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Doubt Q-fuzzy Z- ideals in Z-algebras

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Abstract
The intend of this article is to initiate the concept of doubt Q-fuzzy Z-ideals of Z-algebras and to learn its properties. More Evidently, the theory of doubt Q-fuzzy is analyzed over homomorphism and Cartesian product as well.
. Keywords : Doubt Q-fuzzy subalgebra, Doubt Q-fuzzy Z-ideal , Homomorphism, Cartesian Product.

1.Introduction

The concept of fuzzy set was initiated by L.A.Zadeh in 1965 **[12]**. Further, these thoughts have been utilized to other algebraic structures such as groups, graphs, rings, modules, vector spaces and topologies. The concept of Z-algebra is introduced by Chandramouleeswaran.M **[1]** et.al., in 2017**.** In 2019, Sowmiya .S and Jeyalakshmi.P **[11]**fuzzified Z-algebra . In 2021, Sithar selvam P.M.**[4]** et.al., studied the properties of fuzzy dot Z-algebra over sub algebra and Z-ideals. These works on Z-algebra motivated us to do Doubt Q-fuzzy Z-ideals of Z-algebra as an added feather.

2. Preliminaries

Definition 2.1 [1] : Let X be a nonempty set with a constant 0 and a binary operation ‘ $*$ ’ . It is called as Z – algebra, if it satisfies the following conditions.
(1) $a * 0 = 0$
(2) $0 * a = a$
(3) $a * a = a$
(4) $a * b = b * a$ whenever $a \neq 0$; $b \neq 0$ for all $a , b \in X$
In X, a binary relation $\leq$, we illustrate as, $a \leq b$ if and only if $a * b = 0$.
Definition 2.2 [1] : If X is a Z- algebra and I , a subset of X, is called as Z - ideal of X, provided following axioms are true.

1. $0 \in I$
2. $a * b \in I$ and $b \in I \Rightarrow a \in I$ for all $a,b \in X$.

Definition 2.3 [1,3,5] : A non empty sub set S of a Z-algebra X is to be a sub algebra of X if $a*b \in S$, for every $a , b \in S$.
Definition 2.4 [6, 7] : A map $g : X \to Y$ is called a homomorphism if $g (a * b) = g(a) * g(b)$, for all $a , b\in X$, where X and Y are Z-algebras.
Definition 2.5 [2, 8, 9] : Let X be a non-empty set. A fuzzy subset λ of the set X is a mapping from X to [0,1] . (i.e) $\lambda: X \to [0,1]$.

Definition 2.6 [10, 11]: Let X be a Z-algebra. A fuzzy set λ in X is called a fuzzy Z-ideal of X if it satisfies the following conditions.

i) $\lambda(0) \geq \lambda(a)$

ii) $\lambda(a) \geq \min\{\lambda(a * b), \lambda(b)\}$, for all a, b $\in$ X .

Definition 2.7[7, 11] : A fuzzy set λ in Z-algebra X is called a fuzzy Z- sub algebra of X if

$\lambda(a * b) \geq \min\{\lambda(a), \lambda(b)\}$, for all a, b$\in$ X.

Definition 2.8 : Let Q and G be any two sets. A mapping λ: G x Q $\rightarrow$[0, 1] is called as Q –fuzzy set in G.

MAIN RESULTS

3. DOUBT Q-FUZZY Z – IDEALS OF Z-ALGEBRAS

Definition 3.1 : A Q- fuzzy set λ in X is called a Q-fuzzy Z- ideal of X if

(i) $\lambda(0, q) \geq \lambda(a, q)$

(ii) $\lambda(a, q) \geq \min\{\lambda(a * b, q), \lambda(b, q)\}$, for all a, b, c $\in$ X and q $\in$ Q.

Definition 3.2 : A Q-fuzzy set λ of X is called a Doubt Q-fuzzy Z-ideal of X if

(i) $\lambda(0, q) \leq \lambda(a, q)$

(ii) $\lambda(a, q) \leq \max\{\lambda(a * b, q), \lambda(b, q)\}$, for all a, b $\in$ X and q $\in$ Q.

Theorem 3.1 : Every Doubt Q - fuzzy Z- ideal λ of a Z-algebra X is order preserving.

Proof : Let λ be a Doubt Q-Fuzzy Z- ideal of a Z-algebra X and let a, b $\in$ X and q $\in$ Q be such that $a \leq b$, then $a * b = 0$.

Now $\lambda(a, q) \leq \max\{\lambda(a * b, q), \lambda(b,q)\}$
$= \max\{\lambda(0,q), \lambda(b,q)\}$
$= \lambda(b,q)$

$\Rightarrow \lambda(a,q) \leq \lambda(b,q)$.

Hence λ is order preserving.

Theorem 3.2 : λ is a Q-fuzzy Z-ideal of a Z-algebra X iff λ^c is a Doubt Q-fuzzy Z-ideal of X.

Proof: Let λ be a Q-fuzzy Z- ideal of X and let a , b $\in$ X and q $\in$ Q.

$\lambda(0, q) \geq \lambda(a, q)$

$1- \lambda^c(0, q) \leq 1 - \lambda^c(a, q) \Rightarrow \lambda^c(0, q) \leq \lambda^c(a, q)$

and $\lambda^c(a, q) = 1 - \lambda(a, q)$
$\leq 1 - \min\{\lambda(a * b, q), \lambda(b, q)\}$
$= 1 - \min\{1 - \lambda^c(a * b, q), 1 - \lambda^c(b, q)\}$
$= \max\{\lambda^c(a * b, q), \lambda^c(b, q)\}$

Thus λ^c is a Doubt Q-fuzzy Z-ideal of X. The converse also can be proved similarly.

Theorem 3.3: For any Doubt Q- fuzzy Z-ideal λ of X, $N_\lambda = \{a \in X \text{ and } q \in Q \,/\, \lambda(a, q) = \lambda(0,q)\}$ is a Z-ideal of X.

Proof: Let a * b, b $\in N_\lambda$. Then $\lambda(a * b, q) = \lambda(b, q) = \lambda(0, q)$

Since λ is a Doubt Q-fuzzy Z-ideal of X ,

$\lambda(a, q) \leq \max\{\lambda(a * b, q), \lambda(b, q)\}$
$= \max\{\lambda(0,q), \lambda(0,q)\}$

$= \lambda\,(0,q)$

Hence $a \in N_\lambda$. Therefore N_λ is a Z-ideal of X.

Theorem 3.4 : If λ_1 and λ_2 are Doubt Q-fuzzy Z- ideals of a Z-algebra X, then $\lambda_1 \cap \lambda_2$ is also a Doubt Q-fuzzy Z-ideal of X.

Proof : Let $a, b \in X$ and $q \in Q$. Then

$$(\lambda_1 \cap \lambda_2)(0, q) = \min\{\lambda_1(0, q), \lambda_2(0, q)\}$$
$$\leq \min\{\lambda_1(a, q), \lambda_2(a, q)\}$$
$$= (\lambda_1 \cap \lambda_2)(a, q)$$

$$(\lambda_1 \cap \lambda_2)(a, q) = \min\{\lambda_1(a, q), \lambda_2(a, q)\}$$
$$\leq \min\{\max\{\lambda_1(a * b, q), \lambda_1(b, q)\}, \max\{\lambda_2(a * b, q), \lambda_2(b, q)\}\}$$
$$= \min\{\max\{\lambda_1(a * b, q), \lambda_2(a * b, q)\}, \max\{\lambda_1(b, q), \lambda_2(b, q)\}\}$$
$$\leq \max\{\min\{\lambda_1(a * b, q), \lambda_2(a * b, q)\}, \min\{\lambda_1(b, q), \lambda_2(b, q)\}\}$$
$$= \max\{(\lambda_1 \cap \lambda_2)(a * b, q), (\lambda_1 \cap \lambda_2)(b, q)\}.$$

$\Rightarrow ((\lambda_1 \cap \lambda_2))(a, q) \leq \max\{(\lambda_1 \cap \lambda_2)(a * b, q), (\lambda_1 \cap \lambda_2)(b, q)\}$.

$\Rightarrow \lambda_1 \cap \lambda_2$ is a Doubt Q-fuzzy Z- ideal of X.

Theorem 3.5: Arbitrary union of Doubt Q-fuzzy Z-ideals of Z-algebra X is also a Doubt Q-fuzzy Z-ideal.

Proof : Let $\{\lambda_i\}$ be a family of Doubt Q-fuzzy Z-ideals of Z-algebra X.

Let $a,b \in X$ and $q \in Q$.

$$(\cup \lambda_i)(0, q) = \sup(\lambda_i(0, q))$$
$$\leq \sup(\lambda_i(a, q))$$
$$= (\cup \lambda_i)(a, q)$$

$$(\cup \lambda_i)(a, q) = \operatorname{Sup}(\lambda_i(a, q))$$
$$\leq \operatorname{Sup}\{\max\{\lambda_i(a * b, q), \lambda_i(b, q)\}\}$$
$$= \max\{\operatorname{Sup}(\lambda_i(a * b, q)), \operatorname{Sup}(\lambda_i(b, q))\}$$
$$= \max\{(\cup \lambda_i)(a * b, q), (\cup \lambda_i)(b, q)\}$$

Definition 3.6: If λ is a Q-fuzzy set of X, then for a fixed $s \in [0, 1]$, the set $\lambda_s = \{a \in X \mid \lambda(a,q) \leq s \text{ for all } q \in Q\}$ is as known lower level s-cut of λ. Clearly $\lambda^s \cup \lambda_s = X$ for $s \in [0,1]$ if $s_1 < s_2$, then $\lambda_{s1} \subseteq \lambda_{s2}$.

Theorem 3.7 : If λ is a Doubt Q-fuzzy Z-ideal of Z-algebra X, then the lower level s-cut , λ_s is a Z-ideal of X for every $s \in [0,1]$.

Proof : Let λ be a Doubt Q-fuzzy Z-ideal of Z-algebra X.

Then it is clear that $0 \in \lambda_s$.

Now let $a * b \in \lambda_s$ and $b \in \lambda_s$, for all $a, b \in X$ and $q \in Q$.

$$\Rightarrow \lambda(a * b, q) \leq s \text{ and } \lambda(b, q) \leq s.$$

Since λ is a Doubt Q-fuzzy Z-ideal of X,

$\lambda(a, q) \leq \max\{\lambda(a * b, q), \lambda(b, q)\} \leq \max\{s, s\} = s \Rightarrow a \in \lambda_s$.

Hence λ_s is a Z- ideal of X for every $s \in [0,1]$.

Theorem 3.8 : Let λ be a Q-fuzzy set of Z- algebra X. If for each $s \in [0, 1]$, the lower level s-cut λ_s is a Z-ideal of X, then λ is a Doubt Q- fuzzy Z-ideal of X.

Proof : Let λ_s be a Z-ideal of X.

If $\lambda(0,q) > \lambda(a, q)$ for some $a \in X$ and $q \in Q$, then $\lambda(0, q) > s_0 > \lambda(a, q)$ by taking

$s_0 = \frac{1}{2}\{\lambda(0,q) + \lambda(a,q)\}$.

Hence $0 \notin \lambda_{s0}$ and $a \in \lambda_{s0}$, which is a contradiction.

Therefore, $\lambda(0,q) \le \lambda(a,q)$.

Let a,b $\in$ X and q $\in$ Q be such that $\lambda(a,q) > \max\{\lambda(a*b,q), \lambda(b,q)\}$.

Taking $s_1 = \frac{1}{2}\{\lambda(a,q) + \max\{\lambda(a*b,q), \lambda(b,q)\}\}$

$\Rightarrow \lambda(a,q) > s_1 > \max\{\lambda(a*b,q), \lambda(b,q)\}$.

It follows that $a*b, b \in \lambda_{s1}$ and $a \notin \lambda_{s1}$. This is a contradiction.

Hence $\lambda(a,q) \le \max\{\lambda(a*b,q), \lambda(b,q)\}$

Therefore λ is a Doubt Q-fuzzy Z-ideal of X.

4. HOMOMORPHISM ON DOUBT Q-FUZZY Z- ALGEBRAS

Definition 4.1 : Let (X,*,0) and (Y ,Δ ,0) be Z– algebras. A mapping $g: X \to Y$ is said to be a homomorphism if $g(a*b) = g(a)\,\Delta\, g(b)$ for all a, b $\in$ X.

Definition 4.2 : Let (X,*, 0) and (Y,Δ,0) be Z-algebras. A mapping $g: X \to Y$ is said to be an anti homomorphism if $g(a*b) = g(b)\,\Delta\, g(a)$ for all a, b $\in$ X.

Definition 4.3 : Let $g: X \to X$ be an endomorphism and λ be a fuzzy set in X. A new fuzzy set λ_g in X, is defined as

$\lambda_g(a) = \lambda(g(a))$ for all 'a' in X.

Theorem 4.4 : Let g be an endomorphism of a Z- algebra X. If λ is a Doubt Q- fuzzy Z-ideal of X, then so is λ_g .

Proof: Let λ be a Doubt Q-fuzzy Z-ideal of X.

Now, $\lambda_g(0,q) = \lambda(g(0,q)) \le \lambda(g(a,q)) = \lambda_g(a,q)$, for all a,b $\in$ X and q$\in$Q.

Let a,b $\in$ X and q$\in$ Q.

Then $\lambda_g(a,q) = \lambda(g(a,q))$

$\le \max\{\lambda(g(a*b,q)), \lambda(g(b,q))\}$

$= \max\{\lambda_g(a*b,q), \lambda_g(b,q)\}$

$\therefore \lambda_g(a,q) \le \max\{\lambda_g(a*b,q), \lambda_g(b,q)\}$

Hence λ_g is a Doubt Q- fuzzy Z-ideal of X.

Theorem 4.5 : Let $g: X \to Y$ be an epimorphism of Z- algebra. If λ_g is a Doubt Q-fuzzy Z-ideal of X, then λ is also a Doubt Q-fuzzy Z-ideal of Y.

Proof: Let λ_g be a Doubt Q-fuzzy Z-ideal of X.

Let b $\in$ Y and q$\in$ Q. Then there exists a $\in$ X such that g(a, q) = (b, q).

Now, $\lambda(0,q) = \lambda(g(0,q))$

$= \lambda_g(0,q)$

$\le \lambda_g(a,q) = \lambda(g(a,q)) = \lambda(b,q)$

$\therefore \lambda(0,q) \le \lambda(y,q)$

Let $b_1, b_2, b_3 \in$ Y.

$\lambda(b_1,q) = \lambda(g(a_1), q)$

$= \lambda_g\ (a_1, q)$

$\leq \max\{\lambda_g\ (a_1 * a_2\ , q\ ), \lambda_g\ (a_2, q)\}$

$= \max\{\lambda\ [g\ (a_1 * a_2, q)], \lambda\ [g(a_2,q)]\}$

$= \max\{\lambda\ [g(a_1, q)\ \Delta\ g(a_2, q)], \lambda\ [g(a_2, q)]\}$

$= \max\{\lambda\ [(b_1, q)\ \Delta\ (b_2, q)], \lambda\ [(b_2, q)]\}$

$\Rightarrow$ λ is a Doubt Q- fuzzy Z-ideal of Y.

Theorem 4.6 : Let g: $X \rightarrow Y$ be a homomorphism of Z- algebra. If λ is a Doubt Q-fuzzy Z-ideal of Y then λ_g is also a Doubt Q-fuzzy Z-ideal of X.

Proof: Let λ be a Doubt Q- fuzzy Z-ideal of Y.

Let $a, b \in X$.

$\lambda_g\ (0, q) = \lambda(g(0, q))$

$\leq \lambda(g(a, q)) = \lambda_g\ (a, q)$

$\Rightarrow$ $\lambda_g\ (0, q) \leq \lambda_g\ (a, q)$.

$\lambda_g\ (a, q) = \lambda\ [g\ (a\ , q)]$

$\leq \max\{\lambda\ (g\ (a * b, q)), \lambda\ (g\ (b, q))\}$

$= \max\{\lambda_g\ (a * b, q), \lambda_g\ (b\ , q)\}$

$\therefore\ \lambda_g (a\ , q) \leq \max\{\ \lambda_g\ (a * b, q), \lambda_g\ (b, q)\ \}$.

Hence λ_g is a Doubt Q-fuzzy Z-ideal of X.

5. CARTESIAN PRODUCT OF DOUBT Q-FUZZY Z-IDEALS OF Z–ALGEBRAS

The Cartesian product of Doubt Q-fuzzy Z-ideals of Z-algebra is defined and some of its properties are established.

Definition 5.1 : Let λ and γ be two fuzzy sets in X. The Cartesian product $\lambda \times \gamma : X \times X \rightarrow [0,1]$ is defined by $(\lambda \times \gamma)\ (a, b) = \min\{\lambda(a), \gamma\ (b)\}$, for all $a, b \in X$.

Definition 5.3: Let λ and γ be Doubt Q-fuzzy sets in X. The Cartesian product $\lambda \times \gamma : X \times X \rightarrow [0,1]$ is defined by $(\lambda \times \gamma)\ ((a\ , b),q) = \max\{\lambda(a, q), \gamma(b, q)\}$, for all $a, b \in X$ and $q \in Q$.

Theorem 5.4 : If λ and γ are Doubt Q-fuzzy Z-ideals in Z– algebra X, then $\lambda \times \gamma$ is a Doubt Q-fuzzy Z-ideal in X x X.

Proof: Let $(a_1, a_2) \in X \times X$ and $q \in Q$.

$(\lambda \times \gamma)((0, 0), q)\ \} = \max\{\lambda(0, q), \gamma(0, q)\}$

$\leq \max\{\lambda(a_1, q), \gamma\ (a_2, q)\}$

$= (\lambda \times \gamma)\ ((a_1, a_2), q)$

$\therefore\ (\lambda \times \gamma)((0, 0), q) \leq (\lambda \times \gamma)\ ((a_1, a_2), q)$

Let $(a_1, a_2), (b_1, b_2) \in X \times X$.

$(\lambda \times \gamma)[(a_1, a_2)\ ,q] = \max\{\lambda(a_1\ , q),\gamma(a_2, q)\}$

$\leq \max\{\max\{\lambda(a_1 * b_1, q), \lambda(b_1, q)\},\max\{\gamma\ (a_2 * b_2, q), \gamma\ (b_2, q)\},\}$

$= \max\{\max\{\lambda\ (a_1 * b_1, q), \gamma\ (a_2 * b_2, q)\}, \max\{\lambda(b_1, q), \gamma(b_2, q)\}\}$

$= \max\{(\lambda \times \gamma)\ ((a_1 * b_1, q),(a_2 * b_2\ , q)),(\ \lambda \times \gamma)\ ((\ b_1, b_2), q)\}$

$= \max \{(\lambda \times \gamma) [((a_1, a_2) * (b_1, b_2)), q)], (\lambda \times \gamma) [((b_1, b_2), q)]\}$

Hence, $\lambda \times \gamma$ is a Doubt Q-fuzzy Z- ideal in X x X.

Theorem 5.5: Let λ & γ be fuzzy sets in a Z-algebra X such that $\lambda \times \gamma$ is a Doubt Q-fuzzy Z-ideal of X x X. Then

(i) Either $\lambda(0,q) \leq \lambda(a, q)$ (or) $\gamma(0,q) \leq \gamma(a, q)$ for all $a \in X$ and $q \in Q$.

(ii) If $\lambda(0,q) \leq \lambda(a, q)$ for all $a \in X$ and $q \in Q$, then either $\gamma(0,q) \leq \lambda(a, q)$ (or) $\gamma(0,q) \leq \gamma(a, q)$

(iii) If $\gamma(0,q) \leq \gamma(a, q)$ for all $a \in X$ and $q \in Q$, then either $\lambda(0,q) \leq \lambda(a, q)$ (or) $\lambda(0,q) \leq \gamma(a, q)$.

Proof: Straightforward.

Theorem 5.6: Let λ & γ be fuzzy sets in a Z-algebra X such that $\lambda \times \gamma$ is a Doubt Q-fuzzy Z-ideal of X x X. Then either λ or γ is a Doubt Q-fuzzy Z-ideal of X.

Proof: First we prove that γ is a Doubt Q- fuzzy Z-ideal of X.

Since by 5.5(i) either $\lambda(0,q) \leq \lambda(a, q)$ or $\gamma(0,q) \leq \gamma(a, q)$ for all $a \in X$ and $q \in Q$.

Assume that $\gamma(0,q) \leq \gamma(a, q)$ for all $a \in X$ and $q \in Q$. It follows from 5.5 (iii) that either

$\lambda(0,q) \leq \lambda(a,q)$ (or) $\lambda(0,q) \leq \gamma(a,q)$.

If $\lambda(0,q) \leq \gamma(a, q)$, for any $a \in X$ and $q \in Q$,then

$\gamma(0, q) = \max \{\lambda(a,q), \gamma(0, q)\} = (\lambda \times \gamma) ((a, 0),q)$

$$
\begin{aligned}
\gamma(a, q) &= (\lambda \times \gamma) [(a, 0), q] \\
&\leq \max \{(\lambda \times \gamma) [((a,0),q) * ((b,0), q)], (\lambda \times \gamma) [((b,0), q)]\} \\
&= \max \{(\lambda \times \gamma) [(a*b, 0 * 0), q], (\lambda \times \gamma) [(b , 0), q]\} \\
&= \max \{(\lambda \times \gamma) [(a * b, 0), q], (\lambda \times \gamma) [(b,0) ,q]\} \\
&= \max \{\gamma (a * b, q), \gamma (b , q)\}
\end{aligned}
$$

$\Rightarrow \gamma(a, q) \leq \max \{\gamma (a * b, q), \gamma (b , q)\}$

Hence γ is a Doubt Q- fuzzy Z-ideal of X.

Similarly we will prove that λ is a Doubt Q- fuzzy Z-ideal of X.

6. CONCLUSION

In this article we have discussed Doubt Q-fuzzy Z- ideal of Z-algebras and its lower level s-cuts in detail. We hope that this work would lay other foundations for further study of the theory of Z-algebras. In our future study of fuzzy structure of Z-algebra, can be extended to the topics, intuitionistic fuzzy set, interval valued fuzzy sets, for more interesting results.

AUTHOR CONTRIBUTIONS:

Authors contribution to this work have been shared equally as follows: P.M.Sithar Selvam placed the idea of this whole paper. T.Priya and M.Parimala completed the Compilation work of this paper. The revision and submission of this paper was completed by P.M.Sithar selvam and M. Parimala.

CONFLICTS OF INTEREST:

The authors declare that they have no conflict of interest to this work.

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