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New Operators using B-Open Sets in a Quadripartitioned NeutrosophicTopological Spaces

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Abstract:
In this paper, we introduce some new operators called Quadri partitioned neuromorphic β frontier, quadri-partitioned neutrosophic β border and Quadri partitioned neuromorphic β exterior with the help of quadripar- titioned neutrosophic β-open sets in quadripartitioned neutrosophic topological space. Also, we discuss the important properties of them and the relations between them.

Keywords: Quadri partitioned neutrosophic β-open, Quadri partitioned neutrosophic β frontier, quadriparti- tioned neuromorphic β border, quadripartitioned neutrosophic β exterior.

1. Introduction

In mathematics, Zadeh[26] was first presented a idea of fuzzy set between the intervals in order of logic and sethypothesis. The fuzzy set was attempted in general topology by Chang[2] as fuzzy topological space. The intu- itionistic fuzzy set which contains a membership and non-membership values was introduced by Atanassov[1] in 1983. Coker[4] made intuitionistic fuzzy set in a topology entitled as intuitionistic fuzzy topological spaces. Theideas of neutrosophy and neutrosophic set was presented by Smarandache[16,17] toward the start of 20^{th} century. Salama and Alblowi[14,15] in 2012, originated neutrosophic set and neutrosophic crisp set in a neutrosophic topological space. In the year 2016, Chatterjee et al.[3] grounded the idea of quadripartitioned neutrosophic set and defined several similarity measures between two quadripartitioned neutrosophic sets. Iswaraya and Bageerathi[9] studied the concept of neutrosophic semi-open sets and neutrosophic semi-closed sets. Push- palatha and Nandhini[12]grounded the idea of neutrosophic generalized closed sets in NTS's. The notion of neutrosophic b-open sets in NTS's was presented by Ebenanjar et al.[8] Rao and Srinivasa[13] grounded the concept of pre-open set and pre closed set via neutrosophic topological spaces. Thereafter, Maheswari et al.[10] studied the neutrosophic generalized b-closed sets in NTS's. In the year 2019, Mohammed Ali Jaffer and Ramesh[11] studied the concept of neutrosophic generalized pre-regular closed sets. The generalized neutro- sophic b-open sets in NTS's was introduced by Das and Pramanik.[6] Das and Pramanik[7] also defined the neutrosophic Φ-open sets and neutrosophic Φ-continuous mappings via NTS's. Vadivel and Sundar definedγ open sets,[18] γ continuous maps,[21,22] β-open sets[19] and β continuous maps[23–25] in N -neutrosophic crisp topological spaces and defined some operators[20] in NTS's.

In this paper we introduce quadripartitioned neutrosophic β frontier, quadripartitioned neutrosophic β bor- der and quadripartitioned neutrosophic β exterior and discuss their properties in quadripartitioned neutrosophic topological spaces.

2. Preliminaries

The needful basic definitions & properties are discussed in this section.

Definition 2.1. [3] Let Z be a fixed set. Then, a quadripartitioned neutrosophic set (in-short, Q-$N_s s$) U over Z is defined by $U = \{(u, T_U(u), C_U(u), I_U(u), F_U(u)) : u \in Z\}$ where T_U, C_U, I_U and F_U ($\in [0, 1]$) are the truth, contradiction, ignorance, and falsity membership values of $u \in Z$. So, $0 \leq T_U(u) + C_U(u) + I_U(u) + F_U(u) \leq 4$.

Definition 2.2. [3] Let Z be a non-empty set & the Q-$N_s s$'s U & U_o in the form $U = \{(u, T_U(u), C_U(u), I_U(u), F_U(u)) : u \in Z\}$, $U_o = \{(u, T_{UO}(u), C_{UO}(u), I_{UO}(u), F_{UO}) : u \in Z\}$, then

(i) $0_{QNS} = (u, 0, 0, 1, 1)$ and $1_{QNS} = (u, 1, 1, 0, 0)$,
(ii) $U \subseteq U_o$ iff $T_U(u) \leq T_{UO}(u)$, $C_U(u) \leq C_{UO}(u)$, $I_U(u) \geq I_{UO}(u)$ & $F_U(u) \geq F_{UO}(u) : u \in Z$,
(iii) $1_{QNS} - U = \{(u, F_U(u), I_U(u), C_U(u), T_U(u)) : u \in Z\} = U^c$,
(iv) $U \cup U_o = \{(u, \max(T_U(u), T_{UO}(u)), \max(C_U(u), C_{UO}(u)), \min(I_U(u), I_{UO}(u)), \min(F_U(u), F_{UO}(u))) : u \in Z\}$,
(v) $U \cap U_o = \{(u, \min(T_U(u), T_{UO}(u)), \min(C_U(u), C_{UO}(u)), \max(I_U(u), I_{UO}(u)), \max(F_U(u), F_{UO}(u))) : u \in Z\}$.

Definition 2.3. [5] Let Z be a fixed set. A collection Γ_Q of some Q-$N_s s$'s over Z is called a quadripartitioned neutrosophic topology (in-short, Q-$N_s t$) on Z, if the following conditions holds:

(i) $0_N, 1_N \in \Gamma_Q$.
(ii) $G_\phi \cap G_\varphi \in \Gamma_Q$ for any $G_\phi, G_\varphi \in \Gamma_Q$.
(iii) $G_\phi \Cup \Gamma_Q, \forall \{G_\phi : \phi \in Z\} \subseteq \Gamma_Q$.

Then (Z, Γ_Q) is called a quadripartitioned neutrosophic topological space (in-short, Q-$N_s ts$) in Z. Every element of Γ_Q are called a quadripartitioned neutrosophic open sets (in-short, Q-$N_s o$ set). If $C \in \Gamma_Q$, then C^c is called a quadripartitioned neutrosophic closed sets (in-short, Q-$N_s c$ set).

Definition 2.4. [5] Let (Z, Γ_Q) be Q-$N_s ts$ on Z and U be an Q-$N_s s$ on Z, then a quadripartitioned neutrosophicinterior (resp. closure) of U (in-short, Q-$N_s int(U)$ (resp. Q-$N_s cl(U)$)) are defined as

$$Q\text{-}N_s int(U) = \cup\{U_o : U_o \subseteq U \text{ \& } U_o \text{ is a } Q\text{-}N_s o \text{ in } Z\},$$

$$Q\text{-}N_s cl(U) = \cap\{U_o : U \subseteq U_o \text{ \& } U_o \text{ is a } Q\text{-}N_s c \text{ in } Z\},$$

Definition 2.5. [5] Let (Z, Γ_Q) be Q-$N_s ts$ on Z and U be an Q-$N_s s$ on Z. Then U is said to be a quadripartitioned neutrosophic pre (resp. semi, α & b) open set (in-short, Q-N_s po set (resp. Q-N_s

o set, Q-$N_s\alpha o$ set &Q-$N_s bo$ set)) if $U \subseteq Q$-$N_s int(Q$-$N_s cl(U))$ (resp. U Q-$N_s cl(Q$-$N_s int(U))$, $U \subseteq Q$-$N_s int(Q$-$N_s cl(Q$-$N_s int(U)))$ & $U \subseteq Q$-$N_s cl(Q$-$N_s int(U))$ Q-$N_s int(Q$-$N_s cl(U)))$.

The complement of an Q-N_s po set (resp. Q-N_s o set, Q-$N_s\alpha o$ set & Q-$N_s bo$ set) is called a quadripartitioned neutrosophic pre (resp. semi, α & b) closed set (in-short, Q-N_s Sc set (resp. Q-N_s c set, Q-$N_s\alpha c$ set& Q-$N_s bc$ set)) in Z.

The family of all Q-N_sPo set (resp. Q-N_sPc set, Q-N_sSo set, Q-N_sSc set, Q-$N_s\alpha o$ set, Q-$N_s\alpha c$ set, Q-$N_s bo$ set & Q-$N_s bc$ set) of Z is denoted by Q-N_sP$OS(Z)$ (resp. Q-N_sP$CS(Z)$, Q-N_sS$OS(Z)$, Q- N_sS$CS(Z)$, Q-$N_s\alpha OS(Z)$, Q-$N_s\alpha CS(Z)$, Q-$N_s bOS(Z)$ & Q-$N_s bCS(Z)$).

Definition 2.6. Let (Z, Γ_Q) be Q-$N_s ts$ on Z and U be a Q-$N_s s$ on Z. Then U is said to be a quadriparti-tioned neutrosophic β open set (in-short, Q-$N_s\beta o$) set if U Q-$N_s cl(Q$-$N_s int(Q$-$N_s cl(U)))$.

The complement of an Q-$N_s\beta o$ set is called a quadripartitioned neutrosophic β closed set (in-short, Q-$N_s\beta c$ set in Z.

The family of all Q-$N_s\beta o$ set (resp. Q-$N_s\beta c$ set) of Z is denoted by Q-$N_s\beta OS(Z)$ (resp. Q-$N_s\beta CS(Z)$).

Definition 2.7. The Q-$N_s\beta$ interior of U (briefly, Q-$N_s\beta int(U)$) and Q-$N_s\beta$ closure of U (briefly, Q-$N_s\beta cl(U)$) are defined as

(i) Q-$N_s\beta int(U) = \cup\{U_O : U_O \subseteq U$ & U_O is a Q-$N_s\beta o$ set in $Z\}$.
(ii) Q-$N_s\beta cl(U) = \cap\{U_O : U \subseteq U_O$ & U_O is a Q-$N_s\beta c$ set in $Z\}$.

Theorem 2.8. Let (Z, Γ_Q) be Q-$N_s ts$ on Z and G be a Q-$N_s s$ on Z. Then

(i) Q-$N_s\beta cl(1 - G) = 1 - Q$-$N_s\beta int(G)$.
(ii) Q-$N_s\beta int(1 - G) = 1 - Q$-$N_s\beta cl(G)$.

Theorem 2.9. Let (Z, Γ_Q) be Q-$N_s ts$ on Z and G be an Q-$N_s s$ on Z. Then

(i) Q-$N_s\beta int(G) \subseteq G$.
(ii) G is Q-$N_s\beta o$ iff Q-$N_s\beta int(G) = G$.
(iii) Q-$N_s\beta int(Q$-$N_s\beta int(G)) = Q$-$N_s\beta int(G)$.

Theorem 2.10. Let (Z, Γ_Q) be Q-$N_s ts$ on Z. Let G and T be quadripartitioned neutrosophic subsets of Z, then the following statements hold.

(i) $G \subseteq Q$-$N_s\beta cl(G)$.
(ii) G is Q-$N_s\beta c$ iff Q-$N_s\beta cl(G) = G$.
(iii) Q-$N_s\beta cl(Q$-$N_s\beta cl(G)) = Q$-$N_s\beta cl(G)$.
(iv) $G \subseteq T \Rightarrow Q$-$N_s\beta cl(G) \subseteq Q$-$N_s\beta cl(T)$.
(v) Q-$N_s\beta cl(G \cap T) \subseteq Q$-$N_s\beta cl(G) \cap Q$-$N_s\beta cl(T)$.
(vi) Q-$N_s\beta cl(G \cup T) = Q$-$N_s\beta cl(G) \cup Q$-$N_s\beta cl(T)$.

3 Quadripartitioned neutrosophic β frontier

In this section, we introduce quadripartitioned neutrosophic β frontier and discuss their properties in quadri-partitioned neutrosophic topological spaces.

Definition 3.1. Let (Z, Γ_Q) be a Q-N_sts with respect to F where F is a quadripartitioned neutrosophic subset of Z. Let A be a neutrosophic subset of Z. Then the quadripartitioned neutrosophic β frontier of a quadripartitioned neutrosophic subset A is denoted by Q-$N_s\beta Fr(A)$ and is defined by Q-$N_s\beta Fr(A) = Q$-$N_s\beta cl(A) \cap Q$-$N_s\beta cl(A^c)$.

Remark 3.2. For a quadripartitioned neutrosophic subset A of Z, Q-$N_s\beta Fr(A)$ is a Q-$N_s\beta c$.

Theorem 3.3. For a quadripartitioned neutrosophic subset A in Q-N_sts (Z, Γ_Q), Q-$N_s\beta Fr(A) = Q$-$N_s\beta Fr(A^c)$.

Proof. Let A be a quadripartitioned neutrosophic subset in Q-N_sts (Z, Γ_Q). Then by Definition 3.1, Q-$N_s\beta Fr(A) = Q$-$N_s\beta cl(A) \cap Q$-$N_s\beta cl(A^c) = Q$-$N_s\beta cl(A^c) \cap Q$-$N_s\beta cl(A) = Q$-$N_s\beta cl(A^c) \cap (Q$-$N_s\beta cl(A^c)^c)$. Again by Definition 3.1, this is equal to Q-$N_s\beta Fr(A^c)$. Hence Q-$N_s\beta Fr(A) = Q$-$N_s\beta Fr(A^c)$.

Theorem 3.4. Let A be a quadripartitioned neutrosophic subset in Q-N_sts (Z, Γ_Q). Then Q-$N_s\beta Fr(A) =$

Q-$N_s\beta cl(A) - Q$-$N_s\beta int(A)$.

Proof. Let A be a quadripartitioned neutrosophic subset in Q-N_sts (Z, Γ_Q). By Theorem 2.8 (ii), $(Q$-$N_s\beta cl(A^c))^c = Q$-$N_s\beta int(A)$ and by Definition 3.1, Q-$N_s\beta Fr(A) = Q$-$N_s\beta cl(A) \cap (Q$-$N_s\beta cl(A^c)) = Q$- $N_s\beta cl(A) \cap (Q$-$N_s\beta\ int(A^c))^c$. By using $A - B = A \cap B^c$, Q-$N_s\beta Fr(A) = Q$-$N_s\beta cl(A) - Q$-$N_s\beta int(A)$. Hence Q-$N_s\beta Fr(A) = Q$-$N_s\beta cl(A) - Q$-$N_s\beta int(A)$.

Theorem 3.5. A quadripartitioned neutrosophic subset A is Q-$N_s\beta c$ set in Z if and only if Q-$N_s\beta Fr(A) \subseteq A$.

Proof. Let A be a Q-$N_s\beta c$ set in the Q-N_sts (Z, Γ_Q). Then by Definition 3.1, Q-$N_s\beta Fr(A) = Q$-$N_s\beta cl(A) \cap Q$-$N_s\beta cl(A^c) \subseteq Q$-$N_s\beta cl(A)$. By using Theorem 2.10 (ii), Q-$N_s\beta cl(A) = A$. Hence Q- $N_s\beta Fr(A) \subseteq A$, if A is Q-$N_s\beta c$ in Z.

Conversely, Assume that, Q-$N_s\beta Fr(A) \subseteq A$. Then Q-$N_s\beta cl(A) - Q$-$N_s\beta int(A) \subseteq A$. Since Q-$N_s\beta int(A) \subseteq A$, we conclude that Q-$N_s\beta cl(A) = A$ and hence A is Q-$N_s\beta c$.

Theorem 3.6. If A is a Q-$N_s\beta o$ set in Z, then Q-$N_s\beta Fr(A) \subseteq A^c$.

Proof. Let A be a Q-$N_s\beta o$ set in the Q-N_sts (Z, Γ_Q). By Definition 2.6, A^c is Q-$N_s\beta c$ set in Z. By Theorem 3.5, Q-$N_s\beta Fr(A^c) \subseteq A^c$ and by Theorem 3.5, we get Q-$N_s\beta Fr(A) \subseteq A^c$.

Theorem 3.7. Let $A \subseteq B$ and B be any Q-$N_s\beta c$ set in Z. Then Q-$N_s\beta Fr(A) \subseteq B$.

Proof. By Theorem 2.10 (iv), $A \subseteq B$, Q-$N_s\beta cl(A) \subseteq Q$-$N_s\beta cl(B)$. By Definition 3.1, Q-$N_s\beta Fr(A) = Q$-$N_s\beta cl(A) \cap Q$-$N_s\beta cl(A^c) \subseteq Q$-$N_s\beta cl(B) \cap Q$-$N_s\beta cl(A^c) \subseteq Q$-$N_s\beta cl(B)$. Then by Remark **??**, this is equal to B. Hence Q-$N_s\beta Fr(A) \subseteq B$.

Theorem 3.8. Let A be a quadripartitioned neutrosophic subset in the Q-N_sts (Z, Γ_Q). Then $(Q\text{-}N_s\beta Fr(A))^c = Q\text{-}N_s\beta int(A) \cup Q\text{-}N_s\beta int(A^c)$.

Proof. Let A be a quadripartitioned neutrosophic subset in the Q-N_sts (Z, Γ_Q). Then by Definition 3.1, $(Q\text{-}N_s\beta Fr(A))^c = (Q\text{-}N_s\beta cl(A) \cap Q\text{-}N_s\beta cl(A^c))^c = ((Q\text{-}N_s\beta cl(A))^c \cup (Q\text{-}N_s\beta cl(A^c))^c$. By Theorem(ii), which is equal to $Q\text{-}N_s\beta int(A^c) Q\text{-}N_s\beta int(A)$. Hence $(Q\text{-}N_s\beta Fr(A))^c = Q\text{-}N_s\beta int(A) \cup Q\text{-}N_s\beta int(A^c)$.

Theorem 3.9. For a quadripartitioned neutrosophic subset A in the Q-N_sts (Z, Γ_Q), then $Q\text{-}N_s\beta Fr(A) \subseteq Q\text{-}N_sFr(A)$.

Proof. Let A be a quadripartitioned neutrosophic subset in the Q-N_sts (Z, Γ_Q). Then by Definition 2.7, $Q\text{-}N_s\beta cl(A) \supseteq Q\text{-}N_s\beta cl(A)$ and $Q\text{-}N_s\beta cl(A^c) \subseteq Q\text{-}N_scl(A^c)$. By Definition 3.1, $Q\text{-}N_s\beta Fr(A) = Q\text{-} N_s\beta cl(A) \cap Q\text{-}N_s\beta cl(A^c) \subseteq Q\text{-}N_scl(A) \cap Q\text{-}N_scl(A^c)$, this is equal to $Q\text{-}N_sFr(A)$. Hence $Q\text{-}N_s\beta Fr(A) \subseteq Q\text{-}N_sFr(A)$.

Theorem 3.10. For a quadripartitioned neutrosophic subset A in the Q-N_sts (Z, Γ_Q), $Q\text{-}N_s\beta cl(Q\text{-}N_s\beta Fr(A)) \subseteq Q\text{-}N_s\beta Fr(A)$.

Proof. Let A be the quadripartitioned neutrosophic subset in the Q-N_sts (Z, Γ_Q). Then by Definition 3.1,$Q\text{-}N_s\beta cl(Q\text{-}N_s\beta Fr(A)) = Q\text{-}N_s\beta cl(Q\text{-}N_s\beta cl(A)\ (Q\text{-}N_s\beta cl(A^c))) \subseteq (Q\text{-}N_s\beta cl(Q\text{-}N_s\beta cl(A))) \cap (Q\text{-}N_s\beta cl(Q\text{-}N_s\beta cl(A^c)))$. By Theorem 2.10 (iii), $Q\text{-}N_s\beta cl(Q\text{-}N_s\delta\ Fr(A)) = Q\text{-}N_s\beta cl(A) \cap (Q\text{-}N_s\beta cl(A^c))$. By Definition 3.1, this is equal to $Q\text{-}N_s\beta Fr(A)$.

Theorem 3.11. For a quadripartitioned neutrosophic subset A in the Q-N_sts (Z, Γ_Q), $Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta int(A))\, Q\text{-}N_s\beta Fr(A)$.

Proof. Let A be the quadripartitioned neutrosophic subset in the Q-N_sts (Z, Γ_Q). Then

$$
\begin{aligned}
Q-N_s\beta Fr(Q-N_s\beta int(A) &= Q-N_s\beta cl(Q-N_sint(A)) \cap (Q-N_s\beta cl(Q-N_s\beta int(A))^c) \text{[by Definition 3.1]}\\
&= Q-N_s\beta cl(Q-N_s\beta int(A)) \cap (Q-N_s\beta cl(Q-N_s\beta cl(A^c))) \text{[by Theorem 2.8(i)]}\\
&= Q-N_s\beta cl(Q-N_s\beta int(A)) \cap (Q-N_s\beta cl(A^c)) \text{[by Theorem 2.10 (iii)]}\\
&\subseteq Q-N_s\beta cl(A) \cap Q-N_s\beta cl(A^c) \text{[by Theorem 2.9 (i)]}\\
&= Q-N_s\beta Fr(A) \text{[by Definition 3.1]}.
\end{aligned}
$$

Hence $Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta int(A)) \subseteq (Q\text{-}N_s\beta Fr(A))$.

Theorem 3.12. For a quadripartitioned neutrosophic subset A in the Q-N_sts (Z, Γ_Q), then $Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta cl(A)) \subseteq Q\text{-}N_s\beta Fr(A)$.

Proof. Let A be a quadripartitioned neutrosophic subset in the Q-N_sts (Z, Γ_Q). Then

$$
\begin{aligned}
Q-N_s\beta Fr(Q-N_s\beta cl(A)) &= Q-N_s\beta cl(Q-N_s\beta cl(A)) \cap (Q-N_s\beta cl(Q-N_s\beta cl(A))^c) \text{[byDefinition 3.1]}\\
&= Q-N_s\beta cl(A) \cap (Q-N_s\beta cl(Q-N_s\beta int(A^c))) \text{[byTheorem2.8(ii)and2.10(iii)\&(iv)]}\\
&\subseteq Q-N_s\beta cl(A) \cap Q-N_s\beta cl(A^c) \text{[by Theorem 2.9 (i)]}\\
&= Q-N_s\beta Fr(A) \text{[by Definition 3.1]}
\end{aligned}
$$

Hence $Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta cl(A)) \subseteq Q\text{-}N_s\beta Fr(A)$.

Theorem 3.13. Let A be a quadripartitioned neutrosophic subset in the $Q\text{-}N_sts$ (Z, Γ_Q). Then $Q\text{-}N_s\beta int(A) \subseteq A - Q\text{-}N_s\beta Fr(A)$.

Proof. Let A be a quadripartitioned neutrosophic subset in the $Q\text{-}N_sts(Z,\Gamma_Q)$. Now by Definition 3.1,

$$
\begin{aligned}
A - Q\text{-}N_s\beta Fr(A) &= A \cap (Q\text{-}N_s\beta Fr(A))^c \\
&= A \cap [Q\text{-}N_s\beta cl(A) \cap Q\text{-}N_s\beta cl(A^c)]^c \\
&= A \cap [Q\text{-}N_s\beta int(A^c) \cup Q\text{-}N_s\beta int(A)] \\
&= [A \cap Q\text{-}N_s\beta int(A^c)] \cup [A \cap Q\text{-}N_s\beta int(A)] \\
&= [A \cap Q\text{-}N_s\beta int(A^c)] \cup Q\text{-}N_s\beta int(A) \supseteq Q\text{-}N_s\beta int(A)
\end{aligned}
$$

Hence $Q\text{-}N_s\beta int(A) \subseteq A - Q\text{-}N_s\beta Fr(A)$.

Theorem 3.14. Let A and B be quadripartitioned neutrosophic subsets in the $Q\text{-}N_sts$ (Z, Γ_Q). Then $Q\text{-}N_s\beta Fr(A \cup B) \subseteq Q\text{-}N_s\beta Fr(A) \cup Q\text{-}N_s\beta Fr(B)$.

Proof. Let A and B be quadripartitioned neutrosophic subsets in the $Q\text{-}N_sts$ (Z, Γ_Q). Then

$$
\begin{aligned}
Q\text{-}N_s\beta Fr(A \cup B) &= Q\text{-}N_s\beta cl(A \cup B) \cap Q\text{-}N_s\beta cl(A \cup B)^c \text{[by Definition 3.1]} \\
&= Q\text{-}N_s\beta cl(A \cup B) \cap Q\text{-}N_s\beta cl(A^c \cap B^c) \\
&\subseteq (Q\text{-}N_s\beta cl(A) \cup Q\text{-}N_s\beta cl(B) \cap ((Q\text{-}N_s\beta cl(A))) \cap (Q\text{-}N_s\beta cl(B)) \\
&\qquad \text{[by Theorem 2.10 (v) \& (vi)]} \\
&= [(Q\text{-}N_s\beta cl(A) \cup (Q\text{-}N_s\beta cl(B)) \cap (Q\text{-}N_s\beta cl(A^c)))] \cap [(Q\text{-}N_s\beta cl(A) \cup \\
&\qquad (Q\text{-}N_s\beta cl(B)) \cap (Q\text{-}N_s\beta cl(B^c)))] \\
&= [(Q\text{-}N_s\beta cl(A) \cap Q\text{-}N_s\beta cl(A^c)) \cup ((Q\text{-}N_s\beta cl(B) \cap (Q\text{-}N_s\beta cl(A^c))))] \cap \\
&\qquad [(Q\text{-}N_s\beta cl(A) \cap (Q\text{-}N_s\beta cl(B^c))) \cup ((Q\text{-}N_s\beta cl(B) \cap (Q\text{-}N_s\beta cl(B^c))))] \\
&= [Q\text{-}N_s\beta Fr(A) \cup (Q\text{-}N_s\beta cl(B)) \cap (Q\text{-}N_s\beta cl(A^c))] \cap [(Q\text{-}N_s\beta cl(A) \cap \\
&\qquad (Q\text{-}N_s\beta cl(B^c))) \cup (Q\text{-}N_s\beta Fr(B))] \text{[by Definition 3.1]} \\
&= (Q\text{-}N_s\beta Fr(A) \cup Q\text{-}N_s\beta Fr(B)) \cap [(Q\text{-}N_s\beta cl(B) \cap (Q\text{-}N_s\beta cl(A^c))) \cup \\
&\qquad ((Q\text{-}N_s\beta cl(A) \cap Q\text{-}N_s\beta cl(B^c)))] \\
&\subseteq Q\text{-}N_s\beta Fr(A) \cup Q\text{-}N_s\beta Fr(B).
\end{aligned}
$$

Hence, $Q\text{-}N_s\beta Fr(A \cup B) \subseteq Q\text{-}N_s\beta Fr(A) \cup Q\text{-}N_s\beta Fr(B)$.

Theorem 3.15. For any quadripartitioned neutrosophic subsets A and B in the $Q\text{-}N_sts$ (Z, Γ_Q), $Q\text{-}N_s\beta Fr(A \cap B) \subseteq (Q\text{-}N_s\beta Fr(A) \cap (Q\text{-}N_s\beta cl(B))) \cup (Q\text{-}N_s\beta Fr(B) \cap Q\text{-}N_s\beta cl(A))$.

Proof. Let A and B be quadripartitioned neutrosophic subsets in the $Q\text{-}N_sts$ (Z, Γ_Q). Then

$Q\text{-}N_s\beta Fr(A \cap B)$

$=Q\!-\!N_s\beta cl(A\cap B)\cap(Q\!-\!N_s\beta cl(A\cap B)^c)$[by Definition 3.1]

$=Q\!-\!N_s\beta cl(A\cap B)\cap(Q\!-\!N_s\beta cl(A^c\cup B^c))$

$\subseteq(Q\!-\!N_s\beta cl(A)\cap Q\!-\!N_s\beta cl(B))\cap(Q\!-\!N_s\beta cl(A\ )\cup Q\!-\!N_s\beta cl(B\ \ ))$[by Theorem 2.10 (v) & (vi)]

$=[(Q\!-\!N_s\beta cl(A)\cap Q\!-\!N_s\beta cl(B))\cap Q\!-\!N_s\beta cl(A^c)]\cup[(Q\!-\!N_s\beta cl(A)\cap Q\!-\!N_s\beta cl(B))\cap Q\!-\!N_s\beta cl(B^c)]$

$=(Q\!-\!N_s\beta Fr(A)\cap Q\!-\!N_s\beta cl(B))\cup(Q\!-\!N_s\beta Fr(B)\cap Q\!-\!N_s\beta cl(A))$[by Definition 3.1].

Hence $Q\text{-}N_s\beta Fr(A\cap B)\subseteq((Q\text{-}N_s\beta Fr(A)\cap(Q\text{-}N_s\beta cl(B)))\cup(Q\text{-}N_s\beta Fr(B)\cap(Q\text{-}N_s\beta cl(A))))$.

Corollary 3.16. For any quadripartitioned neutrosophic subsets A and B in the $Q\text{-}N_sts$ (Z,Γ_Q), $Q\text{-}N_s\beta Fr(A\cap B)\subseteq Q\text{-}N_s\beta Fr(A)\cup Q\text{-}N_s\beta Fr(B)$.

Proof. Let A and B be quadripartitioned neutrosophic subsets in the $Q\text{-}N_sts$ (Z,Γ_Q). Then

$Q\!-\!N_s\beta Fr(A\cap B)$

$=Q\!-\!N_s\beta cl(A\cap B)\cap(Q\!-\!N_s\beta cl(A\cap B)^c)$[by Definition 3.1]

$=Q\!-\!N_s\beta cl(A\cap B)\cap(Q\!-\!N_s\beta cl(A^c\cup B^c)$

$\subseteq(Q\!-\!N_s\beta cl(A)\cap Q\!-\!N_s\beta cl(B))\cap(Q\!-\!N_s\beta cl(A)\cup Q\!-\!N_s\beta cl(B\ \ ))$[by Theorem 2.10 (v) & (vi)]

$=(Q\!-\!N_s\beta cl(A)\cap Q\!-\!N_s\beta cl(B))\cap(Q\!-\!N_s\beta cl(A^c)\cup(Q\!-\!N_s\beta cl(A)\cap Q\!-\!N_s\beta cl(B))\cap(Q\!-\!N_s\beta cl(B^c)))$

$=(Q\!-\!N_s\beta Fr(A)\cap Q\!-\!N_s\beta cl(B))\cup(Q\!-\!N_s\beta cl(A)\cap Q\!-\!N_s\beta Fr(B))$[by Definition 3.1]

$\subseteq Q\!-\!N_s\beta Fr(A)\cup(Q\!-\!N_s\beta Fr(B)$.

Hence $Q\text{-}N_s\beta Fr(A\cap B)\subseteq Q\text{-}N_s\beta Fr(A)\cup Q\text{-}N_s\beta Fr(B)$.

Theorem 3.17. For any quadripartitioned neutrosophic subset A in the $Q\text{-}N_sts$ (Z,Γ_Q),

(i) $Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta Fr(A))\subseteq Q\text{-}N_s\beta Fr(A)$,
(ii) $Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta Fr(A)))\subseteq Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta Fr(A))$.

Proof. (i) Let A be a quadripartitioned neutrosophic subset in the $Q\text{-}N_sts$ (Z,Γ_Q). Then

$Q\!-\!N_s\beta Fr(Q\!-\!N_s\beta Fr(A))$

$=Q\!-\!N_s\beta cl(Q\!-\!N_s\beta Fr(A))\cap Q\!-\!N_s\beta cl(Q\!-\!N_s\beta Fr(A)^c)$ by [Definition 3.1]

$=Q\!-\!N_s\beta cl(Q\!-\!N_s\beta cl(A)\cap(Q\!-\!N_s\beta cl\,(A^c))\cap(Q\!-\!N_s\beta cl(Q\!-\!N_s\beta cl(A))\cap(Q\!-\!N_s\beta cl\,(A^c))^c))$

by [Definition 3.1]

$\subseteq(N\,\mathrm{N}\,\delta cl(Q\!-\!N_s\beta cl(A))\cap(Q\!-\!N_s\beta cl(Q\!-\!N_s\beta cl(A)))\cap(Q\!-\!N_s\beta cl(Q\!-\!N_s\beta int(A)))\cup$

$(Q\!-\!N_s\beta int(A)))$[by Theorem 2.10 (iii) & (v)]

$=(Q\!-\!N_s\beta cl(A)\cap(Q\!-\!N_s\beta cl(A^c))\cap(Q\!-\!N_s\beta cl(Q\!-\!N_s\beta int(A)\cup Q\!-\!N_s\beta int(A))))$

[by Theorem 2.10 (iii)]

$\subseteq Q\!-\!N_s\beta cl(A)\cap Q\!-\!N_s\beta cl(A^c)$

$=Q\!-\!N_s\beta Fr(A)$ [by Definition 3.1].

Therefore $Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta Fr(A)) \subseteq Q\text{-}N_s\beta Fr(A)$.

(ii) Again, $Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta Fr(A))) \subseteq Q\text{-}N_s\beta Fr(Q\text{-}N_s\beta Fr(A))$.

4 Quadripartitioned neutrosophic β border and quadripartitioned neutrosophic β exterior

In this section, we introduce the quadripartitioned neutrosophic β border, quadripartitioned neutrosophic β exterior using quadripartitioned neutrosophic β open sets and their properties are discussed in $Q\text{-}N_sts$'s.

Definition 4.1. Let A be a quadripartitioned neutrosophic subset of $Q\text{-}N_sts$ (Z, Γ_Q). Then the set $Q\text{-}N_sBr(A) = A\ Q\text{-}N_sint(A)$ (resp. $Q\text{-}N_s\beta Br(A) = A - Q\text{-}N_s\beta int(A)$) is called the quadripartitioned neutrosophic (resp. quadripartitioned neutrosophic β) border of A.

Theorem 4.2. If a subset A of Z is $Q\text{-}N_s\beta c$, then $Q\text{-}N_s\beta Br(A) = Q\text{-}N_s\beta Fr(A)$.

Proof. Let A be a $Q\text{-}N_s\beta c$ subset of Z. Then by Theorem 2.8 (ii), $Q\text{-}N_s\beta cl(A) = A$. Now, $Q\text{-}N_s\beta Fr(A) = Q\text{-}N_s\beta cl(A) - Q\text{-}N_s\beta int(A) = A - Q\text{-}N_s\beta int(A) = Q\text{-}N_s\beta Br(A)$.

Theorem 4.3. For a quadripartitioned neutrosophic subset A of Z, $A = Q\text{-}N_s\beta int(A) \cup Q\text{-}N_s\beta Br(A)$.

Proof. Let $x_{(e1,e2,e3,e4)} \in A$. If $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta int(A)$, then the result is obvious. If $x_{(e1,e2,e3,e4)} \notin Q\text{-}N_s\beta int(A)$, then by the definition of $Q\text{-}N_s\beta Br(A)$, $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta Br(A)$. Hence $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta int(A) \cup Q\text{-}N_s\beta Br(A)$ and so $A \subseteq Q\text{-}N_s\beta int(A) \cup Q\text{-}N_s\beta Br(A)$. On the other hand, since $Q\text{-}N_s\beta int(A) \subseteq A$ and $Q\text{-}N_s\beta Br(A) \subseteq A$, we have $Q\text{-}N_s\beta int(A) \cup Q\text{-}N_s\beta Br(A) \subseteq A$.

Theorem 4.4. For a quadripartitioned neutrosophic subset A of Z, $Q\text{-}N_s\beta int(A) \cap Q\text{-}N_s\beta Br(A) = 0_N$.

Proof. Suppose $Q\text{-}N_s\beta int(A) \cap Q\text{-}N_s\beta Br(A) \neq 0_N$. Let $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta int(A) \cap Q\text{-}N_s\beta Br(A)$. Then $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta int(A)$ and $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta Br(A)$. Since $Q\text{-}N_s\beta Br(A) = A - Q\text{-}N_s\beta int(A)$, then $x_{(e1,e2,e3,e4)} \in A$. But $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta int(A)$, $x_{(e1,e2,e3,e4)} \in A$. There is a contra- diction. Hence $Q\text{-}N_s\beta int(A) \cap Q\text{-}N_s\beta Br(A) = 0_N$.

Theorem 4.5. For a quadripartitioned neutrosophic subset A of Z, A is a $Q\text{-}N_s\beta o$ set if and only if $Q\text{-}N_s\beta Br(A) = 0_N$.

Proof. Necessity: Suppose A is $Q\text{-}N_s\beta o$. Then by Theorem 2.9 (ii), $Q\text{-}N_s\beta int(A) = A$. Now, $Q\text{-}N_s\beta Br(A) = A - Q\text{-}N_s\beta int(A) = A - A = 0_N$.

Sufficiency: Suppose $Q\text{-}N_s\beta Br(A) = 0_N$. This implies, $A - Q\text{-}N_s\beta int(A) = 0_N$. Therefore $A = Q\text{-}N_s\beta int(A)$ and hence A is $Q\text{-}N_s\beta o$.

Corollary 4.6. For a $Q\text{-}N_sts$, $Q\text{-}N_s\beta Br(0_N) = 0_N$ and $Q\text{-}N_s\beta Br(1_N) = 0_N$.

Proof. Since 0_N and 1_N are $Q\text{-}N_s\beta o$, by Theorem 4.5, $Q\text{-}N_s\beta Br(0_N) = 0_N$ and $Q\text{-}N_s\beta Br(1_N) = 0_N$

Theorem 4.7. For a quadripartitioned neutrosophic subset A of Z, $Q\text{-}N_s\beta Br(Q\text{-}N_s\beta int(A)) = 0_N$.

Proof. By the definition of $Q\text{-}N_s\beta$ border, $Q\text{-}N_s\beta Br(Q\text{-}N_s\beta int(A)) = Q\text{-}N_s\beta int(A) - Q\text{-}N_s\beta int(Q\text{-}N_s\beta int(A))$. By Theorem 2.9 (iii), $Q\text{-}N_s\beta int(Q\text{-}N_s\beta int(A)) = Q\text{-}N_s\beta int(A)$ and hence $Q\text{-}N_s\beta Br(Q\text{-} N_s\beta int(A)) = 0_N$.

Theorem 4.8. For a quadripartitioned neutrosophic subset A of Z, $Q\text{-}N_s\beta int(Q\text{-}N_s\beta Br(A))=0_N$.

Proof. Let $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta int(Q\text{-}N_s\beta Br(A))$. Since $Q\text{-}N_s\beta Br(A) \subseteq A$, by Theorem 2.9 (i), $Q\text{-}N_s\beta int(Q\text{-}N_s\beta Br(A)) \subseteq Q\text{-}N_s\beta int(A)$. Hence $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta int(A)$. Since $Q\text{-}N_s\beta int(Q\text{-} N_s\beta Br(A)) \subseteq Q\text{-}N_s\beta Br(A)$, $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta Br(A)$. Therefore $x_{(e1,e2,e3,e4)} \in Q\text{-}N_s\beta int(A) \cap Q\text{-} N_s\beta Br(A)$, $x_{(e1,e2,e3,e4)} = 0_N$.

Theorem 4.9. For a quadripartitioned neutrosophic subset A of Z, $Q\text{-}N_s\beta Br(Q\text{-}N_s\beta Br(A)) = Q\text{-}N_s\beta Br(A)$.

Proof. By the definition of $Q\text{-}N_s\beta$ border, $Q\text{-}N_s\beta Br(Q\text{-}N_s\beta Br(A)) = Q\text{-}N_s\beta Br(A) - Q\text{-}N_s\beta int(Q\text{-} N_s\beta Br(A))$. By Theorem 4.8 $Q\text{-}N_s\beta int(Q\text{-}N_s\beta Br(A)) = 0_N$ and hence $Q\text{-}N_s\beta Br(Q\text{-}N_s\beta Br(A)) = Q\text{-} N_s\beta Br(A)$.

Theorem 4.10. Let A be a quadripartitioned neutrosophic subset of Z. Then, $Q\text{-}N_s\beta Br(A) = A \cap Q\text{-} N_s\beta cl(A^c)$.

Proof. Since $Q\text{-}N_s\beta Br(A) = A - Q\text{-}N_s\beta int(A)$ and by Theorem 2.10, $Q\text{-}N_s\beta Br(A)=A-(Q\text{-}N_s\beta cl(A^c))^c = A \cap (Q\text{-}N_s\beta cl\ (A^c)^c) = A \cap Q\text{-}N_s\beta cl(A^c)$.

Theorem 4.11. For a quadripartitioned neutrosophic subset A of Z, $Q\text{-}N_s\beta Br(A) \subseteq Q\text{-}N_s\beta Fr(A)$.

Proof. Since $A \subseteq Q\text{-}N_s\beta cl(A)$, $A - Q\text{-}N_s\beta int(A) \subseteq Q\text{-}N_s\beta cl(A) - Q\text{-}N_s\beta int(A)$. That implies, $Q\text{-}N_s\beta Br(A) \subseteq Q\text{-}N_s\beta Fr(A)$.

Definition 4.12. Let A be a quadripartitioned neutrosophic subset of a $Q\text{-}N_s ts$ (Z, Γ_Q). The quadripartitioned neutrosophic (resp. β) interior of A^c is called the quadripartitioned neutrosophic (resp. quadripartitioned neutrosophic β) exterior of A and it is denoted by $Q\text{-}N_s Ext(A)$ (resp. $Q\text{-}N_s\beta Ext(A)$). That is, $Q\text{-}N_s Ext(A) = Q\text{-}N_s int(A^c)$ (resp. $Q\text{-}N_s\beta Ext(A) = Q\text{-}N_s\beta int(A^c)$).

Theorem 4.13. For a quadripartitioned neutrosophic subset A of Z, $Q\text{-}N_s\beta Ext(A)=(Q\text{-}N_s\beta cl(A))^c$.

Proof. We know that, U - $Q\text{-}N_s\beta cl(A =Q\text{-}N_s\beta int(A^c)$, then $Q\text{-}N_s\beta Ext(A)=Q\text{-}N_s\beta int(A^c) = (Q\text{-}N_s\beta cl(A))^c$.

Theorem 4.14. For a quadripartitioned neutrosophic subset A of Z, $Q\text{-}N_s\beta Ext(Q\text{-}N_s\beta Ext(A)) = Q\text{-}N_s\beta int(Q\text{-}N_s\beta cl(A)) \supseteq Q\text{-}N_s\beta int(A)$.

Proof. Now, $Q\text{-}N_s\beta Ext(Q\text{-}N_s\beta Ext(A)) = Q\text{-}N_s\beta Ext(Q\text{-}N_s\beta int(A^c)) = Q\text{-}N_s\beta int((Q\text{-}N_s\beta int(A^c))^c) = Q\text{-}N_s\beta int(Q\text{-}N_s\beta cl(A)) \supseteq Q\text{-}N_s\beta int(A)$.

Theorem 4.15. For a quadripartitioned neutrosophic subset A of Z, If $A \subseteq B$, then $Q\text{-}N_s\beta Ext(B) \subseteq Q\text{-} N_s\beta Ext(A)$.

Proof. Suppose $A \subseteq B$. Now, $Q\text{-}N_s\beta Ext(B)=Q\text{-}N_s\beta int(B^c) \subseteq Q\text{-}N_s\beta int(A^c)= Q\text{-}N_s\beta Ext(A)$.

Theorem 4.16. For a quadripartitioned neutrosophic subset A of Z, $Q\text{-}N_s\beta Ext(1_N) = 0_N$ and $Q\text{-}N_s\beta Ext(0_N) = 1_N$.

Proof. Now, $Q\text{-}N_s\beta Ext(1_N) = Q\text{-}N_s\beta int((1_N)^c) = Q\text{-}N_s\beta int(0_N)$ and $Q\text{-}N_s\beta Ext(0_N) = Q\text{-}N_s\beta int((0_N)^c) = Q\text{-}N_s\beta int(1_N)$. Since 0_N and 1_N are $Q\text{-}N_s\beta o$ sets, then $Q\text{-}N_s\beta int(0_N) = 0_N$ and $Q\text{-}N_s\beta int(1_N) = 1_N$. Hence $Q\text{-}N_s\beta Ext(0_N) = 1_N$ and $Q\text{-}N_s\beta Ext(1_N) = 0_N$.

Theorem 4.17. For a quadripartitioned neutrosophic subset A of Z, $Q\text{-}N_s\beta Ext(A) = Q\text{-}N_s\beta Ext((Q\text{-}N_s\beta Ext(A))^c)$.

Proof. Now, $Q\text{-}N_s\beta Ext((Q\text{-}N_s\beta Ext(A))^c) = Q\text{-}N_s\beta Ext((Q\text{-}N_s\beta int(A^c))^c) = Q\text{-}N_s\beta int((((Q\text{-}N_s\beta int(A^c))^c))^c) = Q\text{-}N_s\beta int(Q\text{-}N_s\beta int(A^c)) = Q\text{-}N_s\beta int(A^c) = Q\text{-}N_s\beta Ext(A)$.

Theorem 4.18. For a sub sets A and B of Z, the followings are valid.

(i) $Q\text{-}N_s\beta Ext(A \cup B) \subseteq Q\text{-}N_s\beta Ext(A) \cap Q\text{-}N_s\beta Ext(B)$.
(ii) $Q\text{-}N_s\beta Ext(A \cap B) \supseteq Q\text{-}N_s\beta Ext(A) \cup Q\text{-}N_s\beta Ext(B)$.

Proof. (i) $Q\text{-}N_s\beta Ext(A \cup B) = Q\text{-}N_s\beta int((A \cup B)^c) = Q\text{-}N_s\beta int((A^c) \cap (B^c)) \subseteq Q\text{-}N_s\beta cl(A^c) \cap Q\text{-}N_s\beta cl(B^c) = Q\text{-}N_s\beta Ext(A) \cap Q\text{-}N_s\beta Ext(B)$.

(ii) $Q\text{-}N_s\beta Ext(A \cap B) = Q\text{-}N_s\beta int((A \cap B)^c) = Q\text{-}N_s\beta int((A^c) \cup (B^c)) \supseteq Q\text{-}N_s\beta cl(A^c) \cup Q\text{-}N_s\beta cl(B^c) = Q\text{-}N_s\beta Ext(A) \cup Q\text{-}N_s\beta Ext(B)$.

Conclusion

In this paper, we have studied some new operators called quadripartitioned neutrosophic β frontier, respective border and exterior with the help of quadripartitioned neutrosophic β-open sets in quadripartitioned neutro- sophic topological space. Also, we discussed the important properties of them and the relations between them.

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