A)}$ .

$$= \frac{Sur}{k \in K} f(A)(f(x)k) , f \text{ is onto and } x \in G.$$

$$= \frac{Sur}{k \in K} A(xk) , \text{ for all } x \in G.$$

$$= \overline{A} (xK)$$

$$= f(\overline{A})(f(x)K)$$

$$= f(\overline{A})(gK).$$
Hence,  $\overline{f(A)}(gK) = f(\overline{A})(gK).$ 

Hence,

D. Theorem 4.4

Let G and G' be any two groups. Let f:  $G \to G'$  be an anti-homomorphism. Let  $\overline{B}$  be a multi-fuzzy quotient group of  $G'_{K'}$ .

Then 
$$f^{-1}(\overline{B})$$
 is a multi-fuzzy quotient group of  $G_{K}$  and  $f^{-1}(\overline{B}) = \overline{f^{-1}(B)}$ .

Let  $\,\overline{B}$  be a multi-fuzzy quotient group of  $\,G'\!\!\!\!\!/ K'$  .

$$\begin{split} f^{-1}(\overline{B})(xyK) &= \overline{B}(f(xy)K) \\ &= \overline{B}(f(y)f(x)K) \\ &\geq \min\{\overline{B}(f(y)K), \overline{B}(f(x)K)\} \\ &\geq \min\{\overline{B}(f(x)K), \overline{B}(f(y)K)\} \\ &\geq \min\{f^{-1}(\overline{B})(xK), f^{-1}(\overline{B})(yK)\} \\ f^{-1}(\overline{B})(xyK) &\geq \min\{f^{-1}(\overline{B})(xK), f^{-1}(\overline{B})(yK)\} \\ f^{-1}(\overline{B})(x^{-1}K) &= \overline{B}(f(x^{-1})K) \\ &= \overline{B}(f(x)K) \\ &= f^{-1}(\overline{B})(xK). \\ f^{-1}(\overline{B})(x^{-1}K) &= f^{-1}(\overline{B})(xK). \\ \end{split}$$
Hence,  $f^{-1}(\overline{B})$  is a multi-fuzzy quotient subgroup of  $G_{K}^{/}$ .  
Also,  $\overline{f^{-1}(B)}(xK) &= f^{-1}(B)(xk)$ , for all  $x \in G$ .  

$$= \underbrace{Suf}_{k \in K} B(f(x)k)$$
, for all  $x \in G$ .  

$$= \overline{B}(f(x)K) \\ &= f^{-1}(\overline{B})(xK). \\ \end{aligned}$$
Hence,  $\overline{f^{-1}(B)}(xK) &= f^{-1}(\overline{B})(xK)$ .

#### **V. CONCLUSION**

In this paper we define a new algebraic structure of multi-fuzzy quotient group of a group and discussed some of its related properties under homomorphism and anti-homomorphism. These are very helpful to the development of the theory of multi-fuzzy set. The purpose of this study is to implement the fuzzy set theory and the group theory in multi-fuzzy set. Characterization of multi-fuzzy quotient group of a group are given.

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