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Intuitionistic Fuzzy Neutrosophic Soft Topological Spaces

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ABSTRACT: The aim of this paper is to construct a topology on an intuitionistic fuzzy neutrosophic soft set. The concepts of intuitionistic fuzzy neutrosophic soft closure, intuitionistic fuzzy neutrosophic soft interior, intuitionistic fuzzy neutrosophic soft exterior, intuitionistic fuzzy neutrosophic soft boundary are introduced and some of its properties are studied.

KEYWORDS: Intuitionistic fuzzy neutrosophic soft set,Intuitionistic fuzzy neutrosophic soft topology,Intuitionistic fuzzy neutrosophic soft interior,Intuitionistic fuzzy neutrosophic soft closure,Intuitionistic fuzzy neutrosophic soft exterior, Intuitionistic fuzzy neutrosophic soft boundary.

I. INTRODUCTION

In 1999, Molodtsov initiated the theory of soft sets as a new mathematical tool for dealing uncertainty. The topological structures of set theory dealing with uncertainties were first studied by Chang in 1968.Chang[4] introduced the notion of fuzzy topology and also studied some of its basic properties. Shabir and Naz[10]introduced the notion of the soft topology and studied some basic concepts such as soft interior, soft closure and soft sub base. Maji, Roy and Biswas [5,6] initiated the concept of fuzzy soft set which is a combination of fuzzy set and soft set. Atanassov[3] defined the concept of intuitionistic fuzzy set which is more general than the fuzzy set and Maji et.al[6] introduced the concept of intuitionistic fuzzy soft set. Smarandache[11] initiated the concept of neutrosophic set and Maji[7] defined the notion of neutrosophic soft set. Arockiarani et.al [1]defined the notion of fuzzy neutrosophic set and fuzzy neutrosophic soft set.

II. RELATED WORK

Fuzzy soft topological spaces are introduced by TridivJyotiNeog et.al[12].Intuitionistic fuzzy soft topological spaces are introduced by SadiBayramov and Gigdemgunduz[8]. Neutrosophic topological spaces are introduced by Salama and Alblowi[9]. Fuzzy neutrosophic topological spaces and Fuzzy neutrosophic soft topological spaces are introduced by Arockiarani, and MartinaJency[1,2].

In this paper intuitionistic fuzzy neutrosophic soft topological spaces are introduced.Also the concepts of intuitionistic fuzzy neutrosophic soft closure, intuitionistic fuzzy neutrosophic soft interior, intuitionistic fuzzy neutrosophic soft exterior, intuitionistic fuzzy neutrosophic soft boundary are introduced and some important theorems are established.

III.PRELIMINARIES

DEFINITION:3.1

Let $A=\{\langle x:T_A(x),I_A(x),F_A(x)\rangle, x\in U\}$ where the functions $T_A, I_A, F_A : U \to \left]^{-}0,1^{+}\right[$ define respectively the degree of membership ,the degree of indeterminacy and the degree of non-membership of the elements

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to the set A with the condition, $^{-}0 \le T_A(x)+I_A(x)+F_A(x) \le 3^{+}$. The neutrosophic set takes the value from real standard (or) non-standard subsets of $\left]^{-}0,1^{+}\right[$ so instead of $\left]^{-}0,1^{+}\right[$ we need to take the interval [0,1] for technical applications

DEFINITION:3.2

A **fuzzy neutrosophic set** A on the universe of discourse U is defined as

$A=\{\langle x: T_A(x), I_A(x), F_A(x)\rangle, x\in U\}$ where $T_A, I_A, F_A : U \to [0,1]$ and satisfies the condition $0 \le T_A(x)+I_A(x)+F_A(x) \le 3$

DEFINITION:3.3

An **intuitionistic fuzzy neutrosophic set** A on the universe of discourse U is defined as

$A=\{\langle x: T_A(x), I_A(x), F_A(x)\rangle, x\in U\}$ where $\min[F_A(x), T_A(x)] \le 0.5$, $\min[I_A(x), T_A(x)] \le 0.5$

$\min[F_A(x), I_A(x)] \le 0.5$, for all $x \in U$, with the condition $0 \le T_A(x)+I_A(x)+F_A(x) \le 2$

DEFINITION:3.4

Let U be an initial universe set and E be a set of parameters .Let *P(U)* denotes the power set of U. Consider a non-empty set $A\subset E$. The pair *(F,A)* is called **soft set** over *U*, where *F* is a mapping given by $F: A \to P(U)$.The soft set *(F,A)*is denoted as F_A

DEFINITION:3.5

Let U be an initial universe set. Let E be a set of parameters and a non-empty set $A\subset E$ .Let IFN(*U*) denotes the set of all intuitionistic fuzzy neutrosophic sets of *U*. The pair *(F,A)* is called **intuitionistic fuzzy neutrosophic soft set(in short IFNSS)**over *U*, where *F* is a mapping given by $F: A \to IFN(U)$ and IFNSS*(F,A)* is denoted as $\tilde{F}_A$

DEFINITION:3.6

Let $\tilde{F}_A$ and $\tilde{G}_B$ be two intuitionistic fuzzy neutrosophic soft sets over the common universe *U*. Then $\tilde{F}_A$ is said to be an **intuitionistic fuzzy neutrosophic soft sub set** of $\tilde{G}_B$ if and only if

1. $A\subset B$
2. $\tilde{F}(e)$ is an intuitionistic fuzzy neutrosophic subset of $\tilde{G}(e)$
   Or $T_{\tilde{F}(e)}(x) \le T_{\tilde{G}(e)}(x), I_{\tilde{F}(e)}(x) \le I_{\tilde{G}(e)}(x), F_{\tilde{F}(e)}(x) \ge F_{\tilde{G}(e)}(x), \forall e\in A, \forall x \in U$

We denote this relationship by $\tilde{F}_A \subseteq \tilde{G}_B$ and $\tilde{F}_A$ is said to be an **intuitionistic fuzzy neutrosophic soft super set** of $\tilde{G}_B$ if $\tilde{G}_B$ is an intuitionistic fuzzy neutrosophic soft subset of $\tilde{F}_A$. We denote this relationship by $\tilde{F}_A \supseteq \tilde{G}_B$.

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DEFINITION:3.7 Let *E*={ $e_1, e_2, ..., e_n$ } be a set of parameters. The **NOT set** of *E* is denoted by $\neg$ E is defined as *E*={ $\neg e_1, \neg e_2, ..., \neg e_n$ } where $\neg e_i = not\ e_i, \forall_i$.

DEFINITION:3.8 The **complement of an intuitionistic fuzzy neutrosophic soft set** $\tilde{F}_A$ is denoted by $\tilde{F}_A^C$ and is defined as $\tilde{F}_A^C = (F^C, \neg A)$ where $\tilde{F}_A^C : \neg A \to IFN(U)$ is a mapping given by $\tilde{F}_A^C(e) =$ intuitionistic fuzzy neutrosophic soft complement with $T_{\tilde{F}^C(e)}(x) = F_{\tilde{F}(e)}(x)$, $I_{\tilde{F}^C(e)}(x) = I_{\tilde{F}(e)}(x)$ and $F_{\tilde{F}^C(e)}(x) = T_{\tilde{F}(e)}(x)$ $\forall x \in U, \forall e \in \neg A$.

DEFINITION:3.9 Let $\tilde{F}_A$ and $\tilde{G}_B$ be two IFNSSs over the common universe *U*. **Intuitionistic fuzzy neutrosophic soft union** of $\tilde{F}_A$ and $\tilde{G}_B$ denoted by '$\tilde{F}_A \cup \tilde{G}_B$' and is defined as $\tilde{F}_A \cup \tilde{G}_B = \tilde{K}_C$, where *C*=*A* $\cup$ *B* and the truth membership, indeterminacy membership and falsity membership of $\tilde{K}_C$ are as follows.

$$T_{\tilde{K}(e)}(x) = \max(T_{\tilde{F}(e)}(x), T_{\tilde{G}(e)}(x)),\ I_{\tilde{K}(e)}(x) = \min(I_{\tilde{F}(e)}(x), I_{\tilde{G}(e)}(x))$$
$$F_{\tilde{K}(e)}(x) = \min(F_{\tilde{F}(e)}(x), F_{\tilde{G}(e)}(x)), \forall e \in A \cap B, \forall x \in U$$

DEFINITION:3.10 Let $\tilde{F}_A$ and $\tilde{G}_B$ be two IFNSSs over the common universe *U*. **Intuitionistic fuzzy neutrosophic soft intersection** of $\tilde{F}_A$ and $\tilde{G}_B$ denoted by '$\tilde{F}_A \cap \tilde{G}_B$' and is defined as $\tilde{F}_A \cap \tilde{G}_B = \tilde{K}_C$, where $C = A \cap B$ and the truth membership, indeterminacy membership and falsity membership of $\tilde{K}_C$ are as follows.

$$T_{\tilde{K}(e)}(x) = \min(T_{\tilde{F}(e)}(x), T_{\tilde{G}(e)}(x)),\ I_{\tilde{K}(e)}(x) = \min(I_{\tilde{F}(e)}(x), I_{\tilde{G}(e)}(x))$$
$$F_{\tilde{K}(e)}(x) = \max(F_{\tilde{F}(e)}(x), F_{\tilde{G}(e)}(x)), \forall e \in A \cap B, \forall x \in U.$$

DEFINITION:3.11 An intuitionistic fuzzy neutrosophic soft set $\tilde{F}_A$ over *U* is said to be **empty intuitionistic fuzzy neutrosophic soft set** with respect to the parameter *A* if

$T_{\tilde{F}_A(e)}(x) = 0, I_{\tilde{F}_A(e)}(x) = 0, F_{\tilde{F}_A(e)}(x) = 1 \forall e \in A, \forall x \in U$ .It is denoted by $\tilde{0}_A$.

$\therefore T_{\tilde{0}_A(e)}(x) = 0, I_{\tilde{0}_A(e)}(x) = 0, F_{\tilde{0}_A(e)}(x) = 1$

DEFINITION:3.12 An intuitionistic fuzzy neutrosophic soft set $\tilde{F}_A$ over *U* is said to be the **Universe intuitionistic fuzzy neutrosophic soft set** with respect to the parameter *A* if

$T_{\tilde{F}_A(e)}(x) = 1, I_{\tilde{F}_A(e)}(x) = 0, F_{\tilde{F}_A(e)}(x) = 0 \forall e \in A, \forall x \in U$ .It is denoted by $\tilde{1}_A$

$\therefore T_{\tilde{1}_A(e)}(x) = 1, I_{\tilde{1}_A(e)}(x) = 0, F_{\tilde{1}_A(e)}(x) = 0$.

NOTE: $(\tilde{0}_A)^C = \tilde{1}_A$ and $(\tilde{1}_A)^C = \tilde{0}_A$

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IV.INTUITIONISTIC FUZZY NEUTROSOPHIC SOFT TOPOLOGICAL SPACES

DEFINITION:4.1 Let *U* be an initial universe set. *E* be a set of parameters. An **intuitionistic fuzzy neutrosophic soft topology** (in short IFNST) τ on *U* is a family of intuitionistic fuzzy neutrosophic soft sets over *U* satisfying the following properties:

i) $\tilde{0}_E, \tilde{1}_E \in \tau$

ii) If $\tilde{F}_A$, $\tilde{G}_B \in \tau$ Then $\tilde{F}_A \cap \tilde{G}_B \in \tau$

iii) If $\tilde{F}_{A_i} \in \tau, \forall i \in I$, *I* be any arbitrary index set, then $\bigcup_{i \in I}(\tilde{F}_{A_i}) \in \tau$.

The triplet (U,E,τ) is said to be an **intuitionistic fuzzy neutrosophic soft topological space**(in short IFNSTS).

DEFINITION:4.2 If τ is an intuitionistic fuzzy neutrosophic soft topology on *U*, the triplet (U,E,τ) is said to be an intuitionistic fuzzy neutrosophic soft topological space .Each member of τ is called an **intuitionistic fuzzy neutrosophic soft open set** in (U,E,τ).

An intuitionistic fuzzy neutrosophic soft set is called **intuitionistic fuzzy neutrosophic soft closed** if its complement is intuitionistic fuzzy neutrosophic soft open.

DEFINITION:4.3 Let (U,E,τ) be an intuitionistic fuzzy neutrosophic soft topological space .Let $\tilde{F}_A$ be an IFNSS over *U*. Then an **intuitionistic fuzzy neutrosophic soft closure** of $\tilde{F}_A$ denoted by $Cl(\tilde{F}_A)$ and is defined as the intersection of all intuitionistic fuzzy neutrosophic soft closed sets containing $\tilde{F}_A$.

$Cl(\tilde{F}_A) = \cap\{\tilde{G}_B : \tilde{G}_B$ is intuitionistic fuzzy neutrosophic soft closed and $\tilde{F}_A \subseteq \tilde{G}_B\}$.It is also clear that $Cl(\tilde{F}_A)$ is IFNS closed and $\tilde{F}_A \subseteq Cl(\tilde{F}_A)$.

NOTE:

i) $Cl(\tilde{0}_E) = \tilde{0}_E$ and $Cl(\tilde{1}_E) = \tilde{1}_E$

ii) $\tilde{F}_A$ is intuitionistic fuzzy neutrosophic soft closed if and only if $\tilde{F}_A = Cl(\tilde{F}_A)$

iii) $Cl(Cl(\tilde{F}_A)) = Cl(\tilde{F}_A)$

THEOREM:4.1

Let (U,E,τ) be IFNSTS. Let $\tilde{F}_A$ and $\tilde{G}_B$ are two IFNSS over *U*.Then,

$$Cl(\tilde{F}_A \cup \tilde{G}_B) = Cl(\tilde{F}_A) \cup Cl(\tilde{G}_B)$$

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PROOF:

Since $\tilde{F}_A \subseteq \tilde{F}_A \cup \tilde{G}_B, \tilde{G}_B \subseteq \tilde{F}_A \cup \tilde{G}_B$

$Cl(\tilde{F}_A) \subseteq Cl(\tilde{F}_A \cup \tilde{G}_B), Cl(\tilde{G}_B) \subseteq Cl(\tilde{F}_A \cup \tilde{G}_B)$

So, $Cl(\tilde{F}_A) \cup Cl(\tilde{G}_B) \subseteq Cl(\tilde{F}_A \cup \tilde{G}_B) \rightarrow (1)$

$\tilde{F}_A \subseteq Cl(\tilde{F}_A)$ and $\tilde{G}_B \subseteq Cl(\tilde{G}_B)$

$\tilde{F}_A \cup \tilde{G}_B \subseteq Cl(\tilde{F}_A) \cup Cl(\tilde{G}_B)$

$Cl(\tilde{F}_A) \cup Cl(\tilde{G}_B)$ is IFNS closed set containing $\tilde{F}_A \cup \tilde{G}_B$ over U. Thus

$Cl(\tilde{F}_A \cup \tilde{G}_B) \subseteq Cl(\tilde{F}_A) \cup Cl(\tilde{G}_B) \rightarrow (2)$

From (1) & (2) $Cl(\tilde{F}_A \cup \tilde{G}_B) = Cl(\tilde{F}_A) \cup Cl(\tilde{G}_B)$

DEFINITION :4.4

Let (U,E,τ) be an intuitionistic fuzzy neutrosophic soft topological space. Let $\tilde{F}_A$ be an IFNSS over U. Then the **intuitionistic fuzzy neutrosophic soft interior** of $\tilde{F}_A$ denoted by $\text{int}(\tilde{F}_A)$ and is defined as the union of all intuitionistic fuzzy neutrosophic soft open sets contained in $\tilde{F}_A$.

$\text{int}(\tilde{F}_A) = \cup\{\tilde{G}_B : \tilde{G}_B$ is intuitionistic fuzzy neutrosophic soft open and $\tilde{G}_B \subseteq \tilde{F}_A\}$

It is also clear that int($\tilde{F}_A$) is intuitionistic fuzzy neutrosophic soft open and int($\tilde{F}_A$)$\subseteq \tilde{F}_A$

NOTE:

i) $\text{int}(\tilde{0}_E) = \tilde{0}_E$ and $\text{int}(\tilde{1}_E) = \tilde{1}_E$

ii) $\tilde{F}_A$ is intuitionistic fuzzy neutrosophic soft open if and only if $\tilde{F}_A = \text{int}(\tilde{F}_A)$

iii) $\text{int}(\text{int}(\tilde{F}_A)) = \text{int}(\tilde{F}_A)$

THEOREM:4.2

Let (U,E,τ) be IFNSTS. Let $\tilde{F}_A$ and $\tilde{G}_B$ are two IFNSS over *U*. Then

$\text{int}(\tilde{F}_A \cap \tilde{G}_B) = \text{int}(\tilde{F}_A) \cap \text{int}(\tilde{G}_B)$

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PROOF:

Since $\tilde{F}_A \cap \tilde{G}_B \subseteq \tilde{F}_A, \tilde{F}_A \cap \tilde{G}_B \subseteq \tilde{G}_B$

$\text{int}(\tilde{F}_A \cap \tilde{G}_B) \subseteq \text{int}(\tilde{F}_A)$ and $\text{int}(\tilde{F}_A \cap \tilde{G}_B) \subseteq \text{int}(\tilde{G}_B)$

$\text{int}(\tilde{F}_A \cap \tilde{G}_B) \subseteq \text{int}(\tilde{F}_A) \cap \text{int}(\tilde{G}_B) \rightarrow (1)$

By definition, $\text{int}(\tilde{F}_A) \subseteq \tilde{F}_A$, $\text{int}(\tilde{G}_B) \subseteq \tilde{G}_B$

$\text{int}(\tilde{F}_A) \cap \text{int}(\tilde{G}_B) \subseteq$

$\text{int}(\tilde{F}_A \cap \tilde{G}_B)$ is the largest IFNS open set contained in $(\tilde{F}_A \cap \tilde{G}_B)$

$\text{int}(\tilde{F}_A) \cap \text{int}(\tilde{G}_B) \subseteq \text{int}(\tilde{F}_A \cap \tilde{G}_B) \rightarrow (2)$

from (1) & (2) $\text{int}(\tilde{F}_A \cap \tilde{G}_B) = \text{int}(\tilde{F}_A) \cap \text{int}(\tilde{G}_B)$

THEOREM: 4.3

Let (U,E, τ) be an IFNSTS. Let $\tilde{F}_A$ be IFNSS over U. Then

$i)[Cl(\tilde{F}_A)]^C = \text{int}(\tilde{F}_A{}^C)$

$ii)[\text{int}(\tilde{F}_A)]^C = Cl(\tilde{F}_A{}^C)$

PROOF:

$i) Cl(\tilde{F}_A) = \cap\{\tilde{G}_B : \tilde{G}_B$ is intuitionistic fuzzy neutrosophic soft closed and $\tilde{F}_A \subseteq \tilde{G}_B\}$

$[Cl(\tilde{F}_A)]^C = [\cap\{\tilde{G}_B : \tilde{G}_B$ is intuitionistic fuzzy neutrosophic soft closed and $\tilde{F}_A \subseteq \tilde{G}_B\}]^C$

$= \cup\{\tilde{G}_B{}^C : \tilde{G}_B{}^C$ is intuitionistic fuzzy neutrosophic soft open and $\tilde{G}_B{}^C \subseteq \tilde{F}_A^C\}$

$= \text{int}(\tilde{F}_A{}^C)$

ii) $\text{int}(\tilde{F}_A) = \cup\{\tilde{G}_B : \tilde{G}_B$ is intuitionistic fuzzy neutrosophic soft open and $\tilde{G}_B \subseteq \tilde{F}_A\}$

$[\text{int}(\tilde{F}_A)]^C = [\cup\{\tilde{G}_B : \tilde{G}_B$ is intuitionistic fuzzy neutrosophicsoft open and $\tilde{G}_B \subseteq \tilde{F}_A\}]^C$

$= \cap\{\tilde{G}_B^C : \tilde{G}_B^C$ is intuitionistic fuzzy neutrosophic soft closed and $\tilde{F}_A{}^C \subseteq \tilde{G}_B{}^C\}$

$= Cl(\tilde{F}_A^C)$

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DEFINITION:4.5

Let (U,E,τ)be an intuitionistic fuzzy neutrosophic soft topological space. Let $\tilde{F}_A$ be an intuitionistic fuzzy neutrosophic soft set over U. Then an **intuitionistic fuzzy neutrosophic soft exterior** of $\tilde{F}_A$ denoted by ext($\tilde{F}_A$)and is defined as ext ($\tilde{F}_A$)=int($\tilde{F}_A^C$)

THEOREM :4.4

Let (U,E,τ)be an intuitionistic fuzzy neutrosophic soft topological space. Let $\tilde{F}_A$ and $\tilde{G}_B$ are two intuitionistic fuzzy neutrosophic soft sets over U.Then

$$i)ext(\tilde{F}_A \cup \tilde{G}_B) = ext(\tilde{F}_A) \cap ext(\tilde{G}_B)$$

$$ii)ext(\tilde{F}_A) \cup ext(\tilde{G}_B) \subseteq ext(\tilde{F}_A \cap \tilde{G}_B)$$

PROOF:

$$\text{i)ext}\left(\tilde{F}_A \cup \tilde{G}_B\right) = \text{int}((\tilde{F}_A \cup \tilde{G}_B)^C)$$

$$= \text{int}(\tilde{F}_A^C \cap \tilde{G}_B^C)$$

$$= \text{int}(\tilde{F}_A^C) \cap \text{int}(\tilde{G}_B^C)$$

$$= ext(\tilde{F}_A) \cap ext(\tilde{G}_B)$$

$$\text{ii)}\ ext(\tilde{F}_A) \cup ext(\tilde{G}_B) = \text{int}(\tilde{F}_A^C) \cup \text{int}(\tilde{G}_B^C)$$

$$\subseteq \text{int}(\tilde{F}_A^C \cup \tilde{G}_B^C)$$

$$= \text{int}(\tilde{F}_A \cap \tilde{G}_B)^C$$

$$= ext\left(\tilde{F}_A \cap \tilde{G}_B\right)$$

$$ext(\tilde{F}_A) \cup ext(\tilde{G}_B) \subseteq ext(\tilde{F}_A \cap \tilde{G}_B)$$

DEFINITION:4.6

Let (U,E,τ)be an intuitionistic fuzzy neutrosophic soft topological space. Let $\tilde{F}_A$ be an intuitionistic fuzzy neutrosophic soft set over U. Then an **intuitionistic fuzzy neutrosophic soft boundary** of $\tilde{F}_A$ denoted by bou($\tilde{F}_A$) and is defined as bou($\tilde{F}_A$) $= Cl(\tilde{F}_A) \cap Cl(\tilde{F}_A{}^C)$

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THEOREM:4.5

Let (U,E,τ) be an intuitionistic fuzzy neutrosophic soft topological space. Let $\tilde{F}_A$ be an intuitionistic fuzzy neutrosophic soft set over U.Then

$$[bou(\tilde{F}_A)]^C = \text{int}(\tilde{F}_A) \cup \text{int}(\tilde{F}_A^C) = \text{int}(\tilde{F}_A) \cup ext(\tilde{F}_A)$$

PROOF:

$$\text{bou}(\tilde{F}_A) = Cl(\tilde{F}_A) \cap Cl(\tilde{F}_A{}^C)$$

$$[bou(\tilde{F}_A)]^C = [Cl(\tilde{F}_A)]^C \cup [Cl(\tilde{F}_A{}^C)]^C$$

$$= \text{int}(\tilde{F}_A) \cup \text{int}(\tilde{F}_A{}^C)$$

$$= \text{int}(\tilde{F}_A) \cup \text{ext}(\tilde{F}_A)$$

NOTE:

i)bou $(\tilde{F}_A) \cap \text{int}(\tilde{F}_A) = \tilde{0}_E$

ii)bou $(\tilde{F}_A) \cap ext(\tilde{F}_A) = \tilde{0}_E$

V.CONCLUSION

In the present work, a new space called intuitionistic fuzzy neutrosophic soft topological space is introduced and some of its properties studied.

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