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Neutrosophic Cubic ℵ-Fuzzy Ideals with Ternion Semigroups

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***Abstract:** The aim of this paper is to define neutrosophic cubic ℵ-ternion subsemigroup, neutrosophic(neut.) cubic ℵ- left ideal(LI), (resp. lateral ideal(ℒI), right ideal(RI)) of ternion semigroup(SG) with suitable example, to define characteristic neut. cubic ℵ-structure(ℵ-S) of ternion SG. Additionally intersection of two neut. cubic ℵ-LI(resp. ℒI, RI) is also a neut. cubic ℵ-LI(resp. ℒI, RI). We find intersection between two neut. cubic ℵ-LI(resp. ℒI, RI) in ternion SG is neut. cubic ℵ-LI(resp. ℒI, RI) in ternion SG. Further if we have an neut. cubic ℵ-LI(resp. ℒI, RI) then its pre-image is also neut. cubic ℵ-LI(resp. ℒI, RI) of ternion SG. In this study a new algebraic approach has been developed in neut. cubic ℵ-ideals in ternion SG. In future this neut. cubic ℵ-fuzzy ideal concept can be used in semiring, ternion semiring etc.*

***Keywords:** Neutrosophic fuzzy set, Interval Valued Neutrosophic cubic ℵ-fuzzy ideals, Ternion Semigroup, Direct product of cubic ternion semigroup, Homomorphism of cubic ternion semigroup.*

I. INTRODUCTION

R.Chinram et al.[4] in 2023 studied a new notion on covered left ideals of ternary SG. A. Nongmanee and S. Leeratanavalee[13] studied about quaternary rectangular bands and representations of ternary SG in 2022. L. A. Zadeh [23] introduced the notion of interval valued (in short i-v) fuzzy subset where the values of the membership functions are closed interval number instead of single value in 1975.

Li. Chunnu et al.[5] discussed a new characterization of fuzzy ideals of SG in 2021. K. T. Atanassove [1] introduced the notion of an intuitionistic fuzzy set. F. Smarandache[20] introduced the notion of neutrosophic sets (in short neut.) which is useful mathematical tool for dealing with membership, non membership and indeterminacy function. D. H. Lehmer[9] introduced ternary analogue of abelian group in 1932. Madad Khan et al. [11] introduced the notion of neut. $\mathcal{N}$-subsemigroup(SSG) in SG and investigated several properties. K. Lenin Muthu Kumaran and S. Selvaraj[10] discussed about interval valued neut. ℵ-fuzzy ideals in SG in 2023. S. Amalanila and S. Jayalakshmi[2] discussed a cubic (1,2) ideals of cubic near-rings. V. Chinnadurai and K. Bharathivelan[3] studied a new notion of cubic lateral ideals in ternary near-rings. Muhammad Gulistan[12] introduced the notion of neutrosophic cubic (α,β)-ideals in semigroup with application. The above ideas motivate us to define the notion of neut. cubic ℵ-fuzzy ideals in ternion SG.

In this paper, the notion of neut. cubic ℵ-ideals in ternion (means ternary) SG is introduced and several properties are investigated such as LI, ℒI, RI etc. Further, conditions for neut. cubic ℵ-S to be neut. cubic ℵ-ideals in ternion SG are provided. Furthermore, we explore the ideas of characteristic function, level sets of neut. cubic ℵ-S of ternion SG, direct product, intersection property of neut. cubic ℵ-S of fuzzy ideal in ternion SG and homomorphism of neut. cubic ℵ-ideals in ternion SG and its related properties.

II. METHODOLOGY

In this research work the results of neut. cubic ℵ-ideals in ternion SG are used such as neut. cubic ℵ-ternion SSG, neut. cubic ℵ-LI(resp. ℒI, RI), negative product between two neut. cubic ℵ-structure in ternion SG.

III. RESULT AND DISCUSSION

In this section, we define the idea of neutrosophic ℵ-cubic ideals in ternion semigroups and investigate using this concept.

Definition 3.1

Consider S_C as a neut. cubic ℵ-S defined over the set S. In such a context, S_C is termed as a neut. cubic ℵ-ternion SSG of S if it meets the following criteria:

$T_{\overline{N}}([uvw]) \leq rmax\{T_{\overline{N}}(u), T_{\overline{N}}(v), T_{\overline{N}}(w)\},$

$I_{\overline{N}}([uvw]) \geq rmin\{I_{\overline{N}}(u), I_{\overline{N}}(v), I_{\overline{N}}(w)\}$,
$F_{\overline{N}}([uvw]) \geq rmin\{F_{\overline{N}}(u), F_{\overline{N}}(v), F_{\overline{N}}(w)\}$, and
$T_N([uvw]) \geq min\{T_N(u), T_N(v), T_N(w)\}$,
$I_N([uvw]) \leq max\{I_N(u), I_N(v), I_N(w)\}$,
$F_N([uvw]) \leq max\{F_N(u), F_N(v), F_N(w)\}$ for all $u, v, w \in S$.

Definition 3.2
An neut. cubic ℵ-S S_C over set S is considered as an neut. cubic $\aleph - LI$ $(resp. \aleph - \mathcal{L}I, \aleph - RI)$ of S if it adheres to the following criteria:

$T_{\overline{N}}([uvw]) \leq T_{\overline{N}}(w)\big(resp. T_{\overline{N}}([uvw]) \leq T_{\overline{N}}(v), T_{\overline{N}}([uvw]) \leq T_{\overline{N}}(u)\big)$
$I_{\overline{N}}([uvw]) \geq I_{\overline{N}}(w)\big(resp. I_{\overline{N}}([uvw]) \geq I_{\overline{N}}(v), I_{\overline{N}}([uvw]) \geq I_{\overline{N}}(u)\big)$
$F_{\overline{N}}([uvw]) \geq F_{\overline{N}}(w)\big(reps. F_{\overline{N}}([uvw]) \geq F_{\overline{N}}(v), F_{\overline{N}}([uvw]) \geq F_{\overline{N}}(u)\big)$, and
$T_N([uvw]) \geq T_N(w)\big(resp. T_N([uvw]) \geq T_N(v), T_N([uvw]) \geq T_N(u)\big)$
$I_N([uvw]) \leq I_N(w)\big(resp. I_N([uvw]) \leq I_N(v), I_N([uvw]) \leq I_N(u)\big)$
$F_N([uvw]) \leq F_N(w)\big(reps. F_N([uvw]) \leq F_N(v), F_N([uvw]) \leq F_N(u)\big)$for all $u, v, w \in S$.

If S_C is a neut. cubic ℵ-LI, ℵ-$\mathcal{L}$I, ℵ- RI of S, then S_C is said to be neut. cubic ℵ-ideal of S.

Note 3.3
Every neut. cubic ℵ-LI $(resp. \mathcal{L}I, RI)$ within a ternion SG qualifies as an neut. cubic ℵ-ternion SSG, the reverse may not hold true, (ie) neut. cubic ℵ-ternion SSG is not necessarily an neut. cubic ℵ-LI, nor is it required to be an neut. cubic ℵ-$\mathcal{L}$I or an neut. cubic ℵ-RI, as demonstrated in the subsequent example.

Example 3.4
Let $S = \{0, 1, 2, 3\}$ and define the ternion operation [ ] on S as follows:

[]	0	1	2	3
00	0	1	2	3
01	0	1	2	3
02	0	1	2	3
03	3	3	3	3

Table 1

[]	0	1	2	3
10	1	1	1	3
11	1	1	1	3
12	1	1	1	3
13	3	3	3	3

Table 2

[]	0	1	2	3
20	0	1	2	3
21	0	1	2	3
22	0	1	2	3
23	3	3	3	3

Table 3

[]	0	1	2	3
30	3	3	3	3
31	3	3	3	3
32	3	3	3	3
33	3	3	3	3

Table 4

Then, $(S, [\,])$ is a ternion SG [16]. Define an neut. cubic ℵ-S, S_C over S as follows:

$T_{\overline{N}}(0) = [-0.7, -0.5]$, $I_{\overline{N}}(0) = [-0.5, -0.1]$, $F_{\overline{N}}(0) = [-0.6, -0.1]$,
$T_{\overline{N}}(1) = [-0.7, -0.5]$, $I_{\overline{N}}(1) = [-0.5, -0.1]$, $F_{\overline{N}}(1) = [-0.6, -0.1]$,
$T_{\overline{N}}(2) = [-0.6, -0.4]$, $I_{\overline{N}}(2) = [-0.6, -0.3]$, $F_{\overline{N}}(2) = [-0.7, -0.4]$,
$T_{\overline{N}}(3) = [-0.4, -0.1]$, $I_{\overline{N}}(3) = [-0.7, -0.5]$, $F_{\overline{N}}(3) = [-0.9, -0.8]$.
$T_N(0) = -0.1$, $I_N(0) = -0.5$, $I_N(0) = -0.8$,
$T_N(1) = -0.4$, $I_N(1) = -0.3$, $I_N(1) = -0.4$,
$T_N(2) = -0.5$, $I_N(2) = -0.1$, $I_N(2) = -0.1$,
$T_N(3) = -0.5$, $I_N(3) = -0.1$, $I_N(3) = -0.1$.

By routine calculation, $S_C = T_{\overline{N}}, I_{\overline{N}}, F_{\overline{N}}, T_N, I_N, F_N$is an neut. cubic ternion ℵ-SSG of S, but it is not an neut. cubic ℵ-LI, because

$$T_{\overline{N}}[130] = [-0.4, -0.1] \nleq [-0.7, -0.5] = T_{\overline{N}}(0),$$
$$I_{\overline{N}}[130] = [-0.7, -0.5] \ngeq [-0.5, -0.1] = I_{\overline{N}}(0),$$
$$F_{\overline{N}}[130] = [-0.9, -0.8] \ngeq [-0.6, -0.1] = F_{\overline{N}}(0).$$

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Example 3.5
Let $S = \{0, 1, 2, 3\}$ and define the ternion operation [ ] on S as follows:

[]	0	1	2	3
00	0	1	0	3
01	0	1	0	3
02	0	1	0	3
03	3	3	3	3

Table 5

[]	0	1	2	3
10	0	1	0	3
11	0	1	0	3
12	0	1	0	3
13	3	3	3	3

Table 6

[]	0	1	2	3
20	0	1	0	3
21	0	1	0	3
22	0	1	0	3
23	3	3	3	3

Table 7

[]	0	1	2	3
30	3	3	3	3
31	3	3	3	3
32	3	3	3	3
33	3	3	3	3

Table 8

Then, $(S, [\,])$ is a ternion SG [16]. Define an neut. cubic ℵ-S, S_N over S as follows:

$T_{\bar{N}}(0) = [-0.9, -0.8]$, $I_{\bar{N}}(0) = [-0.5, -0.2]$, $F_{\bar{N}}(0) = [-0.4, -0.1]$,
$T_{\bar{N}}(1) = [-0.8, -0.6]$, $I_{\bar{N}}(1) = [-0.6, -0.4]$, $F_{\bar{N}}(1) = [-0.5, -0.3]$,
$T_{\bar{N}}(2) = [-0.5, -0.2]$, $I_{\bar{N}}(2) = [-0.8, -0.7]$, $F_{\bar{N}}(2) = [-0.7, -0.6]$,
$T_{\bar{N}}(3) = [-0.9, -0.8]$, $I_{\bar{N}}(3) = [-0.5, -0.2]$, $F_{\bar{N}}(3) = [-0.4, -0.1]$.
$T_N(0) = -0.8$, $I_N(0) = -0.2$, $I_N(0) = -0.1$,
$T_N(1) = -0.2$, $I_N(1) = -0.7$, $I_N(1) = -0.6$,
$T_N(2) = -0.6$, $I_N(2) = -0.4$, $I_N(2) = -0.3$,
$T_N(3) = -0.8$, $I_N(3) = -0.2$, $I_N(3) = -0.1$.

By routine calculation, $S_C = T_{\bar{N}}, I_{\bar{N}}, F_{\bar{N}}, T_N, I_N, F_N$ is a neut. cubic ternion ℵ-SSG of S, but it is not a neut. cubic ℵ-$\mathcal{L}$I, because

$$T_{\bar{N}}[101] = [-0.8, -0.6] \nleq [-0.9, -0.8] = T_{\bar{N}}(0),$$
$$I_{\bar{N}}[101] = [-0.6, -0.4] \ngeq [-0.5, -0.2] = I_{\bar{N}}(0),$$
$$F_{\bar{N}}[101] = [-0.5, -0.3] \ngeq [-0.4, -0.1] = F_{\bar{N}}(0).$$

By addition, S_C is also not a neut. cubic ℵ-RL, because

$$T_{\bar{N}}[021] = [-0.8, -0.6] \nleq [-0.9, -0.8] = T_{\bar{N}}(0),$$
$$I_{\bar{N}}[021] = [-0.6, -0.4] \ngeq [-0.5, -0.2] = I_{\bar{N}}(0),$$
$$F_{\bar{N}}[021] = [-0.5, -0.3] \ngeq [-0.4, -0.1] = F_{\bar{N}}(0).$$

Definition 3.6
Let $S_A = \langle u, T_{\bar{N}}, I_{\bar{N}}, F_{\bar{N}}, T_N, I_N, F_N\rangle$, $S_B = \langle u, T_{\bar{P}}, I_{\bar{P}}, F_{\bar{P}}, T_P, I_P, F_P\rangle$ and $S_C = \langle u, T_{\bar{Q}}, I_{\bar{Q}}, F_{\bar{Q}}, T_Q, I_Q, F_Q\rangle$ a neut. cubic ℵ-S over S. The neut. cubic ℵ-product of $S_{\bar{N}}$, $S_{\bar{P}}$ and $S_{\bar{Q}}$ is defined by

$$S_A \odot S_B \odot S_C = \langle u, \left(T_{\bar{N}\circ\bar{P}\circ\bar{Q}}, I_{\bar{N}\circ\bar{P}\circ\bar{Q}}, F_{\bar{N}\circ\bar{P}\circ\bar{Q}}, T_{N\circ P\circ Q}, I_{N\circ P\circ Q}, F_{N\circ P\circ Q}\right)(u)\rangle$$

Where,

$$T_{\bar{N}\circ\bar{P}\circ\bar{Q}}(u) = \begin{cases} \bigwedge_{u=[pqr]}\left[max\{T_{\bar{N}}(p), T_{\bar{P}}(q), T_{\bar{Q}}(r)\}\right] \\ \bar{0} \quad \text{otherwise} \end{cases}, \quad T_{N\circ P\circ Q}(u) = \begin{cases} \bigvee_{u=[pqr]}\left[min\{T_N(p), T_P(q), T_Q(r)\}\right] \\ 0 \quad \text{otherwise} \end{cases}$$

$$I_{\bar{N}\circ\bar{P}\circ\bar{Q}}(u) = \begin{cases} \bigvee_{u=[pqr]}\left[min\{I_{\bar{N}}(p), I_{\bar{P}}(q), I_{\bar{Q}}(r)\}\right] \\ -\bar{1} \quad \text{otherwise} \end{cases}, \quad I_{N\circ P\circ Q}(u) = \begin{cases} \bigwedge_{u=[pqr]}\left[max\{I_N(p), I_P(q), I_Q(r)\}\right] \\ -1 \quad \text{otherwise} \end{cases}$$

$$F_{\bar{N}\circ\bar{P}\circ\bar{Q}}(u) = \begin{cases} \bigvee_{u=[pqr]}\left[min\{F_{\bar{N}}(p), F_{\bar{P}}(q), F_{\bar{Q}}(r)\}\right] \\ -\bar{1} \quad \text{otherwise} \end{cases}, \quad F_{N\circ P\circ Q}(u) = \begin{cases} \bigwedge_{u=[pqr]}\left[max\{F_N(p), F_P(q), F_Q(r)\}\right] \\ -1 \quad \text{otherwise} \end{cases}$$

Theorem 3.7
Consider a ternion SG denoted as S. If we have two neut. cubic ℵ-LI $(resp. \mathcal{L}I, RI)'s$ of S, the intersection of these ideals also qualifies as a neut. cubic ℵ-LI $(resp. \mathcal{L}I, RI)$ of S.
Proof.
Let $S_A = \langle u, (T_{\bar{N}}, I_{\bar{N}}, F_{\bar{N}}, T_N, I_N, F_N)(u)\rangle$ and $S_B = \langle u, (T_{\bar{M}}, I_{\bar{M}}, F_{\bar{M}}, T_M, I_M, F_M)(u)\rangle$ be neut. cubic $\aleph - LI$ $(resp. \mathcal{L}I, RI)$ of S. Then for any $u, v, w \in S$, we have

$$T_{\bar{N}\cap\bar{M}}([uvw]) = max\{T_{\bar{N}}([uvw]), T_{\bar{M}}([uvw])\}$$
$$\leq max\{T_{\bar{N}}(w), T_{\bar{M}}(w)\} = T_{\bar{N}\cap\bar{M}}(w),$$
$$I_{\bar{N}\cap\bar{M}}([uvw]) = min\{I_{\bar{N}}([uvw]), I_{\bar{M}}([uvw])\}$$

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$$\geq min\{I_{\bar{N}}(w), I_{\bar{M}}(w)\} = I_{\bar{N}\cap\bar{M}}(w),$$
$$F_{\bar{N}\cap\bar{M}}([uvw]) = min\{F_{\bar{N}}([uvw]), F_{\bar{M}}([uvw])\}$$
$$\geq min\{F_{\bar{N}}(w), F_{\bar{M}}(w)\} = F_{\bar{N}\cap\bar{M}}(w),$$
$$T_{N\cap M}([uvw]) = min\{T_N([uvw]), T_N([uvw])\}$$
$$\geq min\{T_N(w), T_M(w)\} = T_{N\cap M}(w),$$
$$I_{N\cap M}([uvw]) = max\{I_N([uvw]), I_M([uvw])\}$$
$$\leq max\{I_N(w), I_M(w)\} = I_{N\cap M}(w),$$
$$F_{N\cap M}([uvw]) = max\{F_N([uvw]), F_M([uvw])\}$$
$$\leq max\{F_N(w), F_M(w)\} = I_{N\cap M}(w).$$

Therefore $S_{A\cap B}$ is a neut. cubic $\aleph - LI$ $(resp. \mathcal{L}I, RI)$ of S.

Corollary 3.8

Consider a ternion SG denoted as S. *If* $\{S_{C_i} | i \in \Lambda\}$ *forms a family of neut. cubic* $\aleph - LI$ $(resp. \mathcal{L}I, RI)$*'s of* S, *then the set* $\cap S_{C_i}$ *also qualifies as an neut. cubic* $\aleph - LI$ $(resp. \mathcal{L}I, RI)$ *of* S.

Theorem 3.9

Assume that S_A, S_B *and* S_N *be a neut. cubic* $\aleph$*-S's over S. If* S_C *is a neut. cubic* $\aleph$*-RI of S, then* $S_A \odot S_B \odot S_N$ *is also a neut. cubic* $\aleph$*-RI of S.*

Proof.

Assume that S_C is a neut. cubic $\aleph$-RI of S. If there exist $p, q, r \in S$ such that $u = [pqr]$, then $[uvw] = [[pqr]vw] = [pq[rvw]]$ for all $u, v, w \in S$. Then,

$$T_{\bar{A}\circ\bar{B}\circ\bar{N}}(u) = \wedge_{u=[pqr]}\{max\{T_{\bar{A}}(p), T_{\bar{B}}(q), T_{\bar{N}}(r)\}\}$$
$$= \wedge_{[uvw]=[pq[rvw]]}\{max\{T_{\bar{A}}(p), T_{\bar{B}}(q), T_{\bar{N}}([rvw])\}\}$$
$$= \wedge_{[uvw]=[pqh]}\{max\{T_{\bar{A}}(p), T_{\bar{B}}(q), T_{\bar{N}}(h)\}\}$$
$$\geq T_{\bar{A}\circ\bar{B}\circ\bar{N}}([uvw]).$$
$$I_{\bar{A}\circ\bar{B}\circ\bar{N}}(u) = \vee_{u=[pqr]}\{min\{I_{\bar{A}}(p), I_{\bar{B}}(q), I_{\bar{N}}(r)\}\}$$
$$= \vee_{[uvw]=[pq[rvw]]}\{min\{I_{\bar{A}}(p), I_{\bar{B}}(q), I_{\bar{N}}([rvw])\}\}$$
$$= \vee_{[uvw]=[pqh]}\{min\{I_{\bar{A}}(p), I_{\bar{B}}(q), I_{\bar{N}}(h)\}\}$$
$$\leq I_{\bar{A}\circ\bar{B}\circ\bar{N}}([uvw]).$$
$$F_{\bar{A}\circ\bar{B}\circ\bar{N}}(u) = \vee_{u=[pqr]}\{min\{F_{\bar{A}}(p), F_{\bar{B}}(q), F_{\bar{N}}(r)\}\}$$
$$= \vee_{[uvw]=[pq[rvw]]}\{min\{F_{\bar{A}}(p), F_{\bar{B}}(q), F_{\bar{N}}([rvw])\}\}$$
$$= \vee_{[uvw]=[pqh]}\{min\{F_{\bar{A}}(p), F_{\bar{B}}(q), F_{\bar{N}}(h)\}\}$$
$$\leq F_{\bar{A}\circ\bar{B}\circ\bar{N}}([uvw]).$$
$$T_{A\circ B\circ N}(u) = \vee_{u=[pqr]}\{min\{T_A(p), T_B(q), T_N(r)\}\}$$
$$= \vee_{[uvw]=[pq[rvw]]}\{min\{T_A(p), T_B(q), T_N([rvw])\}\}$$
$$= \vee_{[uvw]=[pqh]}\{min\{T_A(p), T_B(q), T_N(h)\}\}$$
$$\leq T_{A\circ B\circ N}([uvw])$$
$$I_{A\circ B\circ N}(u) = \wedge_{u=[pqr]}\{max\{I_A(p), I_B(q), I_N(r)\}\}$$
$$= \wedge_{[uvw]=[pq[rvw]]}\{max\{I_A(p), I_B(q), I_N([rvw])\}\}$$
$$= \wedge_{[uvw]=[pqh]}\{max\{I_A(p), I_B(q), I_N(h)\}\}$$
$$\geq I_{A\circ B\circ N}([uvw]).$$
$$F_{A\circ B\circ N}(u) = \wedge_{u=[pqr]}\{max\{F_A(p), F_B(q), F_N(r)\}\}$$
$$= \wedge_{[uvw]=[pq[rvw]]}\{max\{F_A(p), F_B(q), F_N([rvw])\}\}$$
$$= \wedge_{[uvw]=[pqh]}\{max\{F_A(p), F_B(q), F_N(h)\}\}$$
$$\geq F_{A\circ B\circ N}([uvw]).$$

Therefore, $S_A \odot S_B \odot S_N$ is a neut. cubic $\aleph$-RI of S.

Theorem 3.10
Assume that S_A, S_B and S_N be a neut. cubic ℵ-S's over S. If S_C is a neut. cubic ℵ-LI of S, then $S_A \odot S_B \odot S_N$ is also a neut. cubic ℵ-LI of S.
Proof.
It follows similarly from the theorem 3.12

Definition 3.11
Let $f: S \to S'$ be a function of sets. If $S'_D = \langle u, T_{\bar{B}}, I_{\bar{B}}, F_{\bar{B}}, T_B, I_B, F_B \rangle$ is a neut. cubic ℵ-S over $'$, the preimage of S'_D under f is defined to be a neut. cubic ℵ-S's.

$$f^{-1}(S'_D)(u) = \left(f^{-1}(T_{\bar{B}}),\ f^{-1}(I_{\bar{B}}),\ f^{-1}(F_{\bar{B}}), f^{-1}(T_B),\ f^{-1}(I_B),\ f^{-1}(F_B)\right)(u),$$

For every $u \in S$, the inverse function f^{-1} satisfies the equations $f^{-1}(T_{\bar{B}})(u) = T_{\bar{B}}(f(u))$, $f^{-1}(I_{\bar{B}})(u) = I_{\bar{B}}(f(u))$, $f^{-1}(F_{\bar{B}})(u) = F_{\bar{B}}(f(u))$, $f^{-1}(T_B)(u) = T_B(f(u))$, $f^{-1}(I_B)(u) = I_B(f(u))$, $f^{-1}(F_B)(u) = F_B(f(u))$

Theorem 3.12
Assume that $f: S \to S'$ be a homomorphism of ternion SG's. If $S'_D = (T_{\bar{B}}, I_{\bar{B}}, F_{\bar{B}}, T_B, I_B, F_B)$ is an neut. cubic $\aleph - LI$ $(resp. \mathcal{L}I, RI)$ of S' , then the preimage of S'_D under f is an neut. cubic $\aleph - LI$ $(resp. \mathcal{L}I, RI)$ of S.
Proof.
Let $f^{-1}(S'_D) = \left(f^{-1}(T_{\bar{B}}),\ f^{-1}(I_{\bar{B}}),\ f^{-1}(F_{\bar{B}}), f^{-1}(T_B),\ f^{-1}(I_B),\ f^{-1}(F_B)\right)$ is the preimage of S'_D under f. Let $u, v, w \in S$, then,

$$\begin{aligned}
f^{-1}(T_{\bar{B}})([uvw]) &= T_{\bar{B}}(f([uvw])) = T_{\bar{B}}([f(u)f(v)f(w)]) \\
&\le T_{\bar{B}}(f(w)) = f^{-1}(T_{\bar{B}})(w), \\
f^{-1}(I_{\bar{B}})([uvw]) &= I_{\bar{B}}(f([uvw])) = I_{\bar{B}}([f(u)f(v)f(w)]) \\
&\ge I_{\bar{B}}(f(w)) = f^{-1}(I_{\bar{B}})(w), \\
f^{-1}(F_{\bar{B}})([uvw]) &= F_{\bar{B}}(f([uvw])) = F_{\bar{B}}([f(u)f(v)f(w)]) \\
&\ge F_{\bar{B}}(f(w)) = f^{-1}(F_{\bar{B}})(w). \\
f^{-1}(T_B)([uvw]) &= T_B(f([uvw])) = T_B([f(u)f(v)f(w)]) \\
&\ge T_B(f(w)) = f^{-1}(T_B)(w), \\
f^{-1}(I_B)([uvw]) &= I_B(f([uvw])) = I_B([f(u)f(v)f(w)]) \\
&\le I_B(f(w)) = f^{-1}(I_B)(w), \\
f^{-1}(F_B)([uvw]) &= F_B(f([uvw])) = F_B([f(u)f(v)f(w)]) \\
&\le F_B(f(w)) = f^{-1}(F_B)(w).
\end{aligned}$$

Hence, $f^{-1}(S'_D)$ is a neut. cubic ℵ-LI of S.

Definition 3.13
For a subset A of a nonempty S, consider the neut. cubic ℵ-S over S.

$$\chi_{\bar{A}}(S_{\bar{N}}) = \langle u, \left(\chi_{\bar{A}}(T_{\bar{N}}), \chi_{\bar{A}}(I_{\bar{N}}), \chi_{\bar{A}}(F_{\bar{N}}), \chi_A(T_N), \chi_A(I_N), \chi_A(F_N)\right)\rangle\ ,$$

where,

$$\chi_{\bar{A}}(T_{\bar{N}}): S \to D[-1,0], u \to \begin{cases} -\bar{1} & if\ u \in A \\ \bar{0} & otherwise, \end{cases}, \qquad \chi_A(T_N): S \to [-1,0], u \to \begin{cases} 0 & if\ u \in A \\ -1 & otherwise, \end{cases}$$

$$\chi_{\bar{A}}(I_{\bar{N}}): S \to D[-1,0], u \to \begin{cases} \bar{0} & if\ u \in A \\ -\bar{1} & otherwise, \end{cases} \qquad \chi_A(I_N): S \to [-1,0], u \to \begin{cases} -1 & if\ u \in A \\ 0 & otherwise, \end{cases}$$

$$\chi_{\bar{A}}(F_{\bar{N}}): S \to D[-1,0], u \to \begin{cases} \bar{0} & if\ u \in A \\ -\bar{1} & otherwise, \end{cases} \qquad \chi_A(F_N): S \to [-1,0], u \to \begin{cases} -1 & if\ u \in A \\ 0 & otherwise, \end{cases}$$

is said to be a characteristic neut. cubic ℵ-S of S.

Theorem 3.14
Let $\chi_A(S_C), \chi_B(S_C)$ and $\chi_C(S_C)$ be an i-v characteristic neut. cubic ℵ-S's over S for any subsets A, B and C of S. Then the following condition holds:

$$\chi_A(S_C)\odot\chi_B(S_C)\odot\chi_C(S_C) = \chi_{[ABC]}(S_C).$$

Proof.
Let $u \in S$. If $u \notin [ABC]$, then

$$\begin{aligned}
&\big(\chi_{\bar{A}}(T_{\bar{N}})\odot\chi_{\bar{B}}(T_{\bar{N}})\odot\chi_{\bar{C}}(T_{\bar{N}})\big)(u) = \bar{0} = \chi_{[\bar{A}\bar{B}\bar{C}]}(T_{\bar{N}})(u)\\
&\big(\chi_{\bar{A}}(I_{\bar{N}})\odot\chi_{\bar{B}}(I_{\bar{N}})\odot\chi_{\bar{C}}(I_{\bar{N}})\big)(u) = -\bar{1} = \chi_{[\bar{A}\bar{B}\bar{C}]}(I_{\bar{N}})(u)\\
&\big(\chi_{\bar{A}}(F_{\bar{N}})\odot\chi_{\bar{B}}(F_{\bar{N}})\odot\chi_{\bar{C}}(F_{\bar{N}})\big)(u) = -\bar{1} = \chi_{[\bar{A}\bar{B}\bar{C}]}(F_{\bar{N}})(u)\\
&\big(\chi_A(T_N)\odot\chi_B(T_N)\odot\chi_C(T_N)\big)(u) = -1 = \chi_{[ABC]}(T_N)(u)\\
&\big(\chi_A(I_N)\odot\chi_B(I_N)\odot\chi_C(I_N)\big)(u) = 0 = \chi_{[ABC]}(I_N)(u)\\
&\big(\chi_A(F_N)\odot\chi_B(F_N)\odot\chi_C(F_N)\big)(u) = 0 = \chi_{[ABC]}(F_N)(u).
\end{aligned}$$

Thus, $\chi_A(S_C)\odot\chi_B(S_C)\odot\chi_C(S_C) = \chi_{[ABC]}(S_C)$.
If $u \in [ABC]$, then $u = [pqr]$ for some $p \in A, q \in B$ and $r \in C$. It follows that

$$\begin{aligned}
\big(\chi_{\bar{A}}(T_{\bar{N}})\odot\chi_{\bar{B}}(T_{\bar{N}})\odot\chi_{\bar{C}}(T_{\bar{N}})\big)(u) &= \wedge_{u=[lmn]}\{max\{\chi_{\bar{A}}(T_{\bar{N}})(l), \chi_{\bar{B}}(T_{\bar{N}})(m), \chi_{\bar{C}}(T_{\bar{N}})(n)\}\}\\
&\le max\{\chi_{\bar{A}}(T_{\bar{N}})(p), \chi_{\bar{B}}(T_{\bar{N}})(q), \chi_{\bar{C}}(T_{\bar{N}})(r)\}\\
&= -\bar{1} = \chi_{[\bar{A}\bar{B}\bar{C}]}(T_{\bar{N}})(u),\\
\big(\chi_{\bar{A}}(I_{\bar{N}})\odot\chi_{\bar{B}}(I_{\bar{N}})\odot\chi_{\bar{C}}(I_{\bar{N}})\big)(u) &= \vee_{u=[lmn]}\{min\{\chi_{\bar{A}}(I_{\bar{N}})(l), \chi_{\bar{B}}(I_{\bar{N}})(m), \chi_{\bar{C}}(I_{\bar{N}})(n)\}\}\\
&\ge min\{\chi_{\bar{A}}(I_{\bar{N}})(p), \chi_{\bar{B}}(I_{\bar{N}})(q), \chi_{\bar{C}}(I_{\bar{N}})(r)\}\\
&= \bar{0} = \chi_{[\bar{A}\bar{B}\bar{C}]}(I_{\bar{N}})(u),\\
\big(\chi_{\bar{A}}(F_{\bar{N}})\odot\chi_{\bar{B}}(F_{\bar{N}})\odot\chi_{\bar{C}}(F_{\bar{N}})\big)(u) &= \vee_{u=[lmn]}\{min\{\chi_{\bar{A}}(F_{\bar{N}})(l), \chi_{\bar{B}}(F_{\bar{N}})(m), \chi_{\bar{C}}(F_{\bar{N}})(n)\}\}\\
&\ge min\{\chi_{\bar{A}}(F_{\bar{N}})(p), \chi_{\bar{B}}(F_{\bar{N}})(q), \chi_{\bar{C}}(F_{\bar{N}})(r)\}\\
&= \bar{0} = \chi_{[\bar{A}\bar{B}\bar{C}]}(F_{\bar{N}})(u),\\
\big(\chi_A(T_N)\odot\chi_B(T_N)\odot\chi_C(T_N)\big)(u) &= \vee_{u=[lmn]}\{min\{\chi_A(T_N)(l), \chi_B(T_N)(m), \chi_C(T_N)(n)\}\}\\
&\ge min\{\chi_A(T_N)(p), \chi_B(T_N)(q), \chi_C(T_N)(r)\}\\
&= 0 = \chi_{[ABC]}(T_N)(u),\\
\big(\chi_A(I_N)\odot\chi_B(I_N)\odot\chi_C(I_N)\big)(u) &= \wedge_{u=[lmn]}\{max\{\chi_A(I_N)(l), \chi_B(I_N)(m), \chi_C(I_N)(n)\}\}\\
&\le max\{\chi_A(I_N)(p), \chi_B(I_N)(q), \chi_C(I_N)(r)\}\\
&= -1 = \chi_{[ABC]}(I_N)(u),\\
\big(\chi_A(F_N)\odot\chi_B(F_N)\odot\chi_C(F_N)\big)(u) &= \wedge_{u=[lmn]}\{max\{\chi_A(F_N)(l), \chi_B(F_N)(m), \chi_C(F_N)(n)\}\}\\
&\le max\{\chi_A(F_N)(p), \chi_B(F_N)(q), \chi_C(F_N)(r)\}\\
&= -1 = \chi_{[ABC]}(F_N)(u),
\end{aligned}$$

Therefore, $\chi_A(S_C)\odot\chi_B(S_C)\odot\chi_C(S_C) = \chi_{[ABC]}(S_C)$.

Theorem 3.15
Let $A \neq \emptyset$ subset of S. Then the following statements are equivalent:
1. *A is a LI $(resp. \mathcal{L}I, RI)$ of S,*
2. *The characteristic neut. cubic ℵ-S, $\chi_A(S_C)$ over S is an neut. cubic ℵ-LI $(resp. \mathcal{L}I, RI)$ of S.*

Proof.
(1) ⇒ (2) Assume that A is a LI of S. Let $u, v, w \in S$. If $w \notin A$, then

$$\begin{aligned}
&\chi_{\bar{A}}(T_{\bar{N}})([uvw]) \le \bar{0} = \chi_{\bar{A}}(T_{\bar{N}})(w),\\
&\chi_{\bar{A}}(I_{\bar{N}})([uvw]) \ge -\bar{1} = \chi_{\bar{A}}(I_{\bar{N}})(w),\\
&\chi_{\bar{A}}(F_{\bar{N}})([uvw]) \ge -\bar{1} = \chi_{\bar{A}}(F_{\bar{N}})(w),\\
&\chi_A(T_N)([uvw]) \ge -1 = \chi_A(T_N)(w),\\
&\chi_A(I_N)([uvw]) \le 0 = \chi_A(I_N)(w),\\
&\chi_A(F_N)([uvw]) \le 0 = \chi_A(F_N)(w).
\end{aligned}$$

On the other hand, suppose that $w \in A$. Then, $[uvw] \in A$. It follows that

$$\chi_{\bar{A}}(T_{\bar{N}})([uvw]) = -\bar{1} = \chi_{\bar{A}}(T_{\bar{N}})(w),$$
$$\chi_{\bar{A}}(I_{\bar{N}})([uvw]) = \bar{0} = \chi_{\bar{A}}(I_{\bar{N}})(w),$$
$$\chi_{\bar{A}}(F_{\bar{N}})([uvw]) = \bar{0} = \chi_{\bar{A}}(F_{\bar{N}})(w),$$
$$\chi_{A}(T_{N})([uvw]) = 0 = \chi_{A}(T_{N})(w),$$
$$\chi_{A}(I_{N})([uvw]) = -1 = \chi_{A}(I_{N})(w),$$
$$\chi_{A}(F_{N})([uvw]) = -1 = \chi_{A}(F_{N})(w).$$

Therefore, $\chi_A(S_C)$ is a neut. cubic ℵ-LI of S.

(2) ⇒ (1) Assume that $\chi_A(S_C)$ is a neut. cubic $\mathcal{N}$-LI of S. Let $u, v \in S$ and $a \in A$. Then

$$\chi_{\bar{A}}(T_{\bar{N}})([uva]) \le \chi_{\bar{A}}(T_{\bar{N}})(a) = -\bar{1},$$
$$\chi_{\bar{A}}(I_{\bar{N}})([uva]) \ge \chi_{\bar{A}}(I_{\bar{N}})(a) = \bar{0},$$
$$\chi_{\bar{A}}(F_{\bar{N}})([uva]) \ge \chi_{\bar{A}}(F_{\bar{N}})(a) = \bar{0},$$
$$\chi_{A}(T_{N})([uva]) \ge \chi_{A}(T_{N})(a) = 0,$$
$$\chi_{A}(I_{N})([uva]) \le \chi_{A}(I_{N})(a) = -1,$$
$$\chi_{A}(F_{N})([uva]) \le \chi_{A}(F_{N})(a) = -1.$$

Hence, $\chi_{\bar{A}}(T_{\bar{N}})([uva]) = -\bar{1}$, $\chi_{\bar{A}}(I_{\bar{N}})([uva]) = \bar{0}$, $\chi_{\bar{A}}(F_{\bar{N}})([uva]) = \bar{0}$, $\chi_{A}(T_{N})([uva]) = 0$, $\chi_{A}(I_{N})([uva]) = -1$, $\chi_{A}(F_{N})([uva]) = -1$. This implies that $[uva] \in A$. Consequently, A is a LI of S

Theorem 3.16

Assume that S_R be a neut. cubic ℵ-S over S. Then S_R is a neut. cubic ℵ-RI of S iff $S_R \odot S_P \odot S_Q \subseteq S_R$ for every neut. cubic ℵ-S's S_P and S_Q over S.

Proof.

Let S_R is a neut. cubic ℵ-RI of S, and let S_P and S_Q an neut. cubic ℵ-S's over S. Obviously, $S_R \odot S_P \odot S_Q \subseteq S_R$ $\forall\, a, \mathrm{b}, \mathrm{c} \in S$ such that $u \neq [a\mathrm{bc}]$.

If there are elements a, b and c in set S such that $u = [a\mathrm{bc}]$, then we obtain

$$T_{\bar{R}}(u) = T_{\bar{R}}[abc] \le T_{\bar{R}}(a) \le max\{T_{\bar{R}}(a), T_{\bar{P}}(b), T_{\bar{Q}}(c)\},$$
$$I_{\bar{R}}(u) = I_{\bar{R}}[abc] \ge I_{\bar{R}}(a) \ge min\{I_{\bar{R}}(a), I_{\bar{P}}(b), I_{\bar{Q}}(c)\},$$
$$F_{\bar{R}}(u) = F_{\bar{R}}[abc] \ge F_{\bar{R}}(a) \ge min\{F_{\bar{R}}(a), F_{\bar{P}}(b), F_{\bar{Q}}(c)\},$$
$$T_{R}(u) = T_{R}[abc] \ge T_{R}(a) \ge min\{T_{R}(a), T_{P}(b), T_{Q}(c)\},$$
$$I_{R}(u) = I_{R}[abc] \le I_{R}(a) \le max\{I_{R}(a), I_{P}(b), I_{Q}(c)\},$$
$$F_{R}(u) = F_{R}[abc] \le F_{R}(a) \le max\{F_{R}(a), F_{P}(b), F_{Q}(c)\}.$$

This implies that

$$T_{\bar{R}}(u) = \wedge_{u=[abc]} max\{T_{\bar{R}}(a), T_{\bar{P}}(b), T_{\bar{Q}}(c)\} = T_{\bar{R}\circ\bar{P}\circ\bar{Q}}(u),$$
$$I_{\bar{R}}(u) = \vee_{u=[abc]} min\{I_{\bar{R}}(a), I_{\bar{P}}(b), I_{\bar{Q}}(c)\} = I_{\bar{R}\circ\bar{P}\circ\bar{Q}}(u),$$
$$F_{\bar{R}}(u) = \vee_{u=[abc]} min\{F_{\bar{R}}(a), F_{\bar{P}}(b), F_{\bar{Q}}(c)\} = F_{\bar{R}\circ\bar{P}\circ\bar{Q}}(u),$$
$$T_{R}(u) = \vee_{u=[abc]} min\{T_{R}(a), T_{P}(b), T_{Q}(c)\} = T_{R\circ P\circ Q}(u),$$
$$I_{R}(u) = \wedge_{u=[abc]} max\{I_{R}(a), I_{P}(b), I_{Q}(c)\} = I_{R\circ P\circ Q}(u),$$
$$F_{R}(u) = \wedge_{u=[abc]} max\{F_{R}(a), F_{P}(b), F_{Q}(c)\} = F_{R\circ P\circ Q}(u).$$

Therefore, $S_R \odot S_P \odot S_Q \subseteq S_R$. Conversely, assume that S_R is an neut. cubic ℵ-S over S, such that $S_R \odot S_P \odot S_Q \subseteq S_R$ for every neut. cubic ℵ-S's S_P and S_Q over S. Let $u, v, w \in S$ and $a = [uvw]$. Then,

$$T_{\bar{R}}([uvw]) = T_{\bar{R}}(a) \le \left(T_{\bar{R}} \circ \chi_S(T_{\bar{P}}) \circ \chi_S(T_{\bar{Q}})\right)(a)$$
$$= \wedge_{a=[lmn]} max\{T_{\bar{R}}(l), \chi_S(T_{\bar{P}})(m), \chi_S(T_{\bar{Q}})(n)\}$$
$$\le max\{T_{\bar{R}}(u), \chi_S(T_{\bar{P}})(v), \chi_S(T_{\bar{Q}})(w)\} = T_{\bar{R}}(u),$$
$$I_{\bar{R}}([uvw]) = I_{\bar{R}}(a) \ge \left(I_{\bar{R}} \circ \chi_S(I_{\bar{P}}) \circ \chi_S(I_{\bar{Q}})\right)(a)$$
$$= \wedge_{a=[lmn]} min\{I_{\bar{R}}(l), \chi_S(I_{\bar{P}})(m), \chi_S(I_{\bar{Q}})(n)\}$$

$$\geq min\{I_{\bar{R}}(u), \chi_S(I_{\bar{P}})(v), \chi_S(I_{\bar{Q}})(w)\} = I_{\bar{R}}(u),$$

$$F_{\bar{R}}([uvw]) = F_{\bar{R}}(a) \geq \left(F_{\bar{R}} \circ \chi_S(F_{\bar{P}}) \circ \chi_S(F_{\bar{Q}})\right)(a)$$
$$= \wedge_{a=[lmn]} min\{F_{\bar{R}}(l), \chi_S(F_{\bar{P}})(m), \chi_S(F_{\bar{Q}})(n)\}$$
$$\geq min\{F_{\bar{R}}(u), \chi_S(F_{\bar{P}})(v), \chi_S(F_{\bar{Q}})(w)\} = F_{\bar{R}}(u),$$

$$T_R([uvw]) = T_R(a) \geq \left(T_R \circ \chi_S(T_P) \circ \chi_S(T_Q)\right)(a)$$
$$= \wedge_{a=[lmn]} min\{T_R(l), \chi_S(T_P)(m), \chi_S(T_Q)(n)\}$$
$$\geq min\{T_R(u), \chi_S(T_P)(v), \chi_S(T_Q)(w)\} = T_R(u),$$

$$I_R([uvw]) = I_R(a) \leq \left(I_R \circ \chi_S(I_P) \circ \chi_S(I_Q)\right)(a)$$
$$= \wedge_{a=[lmn]} max\{I_R(l), \chi_S(I_P)(m), \chi_S(I_Q)(n)\}$$
$$\leq max\{I_R(u), \chi_S(I_P)(v), \chi_S(I_Q)(w)\} = I_R(u),$$

$$F_R([uvw]) = F_R(a) \leq \left(F_R \circ \chi_S(F_P) \circ \chi_S(F_Q)\right)(a)$$
$$= \wedge_{a=[lmn]} max\{F_R(l), \chi_S(F_P)(m), \chi_S(F_Q)(n)\}$$
$$\leq max\{F_R(u), \chi_S(F_P)(v), \chi_S(F_Q)(w)\} = F_R(u).$$

Consequently, S_R is an neut. cubic ℵ-RI of S.

Theorem 3.17
Assume that S_P be a neut. cubic ℵ-S over S. Then $S_{\bar{P}}$ is a neut. cubic ℵ-ℒI of S iff $S_R \odot S_P \odot S_Q \subseteq S_P$ for every neut. cubic ℵ-S's S_R and S_Q over S.
Proof.
It follows similarly from the theorem 3.16

Theorem 3.18
Assume that S_Q be a neut. cubic ℵ-S over S. Then S_Q is a neut. cubic ℵ-LI of S iff $S_R \odot S_P \odot S_Q \subseteq S_Q$ for every neut. cubic ℵ-S's S_R and S_P over S.
Proof.
It follows similarly from the theorem 3.16

IV. CONCLUSION

This paper explores the notion of a SSG within the framework of neut. cubic ℵ-ternion SG, investigating its inherent properties. The study encompasses neut. cubic ℵ-fuzzy ideals within a ternion SG, scrutinizing their algebraic features. Through illustrative examples, we establish that the combination of two neut. cubic ℵ-fuzzy ideals within a ternion SG results in another neut. cubic ℵ-fuzzy ideal within the same ternion SG. Additionally, we present the notion of the direct product for neut. cubic ℵ-fuzzy ideals in a ternion SG, emphasizing its nature as a neut. cubic ℵ-fuzzy ideal. Furthermore, we can extend this neut. cubic fuzzy ternion SG to a neut. cubic fuzzy ternion semi-ring etc.

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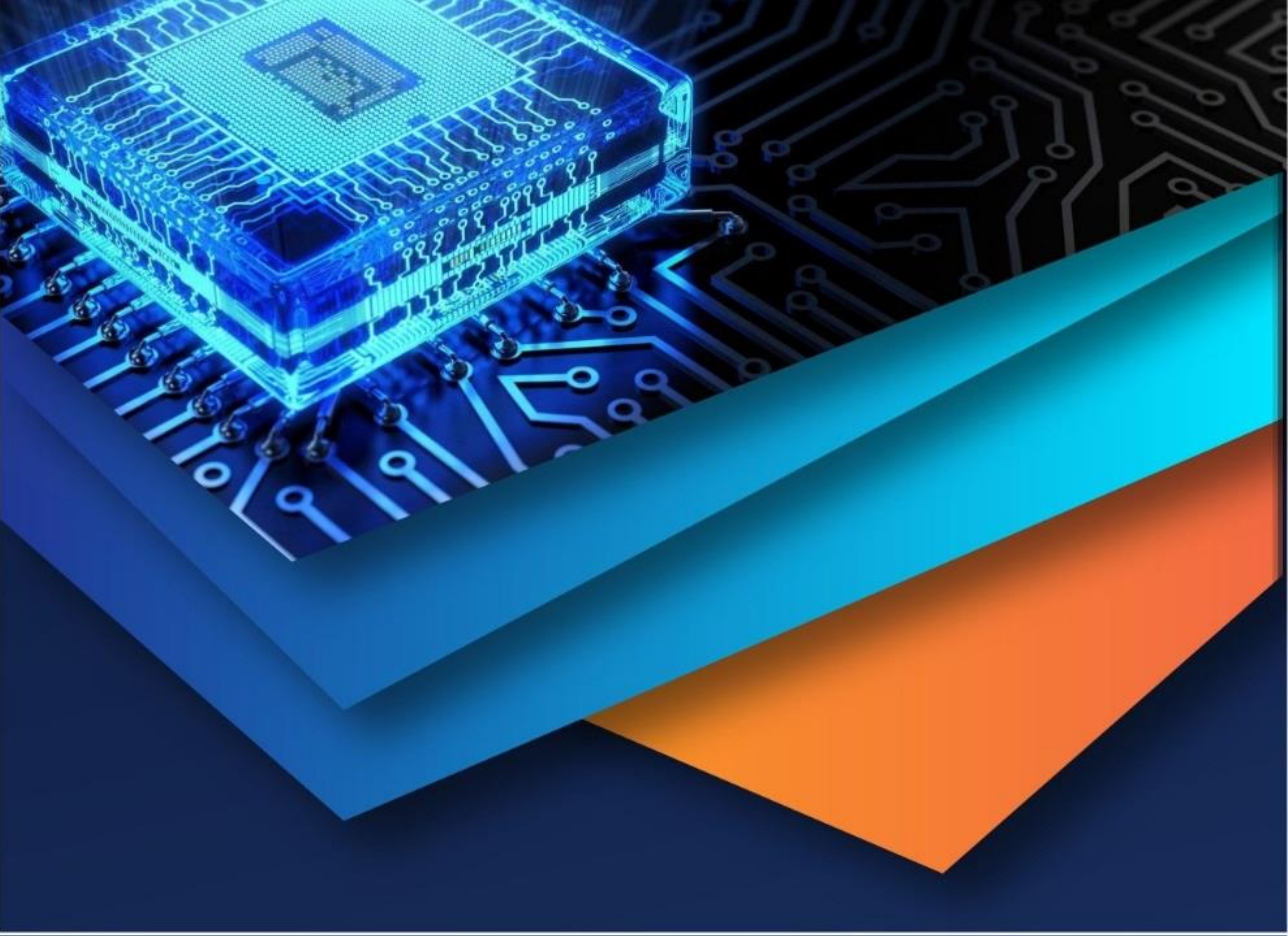

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