Construction of Q- Rung Orthopair (M, N) Uncertainty Level Subgroup Structures

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ABSTRACT

The main objective of this article is to introduce the idea of q-rung orthopair (m, n)-fuzzy subgroups of a finite group. We discuss the concept of q-rung orthopair (m, n) – fuzzy subgroups as a combination of intuitionist fuzzy subgroup and Pythagorean fuzzy subgroup. We provide the definition of q-rung orthopair (m, n) – fuzzy subgroup and examine various properties associated with it. Finally we analyze q-rung orthopair (m, n)- fuzzy cosets, (m, n) – fuzzy normal subgroups and (m, n)- fuzzy level subgroups.

Keywords: intuitionist fuzzy set, Pythagorean fuzzy set, q-rung orthopair (m, n)- fuzzy subgroup, q-rung orthopair (m,n)- fuzzy Coset, normal subgroup, homomorphism.

AMS Subject classification: 20N25, 03E72, 94605.

INTRODUCTION

To handle uncertainty in real-life problems Zadeh LA [1] proposed the concept of Fuzzy Sets (FSs). In 1971 expanding the notion of FSs, Rosenfeld A [2] defined fuzzy subgroup. In recent years many researchers studied various properties of fuzzy subgroups, t-norm fuzzy subgroups, fuzzy level subgroup, fuzzy subgroups and fuzzy homomorphism, anti-fuzzy subgroups, fuzzy normal subgroup, fuzzy coset and fuzzy quotient subgroup etc [3-14]. In 1986, Atanassov KT [15] introduced Intuitionistic Fuzzy Set (IFS). In 1996, Intuitionistic fuzzy subgroup was first studied by Biswas R [16]. Zhan J et al. [17] introduced intuitionistic fuzzy M-group. Furthermore, researchers developed intuitionistic fuzzy subgroup in many ways [18-20]. In 2013, Yager RR [21] invented Pythagorean Fuzzy Sets (PFSs). In 2018, Naz .S et al. [22] proposed a novel approach to decision-making problem using Pythagorean fuzzy set. In 2019, Akram M et al. [23] applied

complex Pythagorean fuzzy set in decision-making problems. Ejegwa PA [24] gave an application of Pythagorean fuzzy set-in career placements based on academic performance using max-min-max composition. Some results related to it were given by Peng X [25] and Yang Y [26]. First time, Bhunia S et al. [27] proposed "On the characterization of Pythagorean fuzzy subgroups". In certain situations, the PFSs unable to handle the problems like if membership degree $\eta = 0.8$ and nonmembership degree $\theta = 0.75$ then 2 2 η θ+= ≥ 1.2025 1 it is clear that PFSs fail to define this type of sets but, 1 q q μ ν+ ≤ where q > 2 . Most recently another amazing generalization of FSs is proposed by Yager RR [28], q-Rung Orthopair Fuzzy Sets (q-ROFSs) which models uncertain and incomplete information better than both IFSs and PFSs with high accuracy. q-ROFSs is more fruitful in many decision-making problems. This concept is perfectly designed to represent imprecision and ambiguity in mathematical way and to produce a formalized tool to handle fuzziness to real problems. Pinar A et al. [29] suggested a q-rung orthopair fuzzy multi-criteria group decision making method for supplier selection based on a novel distance. Peng X et al. [30] published Information measures for q-rung orthopair fuzzy sets. The main objective of this article is to introduce the

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idea of q-rung orthopair (m, n)-fuzzy subgroups of a finite group. We discuss the concept of q-rung orthopair (m, n) – fuzzy subgroups as a combination of intuitionist fuzzy subgroup and Pythagorean fuzzy subgroup. We provide the definition of q-rung orthopair (m, n) – fuzzy subgroup and examine various properties associated with it. Finally we analyze q-rung orthopair (m, n)- fuzzy cosets, (m, n) – fuzzy normal subgroups and (m, n)- fuzzy level subgroups.

Preliminaries : In this section, we recall a some definitions and ideas which are very helpful for further proven.

Definition 2.1 Let A: $X \longrightarrow [0,1]$ be a fuzzy subset of a group (X, 0).Then A is said to be a fuzzy subgroup of (X,0) if the following conditions are exists.

1. $A(w_1, w_2) \geq \min \{A(w_1), A(w_2), \forall w_1, w_2 \in X$

2. $A(w^{-1}) \geq A(w) \; \forall \; w \in X$

Definition 2.2 Let A = {(x, α(x), β(x)/x∊C} be a Ifs of a group (C, α), then A is said to be an IFSG of x if the following conditions hold;

1. $\alpha\,(w_1, w_2) \geq \min \{\alpha(w_1), \alpha(w_2)\}$ and $\beta(w_1, w_2) \geq \max \{\beta(w_1), \beta(w_2)\} \; \forall \; w_1, w_2 \in X$

2. $\alpha\,(w^{-1}) \geq \alpha(w)$ and $\beta(w^{-1}) \geq \beta(w) \; \forall \; w \in X$

In 2017, yager defined q-rung orthopair fuzzy set as a speculation of IFS.

Definition 2.3: Let X be a crisp set. A q-rung orthopair fuzzy set A on X is defined by A = {(x,α(x), β(x)) / x ∊ C} where α(x) ∊ [0,1] and β(x) ∊ [0,1] are the membership and non-membership degree of x ∊ X respectively, which satisfy the condition $D \leq \alpha^2(x) + \beta^2(x) \leq 1$, $(q \geq 1) \; \forall$ W∊ X and its determinacy $\Pi_A = \sqrt{1 -} \alpha^2(x) + \beta^2(x)$.

Definition 2.4: Basic operations on q-rung orthopair fuzzy set: Let A = { $(x, \alpha_1(x), \beta_1(x) / x \in X\}$ and B = { $(x, \alpha_2(x), \beta_2(x) / x \in X\}$ be two q- ROFs of X-then the following holds.

1. $A \cup B = \{(x, \alpha_1(x) \cup \alpha_2(x), \beta_1(x) \cap \beta_2(x) \; / x \in X \}$
2. $A \cap B = \{(x, \alpha_1(x) \cap \alpha_2(x), \beta_1(x) \cup \beta_2(x) \; / x \in X\}$
3. $A^C = \{(x, \alpha_2(x), \alpha_1(x) / x \in X\}$ and
4. $A \subseteq B$ if a. $\alpha_1(x), \alpha_2(x)$ and b. $\beta_1(x) = \beta_2(x) \; \forall \; x \in X$
5. A= B if a. $\alpha_1(x) = \alpha_2(x)$ and b. $\beta_1(x) = \beta_2(x) \; \forall \; x \in X$

In this section let G be a finite group. This section elucidates the concept of a q-rung orthopair (m, n) – fuzzy subgroup of G and delivers certain characteristics associated with it.

Definition 2.5 : Let A = { $(w, \gamma_A(w)) / W \in G$ } be a q-rung orthopair (m, n)- fuzzy set on G, then A is a q-rung orthopair (m, n) – fuzzy subgroup of G if, for w1, w2 ∊G;

(i) $(\delta_A(m_1 w_1, w_2)))^q \geq \min \{ (\delta_A(w_1)^{q,} \; (\delta_A(w_1)^q\}$ and

$(A_A\,(n_1 w_1, w_2)))^q \geq \max \{ (A_A(w_1)^{q,} \, (A_A(w_1)^q\}$

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(i) $(\delta_A(n_1w_1)^q =$ and $(\delta_A(w^{-1})^q$ and $(A_A(n_1w^{-1}))^q = (A_A(w^{-1}))^q$,for m,n ∊ [0,1]

Note that if q=1 called intuitionistic fuzzy subgroup and q=2 Pythagorean fuzzy subgroup, q=3 fermatean fuzzy subgroup of G.

Section :3 Standard Results on q-rung orthopair (m, n) Fuzzy subgroup

Theorem 3.1 Let A be a q- rung orthopair (m,n) – fuzzy subgroup of G, then

$(\delta_A(w^k))^q \geq (\delta_A(w))^q$ and $(\Delta_A(w^k)) \geq (\Delta_A(w))^q$, for K∊N

Proof: By definition 2.5

$(\delta_A(w^2))^q \geq \min \{ (\delta_A(w))^q, (\delta_A(w))^q\} = (\delta_A(w))^q$

and $(\Delta_A(w^2))^q \geq \max \{(\Delta_A(w))^q, (\Delta_A(w))^q\} = (\Delta_A(w))^q$

The proof follows by mathematical induction.

Corollary 3.2 In definition 2.5 since G is a finite group, condition 1 gives condition 2

Proof Let w ∊ G with order of W.

O(W) = S, then $w^{-1} = w^{n-1}$, $(\delta_A(m^{-1}))^q \geq (\delta_A(mw^{n-1})^q \geq (\delta_A(w)^q)$

For $w = w^{-1}$ if follows that $(\delta_A(mw))^q = (\delta_A(w^{-1})^q$

Similarly , for non-membership degree $(A_A(mw))^q = (A_A(w^{-1}))^q$

Theorem 3.3 Let A be a q-rung orthopair (m, n)- fuzzy subgroup of G, 'e' be the identify element in G.Then $(\delta_A(me))^q \geq (\delta_A(w)^q$ and $(A_A(ne))^q \leq (A_A(w))^q$, for w ∊ G

Proof: Let w ∊ G, $(\delta_A(me))^q = (\delta_A(ww^{-1})^q \geq \min \{ (\delta_A(w))^q , (\delta_A(w^{-1})^q\} \geq (\delta_A(w))^q$

Analogously, it can be shown that $(A_A(ne))^q \leq (A_A(w))^q$

Theorem 3.4 Let A be a q-rung orthopair (m,n) – fuzzy subgroup of G if and only if

$(\delta_A(m(w_1w_2^{-1})^q \geq \min \{ (\delta_A(w_1))^q , (\delta_A(w_2)^q\}$ and $(\Delta_A(n(w_1w_2))^q\} \leq \max \{ (\Delta_A(w_1))^q, (\Delta_A(w_2))^q\}$,for w_1w_2 ∊ G and min ∊ [0,1]

Proof Let A be a q-rung orthopair (m, n)-fuzzy set on a group G.

Suppose A is a q-rung orthopair (m, n)- fuzzy subgroup of G, then for w_1w_2 ∊ G,

$(\delta_A(m(w_1w_2^{-1})))^q \geq \min \{ (\delta_A(w_1))^q, (\delta_A(w_1^{-1}))^q\} = \min \{ (\delta_A(w_1))^q, (\delta_A(w_1))^q\}$ and

$(\Delta_A(n(w_1, w_2^{-1})) \leq \max \{(\Delta_A(w_1))^q, (\Delta_A(w_2^{-1}))^q\} = \max \{(\Delta_A(w_1))^q, (\Delta_A(w_2))^q\}$

Conversely,

Let $(\delta_A(m(w_1w_2^{-1})))^q \geq \min \{ (\delta_A(w_1)) \}$ and $(\Delta_A(n(w_1, w_2^{-1}))^q \leq \max \{(\Delta_A(w_1))^q \}$,

for all w_1w_2 ∊ G .Then

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$(\delta_A(m(w_1w_2)))^q = (\delta_A(m(w_1(w_2)))^q \geq \min\{(\delta_A(w_1))^q, (\delta_A(w_2^{-1})^q\} = \min\{(\delta_A(w_1))^q, (\delta_A(w_2)^q\}$

Similarly it can be proved that $(\Delta_A(n(w_1, w_2)))^q \leq \max\{(\Delta_A(w_1))^q, (\Delta_A(w_2))^q\}$

Now consider $(\delta_A(m(w_1^{-1}))^q$,

$(\delta_A(m(w_1^{-1})))^q = (\delta_A(m(cw_1^{-1})))^q \geq \min\{(\delta_A(e))^q, (\delta_A(w_1))^q\}$

$= (\delta_A(w_1))^q$ .... (1) Which will give

$(\delta_A(m(w_1))^q = (\delta_A(m(w_1^{-1}))^q \geq (\delta_A(w_1^{-1}))^q$ .... (2)

From (1) and (2), $(\delta_A(w_1^{-1}))^q = (\delta_A(m(w_1))^q$. Similarly, $(\Delta_A(n(w_1^{-1}))^q = (\Delta_A(w_1))^q$

Hence 'A', is a q-rung ortho pair (m, n)- fuzzy subgroup of G.

Theorem 3.5 Let A and B be two q-rung orthopair (m, n) – fuzzy subgroup of G then

A ∩ B is a q-rung orthopair (m, n) - fuzzy subgroup of G.

Proof : For $w_1, w_2 \in G$

$$(\delta_{A\cap B}(m(w_1w_2^{-1})))^q = \min\{(\delta_A(m(w_1w_2^{-1})))^q, (\delta_B(m(w_1w_2^{-1})))^q\}$$

$$\geq \min\{\min\{(\delta_A(w_1))^q, (\delta_A(w_1^{-1}))^q\}, \min\{(\delta_B(w_2))^q, (\delta_B(w_2))^q\}\}$$

$$= \min\{\min\{(\delta_A(w_1))^q, (\delta_B(w_1))^q\}, \min\{(\delta_A(w_2))^q, (\delta_B(w_2))^q\}\}$$

$$= \min\{\delta_{A\cap B}(w_1), \delta_{A\triangle B}(w_2)\}$$

Similarly it can be shown that

$(\Delta_{A\cap B}(n(w_1, w_2^{-1})))^q \leq \max\{(\Delta_{A\cap B}(w_1))^q, (\Delta_{A\cap B}(w_2))^q\}$

Hence $_{A\cap B}$ is a q-rung orthopair(m ,n) fuzzy subgroup of G.

Theorem 3.6 Let "A' be a q-rung orthopair (m, n) – fuzzy subgroup of G, e be the element in G then $(\delta_A(m(xw)))^q = (\delta_A(w))^q$ and $(\Delta_A(n(xw)))^q = (\Delta_A(w))^q$ for all $w_1w_2 \in G$.If and only if $(\delta_A(x))^q = (\delta_A(e))^q$ and $(\Delta_A(x))^q = (\Delta_A(e))^q$

Proof Suppose $(\delta_A(m(xw)))^q = (\delta_A(w))^q$ and $(\Delta_A(n(xw)))^q = (\Delta_A(w))^q$ for all $w_1w_2 \in G$

Specifically, w = e, it follows that $(\delta_A(x))^q = (\delta_A(e))^q$, $(\Delta_A(x))^q = (\Delta_A(e))^q$

Suppose $(\delta_A(x))^q = (\delta_A(e))^q$ and $(\Delta_A(x))^q = (\Delta_A(e))^q$

Since $(\delta_A(mw))^q \leq (\delta_A(e))^q$ for all $w_1w_2 \in G$, $(\delta_A(m(xw)))^q \geq \min\{(\delta_A(x))^q, (\delta_A(w))^q\}$ and

$$= \min\{(\delta_A(e))^q, (\delta_A(w))^q\} = (\delta_A(w))^q \text{ for all } w_1w_2 \in G$$

Also, $(\delta_A(w))^q = (\alpha_A(x^{-1}w))^q\} \geq \min\{(\delta_A(x))^q, (\delta_A(xw))^q\} = (\delta_A(w))^q$ for all $w_1w_2 \in G$

Hence, $(\delta_A(mw))^q = (\delta_A(xw))^q$ for all $w \in G$.Similar, $(\Delta_A(xw))^q = (\Delta_A(mw))^q$ for all $w \in G$

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Theorem 3.7 Let "A' be a q-rung orthopair (m, n) – fuzzy subgroup of G, e be the element in G then H= { $w \in G/ (\delta_A(mw))^q = (\delta_A(e))^q, (\Delta_A(mw))^q = (\Delta_A(e))^q\}$ is a subgroup of G.

Proof: By definition of H, it follows that e ∊ H. Hence, H is a non – empty subset of G. Let w1, w2 ∊ H. Then $(\delta_A(mw_1))^q = (\delta_A(e))^q = (\Delta_A(mw_2))^q$ and $(\Delta_A(mw_1))^q$

$$= (\Delta_A(e))^q = (\Delta_A(mw_2))^q \text{ . we have}$$

$(\delta_A(m(w_1w_2^{-1})))^q \geq \min\{(\delta_A(w_1)^q, (\delta_A(w_2^{-1}))^q\} = \min\{(\delta_A(w_1)^q, (\delta_A(w_2))^q\}$

$$= \min\{(\delta_A(e)^q), (\delta_A(e))^q\} = (\delta_A(e))^q.$$ By theorem 3.3

$(\delta_A(e))^q \geq (\delta_A(m(w_1w_2^{-1}))^q$ therefore $(\delta_A(m(w_1w_2^{-1}))^q = (\delta_A(e))^q$

Similarly it can be shown that $(\Delta_A(m(w_1w_2^{-1}))^q = (\Delta_A(e))^q$ thus $w_1w^{-1}{}_2 \in H$.

Hence it is a subgroup of G.

Theorem 3.8 Let "A' be a q-rung orthopair (m, n) – fuzzy subgroup of G, then there exists an element x ∊ G such that $(\delta_A(x))^q \leq (\delta_A(mw))^q$ and $(\Delta_A(x))^q \leq (\Delta_A(mw))^q$ for all $w_1w_2 \in G$.

Proof : Let k_1 denote the set of all elements in G with the lowest membership degree, and K_2 denote the set of all elements in G with the highest non-membership degree, if

$k_1 = \{w^1 \in G/ (\delta_A(mw^1))^q \leq (\delta_A(w))^q \ \forall w \in G\}$ and

$K_2 = \{w^{11} \in G/ (\delta_A(mw^{11}))^q \leq (\Delta_A(w))^q \ \forall w \in G\}$

To show $K_1 \cap K_2 \neq \emptyset$. Let $w^1 \in K_1$ and $w^{11} \in K_2$

Clearly $w^1 = w^{11} \in p$ for some $P \in G$ and $(\delta_A(mw^{-1}))^q \geq \min\{(\delta_A(w^{11}))^q, (\delta_A(p))^q\}$

Since, $(\delta_A(w^{11}))^q$ is the lowest membership degree either $(\delta_A(w^{11}))^q = (\delta_A(w^1))^q$ or

$(\delta_A(mp))^q = (\delta_A(mw^1))^q$ if $(\delta_A(mw^{11}))^q = (\delta_A(mw^1))^q$, it follows that

$w^{11} \in K_1$ therefore $K_1 \cap K_2 \neq \emptyset$ and $x = w^{11}$. if $(\delta_A(mp))^q = (\delta_A(mw^{11}))^q$, consider $w^{11} = w^1 * p^{-1}$ then $(\Delta_A(m w^{11}))^q \leq \max\{(\Delta_A(w^{11}))^q, (\Delta_A(p^{-1}))^q\}$. Since $(\Delta_A(m w^{11}))^q$ is the highest non-membership degree ,then $(\Delta_A(nw^1))^q = (\Delta_A(nw^{11}))^q$ or $(\Delta_A(np^{-1}))^q = (\Delta_A(nw^{11}))^q$

if $(\Delta_A(nw^1))^q = (\Delta_A(nw^{11}))^q$ if follows that $w^{11} \in K_2$, $K_1 \cap K_2 \neq \emptyset$ and $x = w^1$

if $(\Delta_A(np^{-1}))^q = (\Delta_A(nw^{11}))^q$, then it follows that $(\delta_A(mp))^q = (\delta_A(mw^1))^q$ and $(\Delta_A(mp^{-1}))^q = (\Delta_A(mw^{11}))^q$, which means $p \in K_1 \cap K_2$ and $x = \emptyset$.

Theorem 3.9 : Let G be a cyclic group and let A be a q-rung orthopair (m, n) – fuzzy subgroup of G. Then the generators of G posses and membership and non-membership degree in K.

Proof: let W_1, W_2 be two generators of G. Since W1 is a generator, $W_2 = W_1{}^r$ for some

$r \in N$.$(\delta_A(mw_2))^q = (\delta_A(mw_1{}^r))^q \geq (\delta_A(w_1))^q$ and $(\Delta_k(mw_2))^q = (\Delta_k(mw_1{}^r))^q \leq \Delta_A(w_1)^q \dashrightarrow (3)$

Since w2 is a generator, $w_1 = w_2$ for some S ∊N.

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$(\delta_A(mw_1))^q = (\delta_A(mw_2{}^s))^q \geq (\delta_A(w_2))^q$ and $(\Delta_A(nw_1))^q = (\Delta_A(nw_2{}^s))^q \leq \Delta_A(w_2)^q \dashrightarrow (4)$

From (3) and (4) $(\delta_A(mw_1))^q = (\delta_A(w_2{}^s))^q$ and $(\Delta_A(nw_1))^q = (\Delta_A(w_1))^q$

Some Orders of Q-Rung Orthopair (M, N) – Fuzzy Subgroups

Definition 4.1: Let 'A' be a q-rung orthopair fuzzy subgroup of group G. For W ∊ G, the least positive integer 'r' such that $(\delta_A(mw^r))^q = (\delta_A(e))^q$ and $(\Delta_A(nw^r))^q = (\Delta_A(e))^q$ is called the order of W in A, denoted as order of q-rung orthopair(m, n)-fuzzy subgroup.

Remark 4.2 The order of an element in a q-rung ortho pair (m, n) – fuzzy subgroup A of G is always less than or equal to its order in G. Also the order of an element and its inverse in 'A' are equal.

Theorem 4.3: Let A be a q-rung orthopair (m, n) – fuzzy subgroup of G, and 'e' be the identity element in G. Let w_1 ∊ G, and let 'u' be a (t) be in satisfying. $(\delta_A(mw_1{}^u))^q = (\delta_A(e))^q$ and $(\Delta_A(nw_1{}^u))^q = (\Delta_A(e))^q$ then order of q-rung orthopair (m, n) – fuzzy subgroup divides 'u'.

Conclusion: This objective of this article introduce the concept of q-rung orthopair (m, n)- fuzzy subgroups of finite groups and examines their fundamental properties. Additionally, it develop and analyzes key concepts such q-rung orthopair (m, n)- fuzzy subgroup, there by providing deeper insights in to the structure of q-rung orthopair (m, n)- fuzzy subgroups.

Future work : The research may explore concepts such as q-rung orthopair (m, n)- fuzzy homomorphism and q-rung orthopair (m, n)- fuzzy isomorphisms..

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