Volume 9, No. 1, Jan. - 2018 (Special Issue)
International Journal of Mathematical Archive-9(1), 2018, 136-140
Available online through www.ijma.info ISSN 2229 – 5046

ON DECOMPOSITION OF INTUITIONISTIC FUZZY NANO CONTINUITY

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ABSTRACT

The aim of this paper is to obtain the decomposition of intuitionistic fuzzy nano continuity in intuitionistic fuzzy nano topological spaces.

2010 AMS Subject Classification: *08A72, 54B05, 54C05.*

Keywords: *intuitionistic fuzzy nano-open sets, intuitionistic fuzzy nano continuity.*

I. INTRODUCTION AND PRELIMINARIES

Nano set theory was proposed by Lellis Thivagar. M and Carmel Richard is a new concept that supports uncertainity. It may be seen as an extension of classical set theory and has been applied decision analysis. Its basic structure is an approximation space. Continuity and its decomposition have been intensively studied in the field of topology and other several branches of mathematics. Lellis Thivagar. M and Carmel Richard in [4] introduced the notion of Nano topology and studied a new class of functions called nano continuous functions and their characterizations in nano topological spaces. In this paper, we study the notions of expansion of intuitionistic fuzzy nano-open sets and obtain decomposition of intuitionistic fuzzy nano continuity in intuitionistic fuzzy nano topological spaces. In this connection, we refer [1], [2], [3], [5], [6], [7] and [9].

Definition 1.1[4]: Let U be the universe, R be an intuitionistic fuzzy equivalence relation on U and $\tau_R(X) = \{1 \sim, 0 \sim, L_R(X), U_R(X), B_R(X)\}$ where$X \subseteq U$. Then $\tau_R(X)$ satisfies the following axioms:

(1)1 $\sim$ and 0 $\sim \in \tau_R(X)$.
(2) The union of the elements of any subcollection of $\tau_R(X)$ is in $\tau_R(X)$.
(3) The intersection of the elements of any finite subcollection of $\tau_R(X)$ is in $\tau_R(X)$.

That is, $\tau_R(X)$ is a topology on U called the intuitionistic fuzzy nano topology on U with respect to X. We call $(U, \tau_R(X))$ as the intuitionistic fuzzy nano topological space. The elements of $\tau_R(X)$ are called as intuitionistic fuzzy nano-open sets. If $(U, \tau_R(X))$ is a nano topological space where $X \subseteq U$ and if $A \subseteq U$, then the intuitionistic fuzzy nano interior of A is defined as the union of all intuitionistic fuzzy nano-open subsets of A and it is denoted by $IFNInt(A)$. $IFNInt(A)$ is the largest intuitionistic fuzzy nano-open subset of A. The intuitionistic fuzzy nano closure of A is defined as the intersection of all intuitionistic fuzzy nano closed sets containing A and it is denoted by $IFNCl(A)$. That is, $IFNCl(A)$ is the smallest intuitionistic fuzzy nano closed set containing A.

Definition 1.4[8]: Let $(U, \tau_R(X))$ and $(V, \tau'_R(Y))$ be two intuitionistic fuzzy nano topological spaces. Then a mapping $f: (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is intuitionistic fuzzy nano continuous on U if the inverse image of every intuitionistic fuzzy nano-open set in V is intuitionistic fuzzy nano-open in U.

II. EXPANSION OF INTUITIONISTIC FUZZY NANO-OPEN SETS.

Definition 2.1: Let $(U, \tau_R(X))$ be a intuitionistic fuzzy nano topological space, 2^U be the set of all subsets of U. A mapping $\mathcal{A}: \tau_R(X) \to 2^U$ is said to be an expansion on $(U, \tau_R(X))$ if $D \subseteq \mathcal{A}D$ for each $D \in \tau_R(X)$.

CONFERENCE PAPER
International Conference dated 08-10 Jan. 2018, on Intuitionistic Fuzzy Sets and Systems (ICIFSS - 2018), Organized by Vellalar College for Women (Autonomous), Erode, Tamil Nadu, India.

Remark 2.2: Let us study the expansion of intuitionistic fuzzy nano-open sets in intuitionistic fuzzy nano topological spaces. Let $(U,\tau_R(X))$ be an intuitionistic fuzzy nano topological space,

1. Define $\mathcal{CL}:\tau_R(X) \to 2^U$ by $\mathcal{CL}(D) = IFNCl(D)$ for each $D \in \tau_R(X)$.Then $\mathcal{CL}$ is an expansion on $(U,\tau_R(X))$, because $D \subseteq IF\mathcal{CL}(D)$ for each $D \in \tau_R(X)$.
2. Since for each $D \in \tau_R(X)$, D is intuitionistic fuzzy nano-open and hence $IFNInt(D) = D$, $\mathcal{F}(D)$ can be defined as $\mathcal{F}:\tau_R(X) \to 2^U$ by $\mathcal{F}(D) = (IFNCl(D) - D)^c$. Then $\mathcal{F}$ is an expansion on $(U,\tau_R(X))$.
   Here, $\mathcal{F}(D) = (IFNCl(D) - D)^c = (IFNCl(D) \cap D^c)^c = (IFNCl(D))^c \cup D \supseteq D$ for each $D \in \tau_R(X)$.
3. Define $IF\mathcal{N}Int\mathcal{CL}:\tau_R(X) \to 2^U$ by $IF\mathcal{N}Int\mathcal{CL}(D) = IF\mathcal{N}IntNCl(D)$ for each $D \in \tau_R(X)$. Then $IF\mathcal{N}Int\mathcal{CL}$ is an expansion on $(U,\tau_R(X))$, because $D \subseteq IF\mathcal{N}Int\mathcal{CL}(D)$ for each $D \in \tau_R(X)$.
4. Define $\mathcal{F}_s:\tau_R(X) \to 2^U$ by $\mathcal{F}_s(D) = D \cup (IF\mathcal{N}IntNCl(D))^C$ for each $D \in \tau_R(X)$. Then $\mathcal{F}_s$ is an expansion on $(U,\tau_R(X))$.

Definition 2.3: Let $(U,\tau_R(X))$ be an intuitionistic fuzzy nano topological space. A pair of expansion $\mathcal{A},\mathcal{B}$ on$(U,\tau_R(X))$ is said to be mutually dual if $\mathcal{A}D \cap \mathcal{B}D = D$ for each $D \in \tau_R(X)$·

Example 2.4: Let (U,R) be an intuitionistic fuzzy approximation space where U={a, b, c} and R∈R(U x U) is defined as follows:
R={<(a,a),1~,0~>,<(a,b),0.3,0.5>,<(b,a),0.3,0.5>,<(c,b),0.3,0.5>,<(c,c),1~,0~>,<(a,c),0.3,0.3>,<(c,a),0.3,0.3>, <(b,c),0.3,0.5>,<(b,b),1~,0~>}. Let A = {<a, 0.6, 0.3>, <b, 0.5, 0.4>, <c, 0.5, 0.4>}

be an intuitionistic fuzzy set with intuitionistic fuzzy nano topology $\tau_R(X) = \{1\sim, 0\sim, \{<a, 0.6, 0.3>, <b, 0.5, 0.4>, <c, 0.5, 0.4>, <a, 0.6, 0.3>, <b, 0.5, 0.4>, <c, 0.5, 0.4>\{<a, 0.3, 0.6>, <b, 0.4, 0.5>, <c, 0.4, 0.5>\}\}$. Here $\mathcal{CL}$ and $\mathcal{F}$ are both mutually dual to $\mathcal{A}$.

Proposition 2.5: Let $(U,\tau_R(X))$ be a intuitionistic fuzzy nano topological space. Then the expansions $\mathcal{CL}$ and $\mathcal{F}$ are mutually dual.

Proof: Let $D \in \tau_R(X)$.
Now,
$\mathcal{CL}(D) \cap \mathcal{F}(D) = IFNCl(D) \cap (IFNCl(D) - D)^c = IFNCl(D) \cap (IFNCl(D) \cap D^c)^c$
$= IFNCl(D) \cap \left((IFNCl(D))^c \cup D\right) = \left(IFNCl(D) \cap (IFNCl(D))^c\right) \cup \left((IFNCl(D)) \cap D\right) = \phi \cup D = D$
That is, $\mathcal{CL}(D) \cap \mathcal{F}(D) = D$, for each $D \in \tau_R(X)$. Therefore the expansions $\mathcal{CL}$ and $\mathcal{F}$ are mutually dual.

Remark 2.6: The identity expansion $\mathcal{A}D = D$ is mutually dual to any expansion $\mathcal{B}$. The pair of expansions $\mathcal{CL}$, $\mathcal{F}$ and $IFNInt\mathcal{CL}$, $\mathcal{F}_s$ are easily seen to be mutually dual.

Definition 2.7: A function $f:(U,\tau_R(X)) \to (V,\tau'_R(Y))$ is said to be intuitionistic fuzzy nano almost continuous if for each nano-open set E in V containing $f(x)$, there exists an nano-open set D in U containing x such that $f(D) \subseteq IFNInt(IFNCl(E))$.

Theorem 2.8: A function $f:(U,\tau_R(X)) \to (V,\tau'_R(Y))$ is intuitionistic fuzzy nano almost continuous if and only if $f^{-1}(E) \subseteq IFNInt(f^{-1}(IFNInt(IFNCl(E))))$ for any intuitionistic fuzzy nano-open set E in V.

Proof: Necessity: Let E be an arbitrary intuitionistic fuzzy nano-open set in V and let $x \in f^{-1}(E)$ then $f(x) \in E$. Since E is intuitionistic fuzzy nano-open, it is a neighborhood of $f(x)$ in V. Since f is intuitionistic fuzzy nano almost continuous at x, there exists a intuitionistic fuzzy nano-open neighbourhood D of x in V such that $f(D) \subseteq IFNInt\big(IFNCl(E)\big)$. This implies that $D \subseteq f^{-1}(IFNInt(IFNCl(E)))$, thus $x \in D \subseteq f^{-1}(IFNInt(IFNCl(E)))$.
Thus $f^{-1}(E) \subseteq IFNInt(f^{-1}(IFNInt(IFNCl(E))))$.

Sufficiency : Let E be an arbitrary intuitionistic fuzzy nano-open set in V such that $f(x) \in E$.
Then, $x \in f^{-1}(E) \subseteq IFNInt(f^{-1}(IFNInt(IFNCl(E))))$. Take $D = IFNInt(f^{-1}(IFNInt(IFNCl(E))))$, then $f(D) \subseteq f(f^{-1}(IFNInt(IFNCl(E)))) \subseteq IFNInt(IFNCl(E))$ such that $f(D) \subseteq IFNInt(IFNCl(E))$.
By Definition 2.7, f is intuitionistic fuzzy nano almost continuous.

Proposition 2.9: If a function $f:(U,\tau_R(X)) \to (V,\tau'_R(Y))$ is intuitionistic fuzzy nano continuous, then f is intuitionistic fuzzy nano almost continuous.

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Proof: Let E be a intuitionistic fuzzy nano-open set in V, then $E \subseteq IFNInt(IFNCl(E))$. Since f is intuitionistic fuzzy nano continuous, $f^{-1}(E)$ is intuitionistic fuzzy nano-open in U such that $f(E) \subseteq f(f^{-1}(IFNInt(IFNCl(E))))$. Since $f^{-1}(E) = IFNInt(f^{-1}(E))$ in $U, f^{-1}(E) = IFNInt(f^{-1}(E)) \subseteq IFNInt(f^{-1}(IFNInt(IFNCl(E))))$. By Theorem 2.8, f is intuitionistic fuzzy nano almost continuous.

III. DECOMPOSITION OF INTUITIONISTIC FUZZY NANO CONTINUITY.

Definition 3.1: Let $(U, \tau_R(X))$ and $(V, \tau'_R(Y))$ be two intuitionistic fuzzy nano topological spaces. A mapping $f:(U, \tau_R(X)) \to (V, \tau'_R(Y))$ is said to be $\mathcal{A}-$expansion intuitionistic fuzzy nano continuous if $f^{-1}(E) \subseteq IFNIntf^{-1}(AE)$, for each $E \in \tau'_R(Y)$.

Theorem 3.2: Let $(U, \tau_R(X))$ and $(V, \tau'_R(Y))$ be two intuitionistic fuzzy nano topological spaces. Let $\mathcal{A}$ and $\mathcal{B}$ be two mutually dual expansion on V. Then a mapping $f:(U, \tau_R(X)) \to (V, \tau'_R(Y))$ is intuitionistic fuzzy nano continuous if and only if f is $\mathcal{A}-$expansion intuitionistic fuzzy nano continuous and $\mathcal{B}-$expansion intuitionistic fuzzy nano continuous.

Proof: Necessity: Since $\mathcal{A}$ and $\mathcal{B}$ are mutually dual on V, $\mathcal{A}E \cap \mathcal{B}E = E$ for each $E \in \tau'_R(Y)$.
Let $E \in \tau'_R(Y)$ then $f^{-1}(E) = f^{-1}(AE) \cap f^{-1}(BE)$. Since f is intuitionistic fuzzy nano continuous,
$f^{-1}(E) = IFNIntf^{-1}(E)$. So, $f^{-1}(E) = IFNInt\left(f^{-1}(\mathcal{A}E) \cap f^{-1}(\mathcal{B}E)\right) = IFNIntf^{-1}(\mathcal{A}E) \cap IFNIntf^{-1}(\mathcal{B}E)$.
Thus $f^{-1}(E) \subseteq IFNIntf^{-1}(\mathcal{A}E)$ and $f^{-1}(E) \subseteq IFNIntf^{-1}(\mathcal{B}E)$, for each $E \in \tau'_R(Y)$.

Hence f is $\mathcal{A}-$expansion intuitionistic fuzzy nano continuous and $\mathcal{B}-$expansion intuitionistic fuzzy nano continuous.

Sufficiency: Let $\mathcal{A}$ and $\mathcal{B}$ be two mutually dual expansion on $(V, \tau'_R(Y))$. Since f is $\mathcal{A}-$expansion intuitionistic fuzzy nano continuous, $f^{-1}(E) \subseteq IFNIntf^{-1}(\mathcal{A}E)$, for each $E \in \tau'_R(Y)$. Since f is $\mathcal{B}-$ expansion intuitionistic fuzzy nano continuous, $f^{-1}(E) \subseteq IFNIntf^{-1}(\mathcal{B}E)$, for each $E \in \tau'_R(Y)$. Also $\mathcal{A}E \cap \mathcal{B}E = E$ for each $E \in \tau'_R(Y)$.
Therefore, $f^{-1}(\mathcal{A}E) \cap f^{-1}(\mathcal{B}E) = f^{-1}(E)$.

Hence, $IFNIntf^{-1}(E) = (IFNIntf^{-1}(\mathcal{A}E) \cap IFNIntf^{-1}(\mathcal{B}E)) \supseteq f^{-1}(E) \cap f^{-1}(E) = f^{-1}(E)$.

So, $IFNIntf^{-1}(E) \supseteq f^{-1}(E)$. But, $IFNIntf^{-1}(E) \subseteq f^{-1}(E)$ always. Therefore, $f^{-1}(E) = IFNIntf^{-1}(E)$. This implies that $f^{-1}(E)$ is an intuitionistic fuzzy nano open set in $(U, \tau_R(X))$ for each $E \in \tau'_R(Y)$. Therefore f is intuitionistic fuzzy nano continuous.

Corollary 3.3: A mapping $f:(U, \tau_R(X)) \to (V, \tau'_R(Y))$ is intuitionistic fuzzy nano continuous if and only if f is intuitionistic fuzzy nano almost continuous and $\mathcal{F}_s -$ expansion intuitionistic fuzzy nano continuous.

Proof: We have that the condition f is intuitionistic fuzzy nano almost continuous is equivalent to f is $IFNInt\mathcal{CL}-$expansion intuitionistic fuzzy nano continuous, and the condition f is $\mathcal{F}_s-$expansion intuitionistic fuzzy nano continuous is equivalent to $f^{-1}(E) \subset IFNIntf^{-1}(E \cup (IFNIntNCl(E)^c))$, for each intuitionistic fuzzy nano-open set E in V. Since $IFNInt\mathcal{CL}$ and $\mathcal{F}_s$ are mutually dual, the result follows from theorem 3.2.

Theorem 3.4. Let $\mathcal{A}$ be any expansion on $(V, \tau'_R(Y))$. Then the expansion $\mathcal{B}E = E \cup (\mathcal{A}E)^c$ is the maximal expansion on $(V, \tau'_R(Y))$ which is mutually dual to $\mathcal{A}$.

Proof: Let $\mathcal{B}_A$ be the set of all expansions on $(V, \tau'_R(Y))$ which are mutually dual to $\mathcal{A}$. Since $E \subset \mathcal{A}E$, for any $E \in \tau'_R(Y)$, $\mathcal{A}E$ can be written as $\mathcal{A}E = E \cup (\mathcal{A}E \backslash E)$. Let $\mathcal{B}E = E \cup (\mathcal{A}E)^c = (\mathcal{A}E \backslash E)^c$. It is obvious that $\mathcal{B}$ is an expansion on $(V, \tau'_R(Y))$ and $\mathcal{A}E \cap \mathcal{B}E = E$ for any $E \in \tau'_R(Y)$. Thus $\mathcal{B} \in \mathcal{B}_A$.Given any expansion $\mathcal{B}'$ on $(V, \tau'_R(Y))$, write $\mathcal{B}'E = E \cup (\mathcal{B}'E \backslash E)$. If $\mathcal{B}' \in \mathcal{B}_A$, then $(\mathcal{A}E \backslash E) \cap (\mathcal{B}'E \backslash E) = \phi$, thus $(\mathcal{B}'E \backslash E) \subset (\mathcal{A}E \backslash E)^c$. Therefore $\mathcal{B}'E \subset \mathcal{B}E$ and we have that $\mathcal{B}' < B$, that is, $\mathcal{B}$ is the maximal element of $\mathcal{B}_A$.

Definition 3.5: Let $(U, \tau_R(X))$ and $(V, \tau'_R(Y))$ be two intuitionistic fuzzy nano topological spaces. Let $\mathcal{B}$ be an expansion on $(V, \tau'_R(Y))$. A mapping $f:(U, \tau_R(X)) \to (V, \tau'_R(Y))$ is said to be closed $\mathcal{B}-$ intuitionistic fuzzy nano continuous if $f^{-1}((\mathcal{B}E)^c)$ is a intuitionistic fuzzy nano closed set in $(U, \tau_R(X))$ for each $E \in \tau'_R(Y)$.

Proposition 3.6: A closed $\mathcal{B}-$ intuitionistic fuzzy nano continuous mapping $f:(U, \tau_R(X)) \to (V, \tau'_R(Y))$ is $\mathcal{B}-$ expansion intuitionistic fuzzy nano continuous.

Proof: We first prove $(f^{-1}((\mathcal{B}E)^c))^c = f^{-1}(\mathcal{B}E)$. Let $x \in (f^{-1}((\mathcal{B}E)^c))^c$.
Then x$\notin f^{-1}((\mathcal{B}E)^c))$. Hence $f(x) \notin (\mathcal{B}E)^c$, this implies $f(x) \in (\mathcal{B}E)$ and $x \in f^{-1}(\mathcal{B}E)$.

So, $(f^{-1}((\mathcal{B}E)^c))^c \subseteq f^{-1}(\mathcal{B}E)$.

Conversely, let $x \in f^{-1}(\mathcal{B}E)$. Then $f(x) \in (\mathcal{B}E)$. Hence, $f(x) \notin (\mathcal{B}E)^c$, $x \notin f^{-1}((\mathcal{B}E)^c))$, this implies $x \in (f^{-1}((\mathcal{B}E)^c))^c$. So, $f^{-1}(\mathcal{B}E) \subseteq (f^{-1}((\mathcal{B}E)^c))^c$. Therefore, $(f^{-1}((\mathcal{B}E)^c))^c = f^{-1}(\mathcal{B}E)$.

Since $f: (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is a $\mathcal{B} -$ intuitionistic fuzzynano continuous mapping, $f^{-1}((\mathcal{B}E)^c))$ is a intuitionistic fuzzy nano closed set in $(U, \tau_R(X))$. Hence $f^{-1}(\mathcal{B}E)$ is intuitionistic fuzzy nano-open in $(U, \tau_R(X))$ and so $f^{-1}(\mathcal{B}E) = IFNIntf^{-1}(\mathcal{B}E)$. Also, and this implies $f^{-1}(E) \subseteq f^{-1}(\mathcal{B}E) = IFNIntf^{-1}(\mathcal{B}E)$. Therefore $f^{-1}(E) \subseteq IFNIntf^{-1}(\mathcal{B}E)$ for each $E \in \tau'_R(Y)$. Hence f is $\mathcal{B}$ −expansion intuitionistic fuzzy nano continuous.

Definition 3.7: An expansion $\mathcal{A}$ on $(U, \tau_R(X))$ is said to be intuitionistic fuzzy nano-open if $\mathcal{A}V \in \tau_R(X)$ for all $V \in \tau_R(X)$.

Definition 3.8: An intuitionistic fuzzy nano-open expansion $\mathcal{A}$ on $(U, \tau_R(X))$ is said to be idempotent.

Example 3.9: The expansion $\mathcal{F}D = (IFNCl(D) - IFNInt(D))^c$ for each $D \in \tau_R(X)$ is idempotent.

In fact the expansion $\mathcal{F}$ is intuitionistic fuzzy nano-open,

$$
\begin{aligned}
\mathcal{F}(\mathcal{F}D) &= \mathcal{F}(IFNCl(D) - NInt(D))^c = \mathcal{F}((IFNCl(D) \cap D^c)^c) \\
&= \mathcal{F}((IFNCl(D))^c \cup D) = (IFNCl((IFNCl(D))^c \cup D))^c \cup ((IFNCl(D))^c \cup D) \\
&= \left(IFNCl\left(IFNCl(D)\right)^c \cup IFNCl(D)\right)^c \cup ((IFNCl(D))^c \cup D \\
&= (IFNCl(IFNCl(D))^c)^c \cap (IFNCl(D))^c \cup ((IFNCl(D))^c \cup D) \\
&= ((IFNCl(D))^c \cup D) \ = \mathcal{F}D
\end{aligned}
$$

Remark 3.10: From the Example 3.9, we conclude that intuitionistic fuzzy nano continuity does not imply closed $\mathcal{B}$ −nano continuity. Since f is intuitionistic fuzzy nano continuous it is $\mathcal{B}$ −expansion intuitionistic fuzzy nano continuous, but it is not closed $\mathcal{B} -$ intuitionistic fuzzynano continuous. The proposition gives a condition under which an $\mathcal{B}$ −expansion nano continuous function is closed $\mathcal{B} -$ intuitionistic fuzzynano continuous and vice versa.

Proposition 3.11: Let $f: (U, \tau_R(X)) \to (V, \tau'_R(Y))$ and $\mathcal{B}$ be idempotent, then f is $\mathcal{B}$ −expansion intuitionistic fuzzy nano continuous if and only if f is closed $\mathcal{B} -$ intuitionistic fuzzy nano continuous.

Proof: The sufficiency follows from Proposition 3.6.

Necessity: Let f be $\mathcal{B}$ −expansion nano continuous,where $\mathcal{B}$ is idempotent and E an intuitionistic fuzzy nano- open subset of $(V, \tau'_R(Y))$. Since $\mathcal{B}E$ is nano-open on $(V, \tau'_R(Y))$and $\mathcal{B}(\mathcal{B}E) = \mathcal{B}E$, then $f^{-1}(\mathcal{B}E) \subseteq IFNIntf^{-1}(\mathcal{B}(\mathcal{B}E)) = IFNIntf^{-1}(\mathcal{B}E)$. Thus $f^{-1}(\mathcal{B}E)$ is intuitionistic fuzzy nano open in $(U, \tau_R(X))$ and therefore f is closed $\mathcal{B} -$ intuitionistic fuzzy nano continuous.

Corollary 3.12: Let $\mathcal{A}$ and $\mathcal{B}$ be two mutually dual expansion on $(V, \tau'_R(Y))$. If $\mathcal{B}$ is idempotent, then $f: (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is nano continuous if and only if f is $\mathcal{A}$ −expansion intuitionistic fuzzy nano continuous and closed $\mathcal{B} -$ intuitionistic fuzzy nano continuous.

IV. CONCLUSION

In this paper, the notions of expansion of intuitionistic fuzzy nano-open sets and decomposition of intuitionistic fuzzy nano continuity in intuitionistic fuzzy nano topological spaces are studied. The theory of expansions and decomposition in intuitionistic fuzzy nano topological spaces has a wide variety of applications in real life. The decomposition of intuitionistic fuzzy nano topological space can be applied in the study of independence of real time problems and in defining its attributes.

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Source of support: Proceedings of UGC Funded International Conference on Intuitionistic Fuzzy Sets and Systems (ICIFSS-2018), Organized by: Vellalar College for Women (Autonomous), Erode, Tamil Nadu, India.

