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IFsgp*-Closed Sets, Open Sets in Intuitionistic Fuzzy Topological Spaces

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Abstract: In this paper, Intuitionistic fuzzy semi gp* - closed sets, Intuitionistic fuzzy semi gp* - open sets, and characteristics of Intuitionistic fuzzy semi gp* - closed sets are introduced. Here, we have also investigated their relations and properties with other Intuitionistic fuzzy sets.
Keywords: Intuitionistic fuzzy topological spaces; Intuitionistic fuzzy gp* - closed set; Intuitionistic fuzzy sgp* - closed sets; Intuitionistic fuzzy sgp* - open sets.

I. INTRODUCTION

The fuzzy concept was introduced by Zadeh [12] in 1965. Later in 1986, Atanassov [1], presented the Intuitionistic fuzzy sets. In 1997, Coker [3] proposed the Intuitionistic fuzzy topological spaces using Intuitionistic fuzzy sets. Young Bae Jun & Seok Zun Song [11] initiated Intuitionistic fuzzy semi-pre-open sets and Intuitionistic fuzzy semi-pre-continuous mapping in 2005. In 2009, Santhi & Jayanthi [6] [7] defined the concept of Intuitionistic fuzzy generalized semi-pre-closed sets and Intuitionistic fuzzy semi-pre-continuous mapping. In 2010, Thakur & Jyoti Pandey Bajpai [10] proposed Intuitionistic fuzzy w closed sets and Intuitionistic fuzzy w continuity. In 2010, Shyla Isac Mary & Thangavelu [9] discovered the regular pre-semi-closed sets in topological spaces. Sakthivel [8] founded the Intuitionistic fuzzy alpha generalized closed set and Intuitionistic fuzzy alpha generalized open set in 2012. Ramesh & Thirumalaiswamy [5] in 2019 instituted the generalized semi pre-closed set in Intuitionistic fuzzy topological spaces. In 2016, Jeyaraman, Ravi & Yuvarani [4] proposed the Intuitionistic fuzzy alpha generalized semi-closed set. Chandhini & Uma [2] in 2022 developed the concept of Intuitionistic fuzzy generalized pre-star neighborhood in Intuitionistic fuzzy topological spaces.

In this paper, we have defined the new notions of Intuitionistic fuzzy semi-generalized pre-star closed set, Intuitionistic fuzzy generalized pre-star open set in Intuitionistic fuzzy topological spaces and some of their features. Further, we have showed that the IFsgp* of IFTS is productive and have demonstrated some of its features.

II. PRELIMINARIES

1) *Definition 2.1 [1]:* Let X be a non-empty fixed set. An **Intuitionistic fuzzy set** (IFS in short) A in X is an object having the form $A = \{< x, \mu_A(x), \nu_A(x) > / x \in X\}$ where the functions $\mu_A(x) : X \to [0,1]$ and $\nu_A(x) : X \to [0,1]$ denote the degree of membership (namely μ_A (x)) and the degree of non - membership (namely $\nu_A(x)$) of each element $x \in X$ to a set A respectively and $0 \leq \mu_A(x) + \nu_A(x) \leq 1$ for each $x \in X$.

2) *Definition 2.2 [1]:* Let $A = \{< x, \mu_A(x), \nu_A(x) > / x \in X\}$ and $B = \{< x, \mu_B(x), \nu_B(x) > / x \in X\}$ be the IFSs, Then
   a) $A \subset B$ if and only if $\mu_A(x) \leq \mu_B(x)$ and $\nu_A(x) \geq \nu_B(x)$ for all $x \in X$,
   b) $A = B$ if and only if $A \subseteq B$ and $B \subseteq A$,
   c) $A^C = \{< \mu_A(x), \nu_A(x) > / x \in X\}$,
   d) $A \cap B = \{< x, \mu_A(x) \cap \mu_B(x), \nu_A(x) \cup \nu_B(x) > / x \epsilon X\}$,
   e) $A \cup B = \{< x, \mu_A(x) \cup \mu_B(x), \nu_A(x) \cap \nu_B(x) > / x \epsilon X\}$.

We shall use $A = < x, \mu_A, \nu_A >$ instead of $A = \{< x, \mu_A(x), \nu_A(x) > / x \epsilon X\}$ and $A = \{< x, (\mu_A(x)\ \mu_B(x)), (\nu_A(x), \nu_B(x)) >\}$ for $A = \{< x, (A/\mu_A, B/\mu_B), (A/\nu_A, B/\nu_B)\}$.
And, $0_{\sim} = \{< x, 0, 1 > /\ x \epsilon X\}$ is the empty set and $1_{\sim} = \{< x, 1, 0 > /\ x \epsilon X\}$ is the whole set of X ,the Intuitionistic fuzzy set.

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3) *Definition 2.3 [3]:* Let X be a non-empty set, An **Intuitionistic fuzzy topology** (IFT in short) is a family τ of IFSs in X satisfying the following axioms:
   a) $0_{\sim}, 1_{\sim} \in \tau$,
   b) $G_1 \cap G_2 \in \tau$ for any $G_1, G_2 \in \tau$,
   c) $UG_i \in \tau$ for any arbitrary family $\{G_i | i \in J\} \subseteq \tau$.

The pair (X, τ) is called an Intuitionistic fuzzy topological space (IFTS in short) and any IFS in τ is known as an Intuitionistic fuzzy open set (IFOS in short) in X. The complement A^C of an IFOS A is an IFTS (X, τ) is called an Intuitionistic fuzzy closed set (IFCS in short) in X.

4) *Definition 2.4 [3]:* Let (X, τ) be an IFTS and $A = < x, \mu_A, \nu_A >$ be an IFS in X. Then the Intuitionistic fuzzy interior and an Intuitionistic fuzzy closure are defined by
   (a) $int(A) = \cup \{G / G \; is \; an \; IFOS \; in \; X \; and \; G \subseteq A\}$,
   (b) $cl(A) = \cap \{K / K \; is \; an \; IFCS \; in \; X \; and \; A \subseteq K\}$.

5) *Result 2.5 [3]:* Let A and B be any two Intuitionistic fuzzy sets of an Intuitionistic fuzzy topological space(X, τ). Then
   a) A is an Intuitionistic fuzzy closed set in $X \Leftrightarrow cl(A) = A$,
   b) A is an Intuitionistic fuzzy closed set in $X \Leftrightarrow int(A) = A$,
   c) $cl(A^C) = (int(A))^C$,
   d) $int(A^C) = (cl(A))^C$,
   e) $A \subseteq B \Rightarrow int(A) \subseteq int(B)$,
   f) $A \subseteq B \Rightarrow cl(A) \subseteq cl(B)$,
   g) $cl(A \cup B) = cl(A) \cup cl(B)$,
   h) $int(A \cap B) = int(A) \cap int(B)$.

6) *Definition 2.6 [11]:* Let (X, τ) be an IFTS and $A = < x, \mu_A, \nu_A >$ be an IFS in X. Then the semi closure of A ($scl(A)$ in short) and semi-interior of A ($sint(A)$ in short) are defined as
   (a) $sint(A) = \cup \{G / G \; is \; an \; IFsos \; in \; X \; and \; G \subseteq A\}$,
   (b) $scl(A) = \cap \{K / K \; is \; an \; IFscs \; in \; X \; and \; A \subseteq K\}$.

7) *Result 2.7 [9]:* Let A be an IFS in (X, τ), then
   (a) $scl(A) = A \cup int(cl(A))$,
   (b) $sint(A) = A \cap cl(int(A))$.

8) *Definition 2.8 [8]:* Let (X, τ) be an IFTS and $A = < x, \mu_A, \nu_A >$ be an IFS in X. Then the alpha closure of A ($\alpha cl(A)$ in short) and alpha interior of A ($\alpha int(A)$ in short) are defined as
   (a) $\alpha int(A) = \cup \{G / G \; is \; an \; IF\alpha os \; in \; X \; and \; G \subseteq A\}$,
   (b) $\alpha cl(A) = \cap \{K / K \; is \; an \; IF\alpha cs \; in \; X \; and \; A \subseteq K\}$.

9) *Result 2.9 [8]:* Let A be an IFS in (X, τ), then
   (a) $\alpha cl(A) = A \cup cl(int(cl(A)))$,
   (b) $\alpha int(A) = A \cap int(cl(int(A)))$.

10) *Definition 2.10 [11]:* An IFS A of an IFTS (X, τ) is an
   (a) Intuitionistic fuzzy semi pre-closed set (IFspcs for short) if there exists an IFpcs B such that $int(B) \subseteq A \subseteq B$,
   (b) Intuitionistic fuzzy semi pre-open set (IFspos for short) if there exists an IFpos B such that $B \subseteq A \subseteq cl(B)$.
11) *Result 2.11 [7]:* Let A be an IFS in (X, τ), then
   (a) $spint(A) = \cup \{G / G \; is \; an \; IFspos \; in \; X \; and \; G \subseteq A\}$,
   (b) $spcl(A) = \cap \{K / K \; is \; an \; IFspcs \; in \; X \; and \; A \subseteq K\}$.
   for any IFS A in (X, τ), we have $spcl(A^C) = (spint(A))^C$ and $spint(A^C) = (\, spcl(A))^C$.

12) *Definition 2.12:* An IFS $A = \{< x, \mu_A(x), \nu_A(x) > / x \in X\}$ in an IFTS (X, τ) is called an
(a) An intuitionistic fuzzy pre - open set [3] if $A \subseteq int(cl(A))$ and an intuitionistic fuzzy pre - closed set if $cl(int(A)) \subseteq A$.
(b) An intuitionistic fuzzy semi - open set [3] if $A \subseteq cl(int(A))$ and an intuitionistic fuzzy semi - closed set if $int(cl(A)) \subseteq A$.
(c) An intuitionistic fuzzy α - open set [3] if $A \subseteq int\left(cl\left(int(A)\right)\right)$ and an intuitionistic fuzzy α - closed set if$cl\left(int\left(cl(A)\right)\right) \subseteq A$.
(d) An intuitionistic fuzzy regular - open set [3] if $int(cl(A)) = A$ and an intuitionistic fuzzy regular- closed set if $cl(int(A)) = A$.
(e) An intuitionistic fuzzy weakly - closed set [10] (briefly IFw - closed) if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is an IFsos in X.
(f) An intuitionistic fuzzy α generalized semi - closed set [4] (briefly IFαgs - closed) if $\alpha cl(A) \subseteq U$, whenever $A \subseteq U$ and U is an IFsos in X.
(g) An intuitionistic fuzzy generalized semi pre regular - closed set [5] (briefly IFgspr - closed) if $spcl(A) \subseteq U$, whenever $A \subseteq U$ and U is an IFros in X.
(h) An intuitionistic fuzzy generalized semi pre - closed set [6] (briefly IFgsp - closed) if $spcl(A) \subseteq U$, whenever $A \subseteq U$ and U is an IFos in X.
(i) An intuitionistic fuzzy generalized pre star - closed set [2] (briefly IFgp* - closed) if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is an IFgpos in X.

III. INTUITIONISTIC FUZZY SEMI GENERALIZED PRE STAR - CLOSED SET

In this section, we have introduced the **Intuitionistic fuzzy semi generalized pre star - closed set (in brief IFsgp*cs)** in Intuitionistic fuzzy topological space and studied some of their properties.

1) *Definition 3.1:* An intuitionistic fuzzy set A of an Intuitionistic fuzzy topological set (IFTS) (X, τ) is an called Intuitionistic fuzzy semi generalized pre star closed (briefly IFsgp* - closed) if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is intuitionistic fuzzy generalized pre* - open set in X. The family of all IFsgp*cs of IFTs (X, τ) is denoted by IFsgp*c(X).
2) *Example 3.2:* Let $X = \{a, b\}$ and let $\tau = \{0_\sim, T, 1_\sim\}$ be an IFT on X, where $T = \{x, (0.3, 0.4), (0.7, 0.6)\}$. Then the IFS $A = \{x, (0.1, 0.2), (0.9, 0.8)\}$ is an IFsgp*cs in X.
3) *Theorem 3.3:* Every IF closed set is IFsgp* closed set but not conversely.

Proof: Let $A \subseteq U$, U is IFgp* open in (X, τ). Since A is IF closed ie) $A = cl(A)$. Hence $cl(A) \subseteq U$. Every closed set is semi closed that is $scl(A) \subseteq cl(A) \subseteq U$. Therefore $scl(A) \subseteq U$. We know that every IFgp* open set is IF open. Hence A is IFsgp* closed.

The converse of the above theorem need not be true by the following example.

4) *Example 3.4:* Let $X = \{a, b\}$ and let $\tau = \{0_\sim, T, 1_\sim\}$ be an IFT on X, where $T = \{x, (0.2, 0.7), (0.8, 0.3)\}$. Then the IFS $A = \{x, (0.1, 0.2), (0.9, 0.5)\}$ is an IFsgp*cs in X but not IFcs in X. Since $cl(A) = T^C \neq A$.
5) *Theorem 3.5:* Every IFr closed set is IFsgp* closed set but not conversely

Proof: It follows from the fact that every IFr closed set if IF closed set and by Theorem 3.3.

The converse of the above theorem need not be true by the following example.

6) *Example 3.6:* Let $X = \{a, b\}$ and let $\tau = \{0_\sim, T, 1_\sim\}$ be an IFT on X, where $T = \{x, (0.3, 0.6), (0.7, 0.4)\}$. Then the IFS $A = \{x, (0.1, 0.3), (0.9, 0.6)\}$ is an IFsgp*cs in X but not IFrcs in X. Since $cl(int(A)) \neq A$.

7) *Theorem 3.7:* Every IFw closed set is IFsgp* closed set but not conversely

Proof: Let $A \subseteq U$, U is IFgp* open in (X, τ). Hence $cl(A) \subseteq U$. Since every closed set is semi closed that is $scl(A) \subseteq cl(A) \subseteq U$ Which implies $scl(A) \subseteq U$. We know that every IFgp* open set is IF semi open. Hence A is IFsgp* closed.

The converse of the above theorem need not be true by the following example.

8) *Example 3.8:* Let $X = \{a, b\}$ and let $\tau = \{0_\sim, T, 1_\sim\}$ be an IFT on X, where $T = \{x, (0.4, 0.7), (0.6, 0.3)\}$. Then the IFS $A = \{x, (0.1, 0.2), (0.9, 0.5)\}$ is an IFsgp*cs in X but not IFwcs in X.

9) *Theorem 3.9:* Every IFα closed set is IFsgp* closed set but not conversely.
Proof: Let $A \subseteq U$, U is IFgp* open in (X,τ). Since A is IFα closed. Thus $A = \alpha cl(A)$ that is $\alpha cl(A) \subseteq U$. Every α closed set is semi closed ie) $scl(A) \subseteq \alpha cl(A) \subseteq U$ which implies $scl(A) \subseteq U$. We know that every IFgp* open set is IFα open. Hence A is IFsgp* closed. The converse of the above theorem need not be true by the following example.

10) *Example 3.10:* Let $X = \{a,b\}$ and let $\tau = \{0_{\sim}, T, 1_{\sim}\}$ be an IFT on X, where $T = \{x,(0.3,0.6),(0.7,0.4)\}$. Then the IFS $A = \{x,(0.1,0.3),(0.9,0.6)\}$ is an IFsgp*cs in X but not IFαcs in X. Since $\alpha cl(A) \neq A$.
11) *Theorem 3.11:* Every IFαgs closed set is IFsgp* closed set but not conversely.
Proof: Let $A \subseteq U$, U is IFgp* open in (X,τ). Hence $\alpha cl(A) \subseteq U$. Since every α closed set is semi closed. ie) $scl(A) \subseteq \alpha cl(A) \subseteq U$ which implies $scl(A) \subseteq U$. We know that every IFgp* open set is IF semi open. Hence A is IFsgp* closed.
The converse of the above theorem need not be true by the following example.

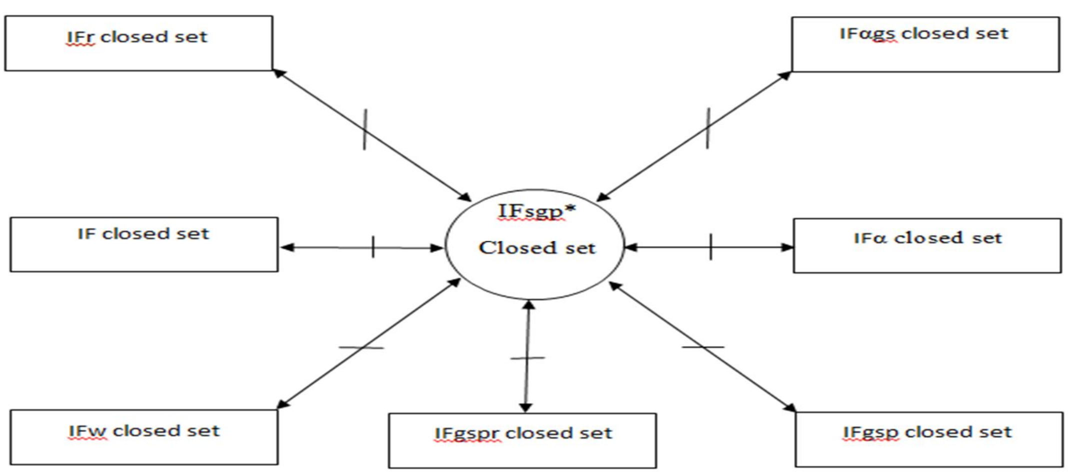
12) *Example 3.12:* Let $X = \{a,b\}$ and let $\tau = \{0_{\sim}, T_1, T_2, 1_{\sim}\}$ be an IFT on X, where $T_1 = \{x,(0.1,0.4),(0.9,0.6)\}$ and $T_2 = \{x,(0.3,0.4),(0.7,0.6)\}$. Then the IFS $A = \{x,(0.4,0.5),(0.6,0.4)\}$ is an IFsgp*cs in X but not IFαgscs in X.

13) *Theorem 3.13:* Every IFsgp* closed set is IFgspr closed set but not conversely.
Proof: Let $A \subseteq U$, U is IFr open in (X,τ). Since A is IFsgp* closed set that is $scl(A) \subseteq U$. Every semi closed set is semi pre closed. ie) $spcl(A) \subseteq scl(A) \subseteq U$ which implies $spcl(A) \subseteq U$. We know that every IFr open set is IFgp* open. Hence A is IFgspr closed. The converse of the above theorem need not be true by the following example.

14) *Example 3.14:* Let $X = \{a,b\}$ and let $\tau = \{0_{\sim}, T, 1_{\sim}\}$ be an IFT on X, where $T = \{x,(0.1,0.5),(0.9,0.5)\}$. Then the IFS $A = \{x,(0.1,0.5),(0.9,0.5)\}$ is an IFgsprcs in X but not IFsgp*cs in X.

15) *Theorem 3.15:* Every IFsgp* closed set is IFgsp closed set but not conversely.
Proof: Let $A \subseteq U$, U is IF open in (X,τ). Since A is IFsgp* closed set that is $scl(A) \subseteq U$. Every semi closed is semi pre closed. ie) $spcl(A) \subseteq scl(A) \subseteq U$ which implies $spcl(A) \subseteq U$. We know that every IF open set is IFgp* open. Hence A is IFgsp closed.
The converse of the above theorem need not be true by the following example.

16) *Example 3.16:* Let $X = \{a,b\}$ and let $\tau = \{0_{\sim}, T, 1_{\sim}\}$ be an IFT on X, where $T = \{x,(0.4,0.5),(0.6,0.5)\}$. Then the IFS $A = \{x,(0.2,0.3),(0.8,0.6)\}$ is an IFgspcs in X but not IFsgp*cs in X.
17) *Remark 3.17:* The following diagram depicts the relation of Intuitionistic fuzzy gp* closed set. The reverse implications are not true in general.



18) *Definition 3.18:* Suppose a Intuitionistic fuzzy set A is Intuitionistic fuzzy semi generalized pre star closed set in IFTS (X, τ), Then its complement i,e $1 - A$ is called **Intuitionistic fuzzy semi generalized pre star open set** (briefly IFsgp* - open) in (X, τ).
19) *Example 3.19:* Let $X = \{a, b\}$ and let $\tau = \{0_\sim, T, 1_\sim\}$ be an IFT on X, where $T = \{x, (0.4, 0.5), (0.6, 0.5)\}$. Then the IFS $A = \{x, (0.5, 0.7), (0.5, 0.3)\}$ is an IFsgp*os in X.

20) *Theorem 3.20:* Every IFos is IFsgp*os but not conversely.

Proof: Consider U is a IFgp* open set in Intuitionistic fuzzy topological space (X, τ), implies $1 - U$ is a Intuitionistic fuzzy closed set. Now from the theorem 3.3 all intuitionistic fuzzy closed sets are IFsgp* - closed sets. So $1 - U$ is also a intuitionistic fuzzy sgp* - closed set implying that U is intuitionistic fuzzy sgp* - open in intuitionistic fuzzy topological space (X, τ).

Remark 3.20:

a) Every IFr open set is IFsgp* open set.
b) Every IFw open set is IFsgp* open set.
c) Every IFα open set is IFsgp* open set.
d) Every IFαgs open set is IFsgp* open set.
e) Every IFsgp* open set is IFgspr open set.
f) Every IFsgp* open set is IFgsp open set.

IV. PROPERTIES OF IFsgp* - CLOSED SET AND OPEN SET IN INTUITIONISTIC FUZZY TOPOLOGICAL SPACE

1) *Theorem 4.1:* Let A be an Intuitionistic Fuzzy gp* closed set in an Intuitionistic fuzzy topological space (X, τ) and $A \subseteq B \subseteq scl(A)$. Then B is IFsgp* closed in X.

Proof: Let U be an IFgp* open set in X, such that $B \subseteq U$. Then $A \subseteq U$ and since A is IFsgp* closed, $scl(A) \subseteq U$. Now $B \subseteq scl(A) \Longrightarrow cl(B) \subseteq scl(A) \subseteq U$. Consequently B is IFsgp* closed.

2) *Theorem 4.2:* Let A be an IFsgp* open set of an Intuitionistic fuzzy topological space (X, τ) and $sint(A) \subseteq B \subseteq A$. Then B is IFsgp* open.

Proof: Suppose A is an IFsgp* open in X and $sint(A) \subseteq B \subseteq A \Longrightarrow A^C \subseteq B^C \subseteq (sint(A))^C \Longrightarrow A^C \subseteq B^C \subseteq scl(A^C)$ by Remark 2.5 (c) and AC is IFsgp* closed it follows from the above theorem 4.1 that BC is IFsgp* closed. Hence B is IFsgp* open.

3) *Theorem 4.3:* If A and B are IFsgp* closed set in X then $A \cup B$ is IFsgp* closed set in X.

Proof: Let A and B are IFsgp* closed sets in X and U be any IFgp* open set containing A and B. Therefore $scl(A) \subseteq U, scl(B) \subseteq U$. Since $A \subseteq U, B \subseteq U$ then $A \cup B \subseteq U$. Hence $scl(A \cup B) = scl(A) \cup scl(B) \subseteq U$. Therefore, $A \cup B$ is IFsgp* closed set in X.

4) *Theorem 4.4:* If A and B are IFsgp* closed set in X then $A \cap B$ is IFsgp* closed set in X.

Proof: Let A and B are IFsgp* closed sets in X and U be any IFgp* open set containing A and B. Therefore $scl(A) \subseteq U, scl(B) \subseteq U$. Since $A \subseteq U, B \subseteq U$ then $A \cap B \subseteq U$. Hence $scl(A \cap B) \subseteq U$, U is IFgp* open in X. Since A and B are IFsgp* closed set, hence $A \cap B$ is IFsgp* closed set in X.

5) *Theorem 4.5:* If A is both IFgp* open and IFsgp* closed set in X, then A is IFgp* closed set.

Proof: Since A is IFgp* open and IFsgp* closed set in X, $scl(A) \subseteq U$ but always $A \subseteq scl(A)$. Therefore $A = scl(A)$. Hence A is IFgp* closed set.

V. CONCLUSION

In this paper, we have introduced the Intuitionistic fuzzy semi generalized pre star closed sets and Intuitionistic fuzzy semi generalized pre star open sets. Additionally, we have presented few of its characteristics as well as the connections between it and other Intuitionistic fuzzy closed and open sets that already exist.

In our future research, we will use the Intuitionistic fuzzy semi generalized pre star sets to derive continuous mapping, irresolute mapping, connectedness, and disconnectedness.

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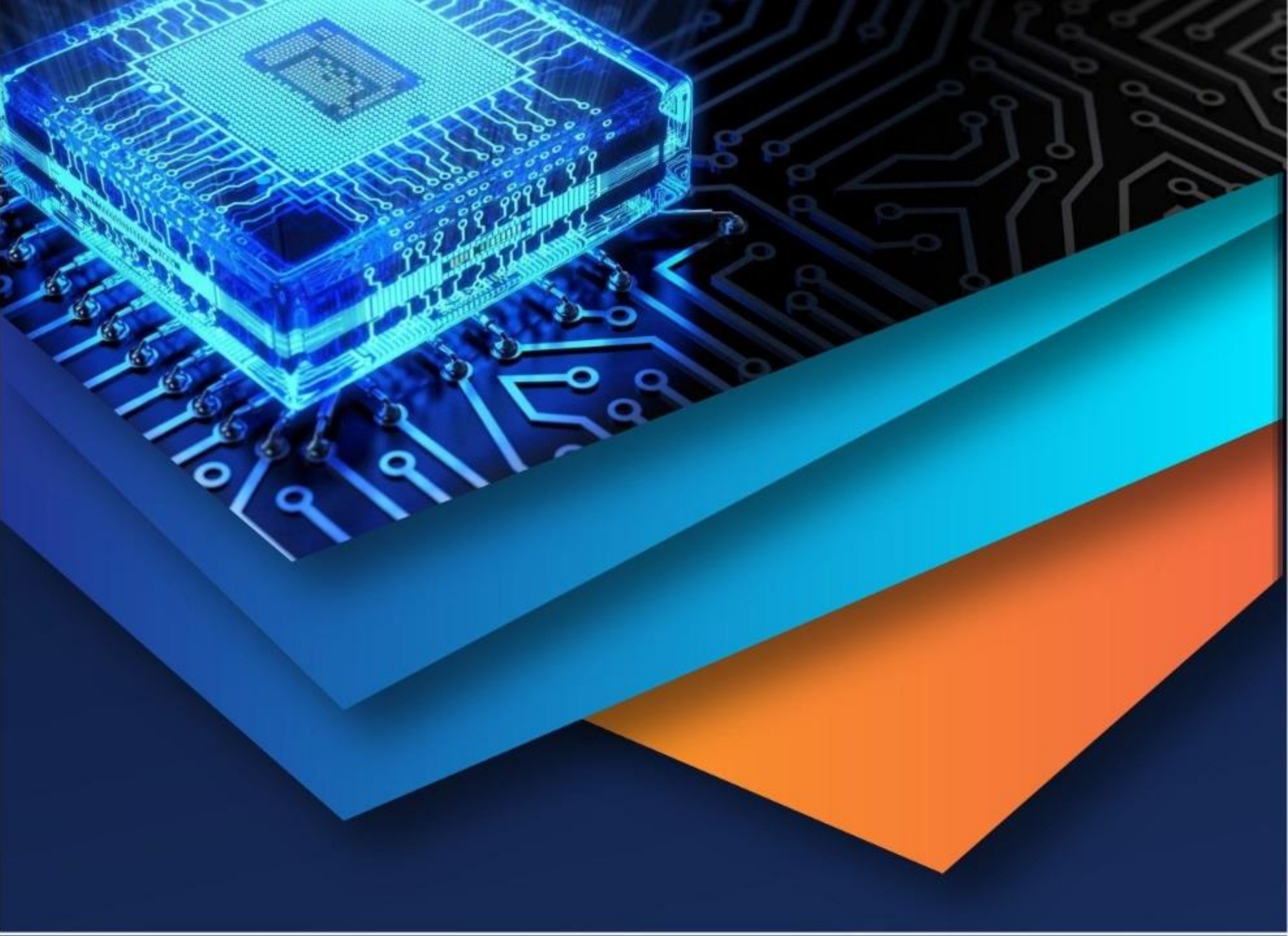

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