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Pairwise Ordered $\zeta-$Extremely Disconnected Spaces

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Abstract: In this paper, a new class of intuitionistic fuzzy topological spaces called pairwise ordered intuitionistic fuzzy $\zeta-$extremally disconnected space is introduced. We also apply these notions of $\zeta-$extremally disconnectedness to discuss Tietze's extension theorem and several other properties.

Keywords: intuitionistic fuzzy $\zeta-$extremally disconnected space, intuitionistic fuzzy $\zeta-$space, intuitionistic fuzzy real line, intuitionistic fuzzy unit interval, intuitionistic fuzzy continuous function.

1. INTRODUCTION

After the introduction of the concept of fuzzy sets by Zadeh [12], several researches were conducted on the generalisations of the notion of fuzzy set. The concept of "Intuitionistic fuzzy sets" was first published by Atanassov and many works by the same author and his colleagues[1,2] appeared in the literature. An introduction to intuitionistic fuzzy topological space was introduced by Dogan Coker[5]. In this paper a new class of intuitionistic fuzzy topological spaces namely, pairwise ordered intuitionistic fuzzy $\zeta-$extremally disconnected spaces is introduced by using the concepts of ordered fuzzy topology and fuzzy bitopology.

2. PRELIMINARIES

Definition 2.1.[1]. An intuitionistic fuzzy set (IFS, in short) A in X is an object having the form $A=\{x,\mu_A(x),\upsilon_A(x)/x\in X\}$ where the functions $\mu_A:X\to I$ and $\upsilon_A:X\to I$ denote the degree of membership (namely $\mu_A(x)$) and the degree of non-membership (namely $\upsilon_A(x)$) of each element $x\in X$ to the set A on a nonempty set X and $0\le\mu_A(x)+\upsilon_A(x)\le 1$ for each $x\in X$. Obviously every fuzzy set A on a nonempty set X is an IFS's A and B be in the form $A=\{x,\mu_A(x),1-\mu_A(x)/x\in X\}$

Definition 2.2.[1]. Let X be a nonempty set and the IFS's A and B be in the form $A=\{x,\mu_A(x),\upsilon_A(x)/x\in X\}$, $B=\{x,\mu_B(x),\upsilon_B(x)/x\in X\}$ and let $A=\{A_j:j\in J\}$ be an arbitrary family of IFS's in X. Then we define

(i) $A\subseteq B$ if and only if $\mu_A(x)\le\mu_B(x)$ and $\upsilon_A(x)\ge\upsilon_B(x)$ for all $x\in X$.

(ii) A=B if and only if $A\subseteq B$ and $B\subseteq A$.

(iii) $\overline{A}=\{x,\upsilon_A(x),\mu_A(x)/x\in X\}$.

(iv) $A\cap B=\{x,\mu_A(x)\cap\mu_B(x),\upsilon_A(x)\cup\upsilon_B(x)/x\in X\}$.

(v) $A\cup B=\{x,\mu_A(x)\cup\mu_B(x),\upsilon_A(x)\cap\upsilon_B(x)/x\in X\}$

(vi) $1_\sim=\{\langle x,1,0\rangle x\in X\}$ and

$0_\sim=\{\langle x,0,1\rangle x\in X\}$.

Definition 2.3.[5]. An intuitionistic fuzzy topology (IFT, in short) on a nonempty set X is a family τ of an intuitionistic fuzzy set (IFS, in short) in X satisfying the following axioms:

(i) $0_\sim, 1_\sim\in\tau$.

(ii) $A_1\cap A_2\in\tau$ for any $A_1, A_2\in\tau$.

(iii) $\bigcup A_j\in\tau$ for any $A_j: j\in J\subseteq\tau$.

In this paper we denote intuitionistic fuzzy topological space (IFTS, in short) by $(X,\tau),(Y,\kappa)$ or X,Y. Each IFS which belongs to τ is called *an intuitionistic fuzzy open set* (*IFOS*, in short) in X. The complement $\overline{A}$ of an IFOS A in X is called an *intuitionistic fuzzy closed set*(*IFCS*, in short). An IFS X is called *intuitionistic fuzzy clopen* (*IF clopen*) iff it is both intutionistic fuzzy open and intuitionistic fuzzy closed.

Definition 2.4.[5]. Let (X,τ) be an IFTS and $A=\{x,\mu_A(x),\upsilon_A(x)\}$ be an IFS in X. Then the fuzzy interior and closure of A are denoted by

(i) $cl(A)=\bigcap$ {K: K is an IFCS in X and $A\subseteq K$ }.

(ii) $\text{int}(A)=\bigcup$ {G: G is an IFOS in X and $G\subseteq A$}.

Note that, for any IFS A in (X,τ), we have $cl(\overline{A})=\overline{\text{int}(A)}$ and $\text{int}(\overline{A})=\overline{cl(A)}$.

Definition 2.10.[10]. Let A be an IFTS (X,τ). Then A is called an *intuitionistic fuzzy* ζ *open* set($IF\zeta OS$, in short) in X if $A\subseteq bcl(\text{int}(A))$.

Definition 2.11.[10]. Let A be an IFTS (X,τ). Then A is called an *intuitionistic fuzzy* ζ *closed* set ($IF\zeta CS$, in short) in X if $b\text{int}(cl(A))\subseteq A$.

Definition 2.12.[10]. Let $f : X \to Y$ from an IFTS X into an IFTS Y. Then f is said to be an Intuitionistic fuzzy ζ continuous (IF ζ cont, in short)[11] if $f^{-1}(B) \in IF\zeta OS(X)$ for every $B \in \kappa$.

Definition 2.12.[8]. An ordered set on which there is given a fuzzy topology is called an ordered fuzzy topological space.

Definition 2.12.[7]. A fuzzy bitopological space is a triple $(X, \tau_1, \tau_2 \leq)$ where X is a set and τ_1, τ_2 are any two fuzzy topologies on X.

3. PAIRWISE ORDERED INTUIIONISTIC FUZZY ζ – EXTREMALLY DISCONNECTED SPACES

Definition 3.1. Let (X, τ) be an IFTS. Let A be any intuitionistic fuzzy ζ open set (in short, $IF\zeta OS$) in (X, τ). If $IF\zeta cl(A)$ is $IF\zeta$ open, then (X, τ) is said to be intuitionistic fuzzy ζ – extremally disconnected (in short, $IF\zeta$ – extremally disconnected).

Proposition 3.2. Let (X, ζ) is an intuitionistic fuzzy ζ space. Then the following statements are equivalent.

(i) (X, τ) is an intuitionistic fuzzy ζ extremally disconnected space.

(ii) For each $IF\zeta CS$ set A, we have $IF\zeta\,\mathrm{int}(A)$ is intuitionistic fuzzy ζ closed.

(iii) For each $IF\zeta OS$ set A, we have $IF\zeta cl(IF\zeta\,\mathrm{int}(\overline{A})) = \overline{IF\zeta cl(A)}$.

(iv) For each pair of $IF\zeta OS$ A and B in (X, τ), we have $\overline{IF\zeta cl(A)} = B, IF\zeta cl(B) = I\,\overline{F\zeta cl(A)}$

Proposition 3.3. Let (X, τ) be an IFTS. Then (X, τ) is intuitionistic fuzzy ζ extremally disconnected space if and only if for any $IF\zeta OS$ A and $IF\zeta CS$ B such that $A \subseteq B$, $IF\zeta cl(A) \subseteq IF\zeta\,\mathrm{int}(B)$.

Notation 3.4. An IFS which is both $IF\zeta OS$ and $IF\zeta CS$ is called intuitionistic fuzzy ζ clopen set.

Remark 3.5. Let (X, τ) is intuitionistic fuzzy ζ basically disconnected space. Let $\{A_i, \overline{B_i} / i \in N\}$ be collection such that A_i's are $IF\zeta OS$ and B_i's are $IF\zeta CS$ sets. If $A_i \subseteq A \subseteq B_j$ and $A_i \subseteq B \subseteq B_j$ for all $i, j \in N$, then there exists an $IF\zeta COGF$ set C such that $IF\zeta cl(A_i) \subseteq C \subseteq IF\zeta\,\mathrm{int}(B_j)$ for all $i, j \in N$.

Theorem 3.6. Let (X, τ) is intuitionistic fuzzy ζ basically disconnected space. Let $\{A_q\}_{q \in Q}$ and $\{B_q\}_{q \in Q}$ be monotone increasing collections of an $IF\zeta OS$ sets and $IF\zeta CS$ of (X, τ). Suppose that $A_{q1} \subseteq B_{q2}$ whenever $q_1 < q_2$ (Q is the set of all rational numbers). Then there exists a monotone increasing collection $\{C_q\}_{q \in Q}$ of an $IF\zeta COGF$ sets of (X, τ) such that $IF\zeta cl(A_{q1}) \subseteq C_{q2}$ and $C_{q1} \subseteq IF\zeta\,\mathrm{int}(B_{q2})$ whenever $q_1 < q_2$.

Notation 3.7. $I^0(A)$ denotes increasing intuitionistic fuzzy interior of A, $I(A)$ denotes increasing intuitionistic fuzzy closure of A.

Definition 3.8. Let $(X, \tau, \leq)$ be an ordered IFTS and let A be any IFS in $(X, \tau, \leq)$, A is called increasing $IF\zeta$ open if $A \subseteq I\ (I^0(A))$. The complement of an increasing $IF\zeta OS$ is called decreasing $IF\zeta$ closed.

Definition 3.9. Let (X, τ) be an IFTS. For any IFS A in $(X, \tau, \leq)$,

$I^{IF\zeta}(A)$ = increasing intuitionistic fuzzy ζ closure of A

$= \bigcap \{B / B$ is an increasing intuitionistic fuzzy ζ closed set and $B \supseteq A\}$,

$D^{IF\zeta}(A)$ = decreasing intuitionistic fuzzy ζ closure of A

$= \bigcap \{B / B$ is an decreasing intuitionistic fuzzy ζ closed set and $B \supseteq A\}$,

$I^{0IF\zeta}(A)$ = increasing intuitionistic fuzzy ζ interior of A

$= \bigcup \{B / B$ is an increasing intuitionistic fuzzy ζ open set and $B \subseteq A\}$,

$D^{0IF\zeta}(A)$ = decreasing intuitionistic fuzzy ζ interior of A

$= \bigcup \{B / B$ is an increasing intuitionistic fuzzy ζ open set and $B \subseteq A\}$,

Clearly, $I^{IF\zeta}(A)$ (resp. $D^{IF\zeta}(A)$) is the smallest increasing (resp. decreasing) intuitionistic fuzzy ζ closed set containing A and $I^{0IF\zeta}(A)$ (resp. $D^{0IF\zeta}(A)$) is the largest increasing (resp. decreasing) intuitionistic fuzzy ζ open set contained in A.

Proposition 3.10. For any IFS A of an ordered intuitionistic fuzzy topological space $(X,\tau,\leq)$, the following statements hold :

(i) $\overline{I^{IF\zeta}(A)} = D^{0IF\zeta}(\overline{A})$

(ii) $\overline{D^{IF\zeta}(A)} = I^{0IF\zeta}(\overline{A})$

(iii) $\overline{I^{0IF\zeta}(A)} = D^{IF\zeta}(\overline{A})$

(iv) $\overline{D^{0IF\zeta}(A)} = I^{IF\zeta}(\overline{A})$

Definition 3.11. Let $(X,\tau_1,\tau_2\leq)$ be an ordered IF bitopological space. Let A be any τ_1-increasing (resp. decreasing) $IF\zeta OS$ in $(X,\tau_1,\tau_2\leq)$. If $I_{\tau_2}^{IF\zeta}(A)$ (resp. $D_{\tau_2}^{IF\zeta}(A)$ is τ_2-increasing (resp. decreasing) $IF\zeta OS$ in c, then $(X,\tau_1,\tau_2\leq)$ is said to be τ_1-upper (τ_1-lower) $IF\zeta-$extremally disconnected. Similarly we can define τ_2-upper (τ_2-lower) $IF\zeta-$extremally disconnected. An IFTS $(X,\tau_1,\tau_2\leq)$ is said to be *pairwise upper* $IF\zeta-$*extremally disconnected* if it is both τ_1-upper $IF\zeta-$extremally disconnected and τ_2-upper $IF\zeta-$extremally disconnected. Similarly we can define *pairwise lower* $IF\zeta-$*extremally disconnected.* An IF bitopological space $(X,\tau_1,\tau_2\leq)$ is said to be *pairwise ordered* $IF\zeta-$*extremally disconnected* if it is both pairwise upper $IF\zeta-$*extremally disconnected and* pairwise lower $IF\zeta-$*extremally disconnected.*

Proposition 3.12. For an ordered IF bitopological space $(X,\tau_1,\tau_2\leq)$ the following statements are equivalent:

(i) $(X,\tau_1,\tau_2\leq)$ is pairwise upper $IF\zeta-$*extremally disconnected*

(ii) For each τ_1-decreasing $IF\zeta CS$ A, $D_{\tau_2}^{0IF\zeta}(A)$ is τ_2-decreasing $IF\zeta CS$ A, $D_{\tau_1}^{0IF\zeta}(A)$ is τ_1-decreasing $IF\zeta$ closed.

(iii) For each τ_1-increasing $IF\zeta OS$ A, $D_{\tau_2}^{IF\zeta}(\overline{I_{\tau_2}^{IF\zeta}(A)}) = \overline{(I_{\tau_2}^{IF\zeta}(A)}$. Similarly, for each $D_{\tau_1}^{IF\zeta}(\overline{I_{\tau_1}^{IF\zeta}(A)}) = \overline{(I_{\tau_1}^{IF\zeta}(A)}$.

(iv) For each pair of a τ_1-increasing τ_2-increasing $IF\zeta OS$ A and τ_1-decreasing $IF\zeta OS$ B in $(X,\tau_1,\tau_2\leq)$ with $\overline{I_{\tau_2}^{IF\zeta}(A)} = B$, $D_{\tau_2}^{IF\zeta}(B) = \overline{I_{\tau_2}^{IF\zeta}(A)}$. Similarly, for each pair of a τ_2-increasing $IF\zeta OS$ A and τ_2-decreasing $IF\zeta OS$ B in $(X,\tau_1,\tau_2\leq)$ with $\overline{I_{\tau_1}^{IF\zeta}(A)} = B$, $D_{\tau_1}^{IF\zeta}(B) = \overline{I_{\tau_1}^{IF\zeta}(A)}$.

Proposition 3.13. Let $(X,\tau_1,\tau_2\leq)$ be an ordered IF bitopological space. Then $(X,\tau_1,\tau_2\leq)$ is pairwise ordered $IF\zeta-$*extremally disconnected* space if and only if for a τ_1-decreasing $IF\zeta OS$ A and τ_2-decreasing $IF\zeta CS$ B such that $A\subseteq B$, we have $D_{\tau_1}^{IF\zeta}(A)\subseteq D_{\tau_1}^{0IF\zeta}(B)$.

Notation 3.14. An ordered IFS which is both decreasing (resp. increasing) $IF\zeta OS$ and $IF\zeta CS$ is called a decreasing (resp.increasing) $IF\zeta COS$.

Remark 3.15. Let $(X,\tau_1,\tau_2\leq)$ be a pairwise upper $IF\zeta-$*extremally disconnected* space. Let $\{A_i,\overline{B_i}/i\in N\}$ be a collection such that A_i's are τ_1-decreasing $IF\zeta OS$, B_i's are τ_2-decreasing $IF\zeta CS$ and let $A,\overline{B}$ be τ_1-decreasing $IF\zeta OS$ and T_2-increasing $IF\zeta OS$ respectively. If $A_i\subseteq A\subseteq B_j$ and $A_i\subseteq B\subseteq B_j$ for all $i,j\in N$, then there exists a τ_1 and τ_2-decreasing $IF\zeta COS$ C such that $D_{\tau_1}^{IF\zeta}(A_i)\subseteq C\subseteq D_{\tau_1}^{0IF\zeta}(B_j)$ for all $i,j\in N$.

Proposition 3.16. Let $(X,\tau_1,\tau_2\leq)$ be a pairwise ordered $IF\zeta-$*extremally disconnected* space. Let $(A_q)_{q\in Q}$ and $(B_q)_{q\in Q}$ be the monotone increasing collections of τ_1-decreasing $IF\zeta OS$ and τ_2-decreasing $IF\zeta CS$ of $(X,\tau_1,\tau_2\leq)$ respectively and suppose that $A_{q_1}\subseteq B_{q_2}$ whenever $q_1<q_2$ (Q is the set of rational numbers). Then there exists a monotone increasing collection $(C_q)_{q\in Q}$ of τ_1 and τ_2-decreasing $IF\zeta COS$ of $(X,\tau_1,\tau_2\leq)$ such that $D_{\tau_1}^{IF\zeta}(A_{q_1})\subseteq C_{q_2}$ and $C_{q_1}\subseteq D_{\tau_1}^{0IF\zeta}(B_{q_2})$ whenever $q_1<q_2$.

Definition 3.17. An intuitionistic fuzzy real line is the set of all monotone decreasing IFS $A\in\zeta_R$ satisfying $\bigcup\{A(t):t\in\Re\}=1_\sim$ and $\bigcap\{A(t):t\in\Re\}=0_\sim$ after the identification of an IFSs $A,B\in\Re\ (I)$ if and only if A(t-)=B(t-) and A(t+)=B(t+) for all $t\in\Re$ where $A(t-)=\bigcap\{A(s):s<t\}$ and $A(t+)=\bigcup\{A(s):s>t\}$.

The intuitionistic fuzzy unit interval $I(I)$ is a subset of $\Re(I)$ such that $[A]\in I(I)$ if the membership and nonmembership of an IFS line $\Re(I)$ $A \in \zeta_R$ are defined by

$$\mu_A(t) = \begin{cases} 1, t < 0 \\ 0, t > 1 \end{cases} \quad \text{and} \quad \upsilon_A(t) = \begin{cases} 0, t < 0 \\ 1, t > 1 \end{cases}$$

respectively.

The natural intuitionistic fuzzy topology on $\Re(I)$ is generated from the subbasis $\{L_t, R_t : s < t\}$ where $\mathrm{Lt}, \mathrm{Rt} : \Re(\mathrm{I}) \to \mathrm{I}(\mathrm{I})$ are given by $L_t[A] = \overline{A(t-)}$ and $R_t[A] = A(t+)$ respectively.

Definition 3.18. Let $(X, \tau_1, \tau_2 \leq)$ be an ordered IF bitopological space. A function $f : X \to \Re(I)$ is said to be lower (resp. upper) intuitionistic fuzzy ζ continuous function if $f^{-1}(\Re_t)(f^{-1}(L_t))$ is an $IF\zeta OS$ set, for each

Notation 3.19. Let X be any nonempty set and $A \in \zeta^X$. Then for $x \in X$, $<\mu_A(x), \upsilon_A(x)>$ is denoted by A~.

Proposition 3.20. Let $(X, \tau_1, \tau_2 \leq)$ be an ordered IF bitopological space , $A \in \zeta^X$ be an $\tau_1 -$IFS, and let $f : X \to \Re(I)$ be such that

$$f(x)(t) = \begin{cases} 1^{\sim}, t < 0 \\ A^{\sim}, 0 \leq t \leq 1 \\ 0^{\sim}, t > 1 \end{cases} \text{ for all } x \in X \text{ and } t \in \Re.$$

Then f is $\tau_1 -$ lower(resp.upper) intuitionistic fuzzy ζ continuous function if and only if A is an $\tau_1 -$increasing or $\tau_1 -$decreasing $IF\zeta OS$.

Definition 3.21. Let $(X, \tau_1, \tau_2 \leq)$ be an ordered IF bitopological space. The characteristic function of IFS A in X is the function $\chi_A : X \to I(I)$ defined by

$\chi_A(x) = A^{\sim}$, $x \in X$.

Proposition 3.22. Let $(X, \tau_1, \tau_2 \leq)$ be an IFTS and let $A \in \zeta^X$ be an $\tau_1 -$IFS. Then χ_A is $\tau_1 -$lower (resp. $\tau_1 -$upper) continuous if and only if A is an $\tau_1 -$increasing or $\tau_1 -$decreasing $IF\zeta OS$.

Proof. The proof follows from Proposition 4.1.

Definition 3.23. Let $(X, \tau_1, \tau_2 \leq)$ and $(Y, \kappa_1, \kappa_2 \leq)$ be ordered IF bitopological spaces. A function $f : (X, \tau_1, \tau_2) \to (Y, \kappa_1, \kappa_2)$ is called $\tau_1 -$increasing (resp. $\tau_1 -$decreasing) intuitionistic fuzzy strongly ζ continuous (in short, $\tau_1 -$increasing(resp. $\tau_1 -$decreasing)IFstrongly strongly ζ continuous) if $f^{-1}(A)$ is $\tau_1 -$increasing (resp. $\tau_1 -$decreasing) IF ζ clopen in $(X, \tau_1, \tau_2 \leq)$ for every S1 and S2 $IF\zeta OS$ in $(Y, \kappa_1, \kappa_2 \leq)$. If f is both $\tau_1 -$increasing and $\tau_1 -$decreasing IFstrongly ζ continuous, then it is called ordered $\tau_1 -$IF strongly ζ continuous.

Proposition 3.24. Let $(X, \tau_1, \tau_2 \leq)$ be an ordered IF bitopological space. Then the following statements are equivalent.

(i) $(X, \tau_1, \tau_2 \leq)$ is pairwise ordered $IF\zeta -$*extremally disconnected* .

(ii) If $g, h : X \to R(I)$, g is $\tau_1 -$lower IF ζ continuous function, h is $\tau_2 -$upper IF ζ continuous function and $g \subseteq h$, then there exists an τ_1 and τ_2 increasing IF strongly ζ continuous function, $f : (X, \tau_1, \tau_2, \leq) \to R(I)$ such that $g \subseteq f \subseteq h$.

(iii) If $\overline{A}$ is $\tau_2 -$ increasing $IF\zeta OS$ and B is $\tau_1 -$decreasing $IF\zeta OS$ such that $B \subseteq A$, then there exists an τ_1 and $\tau_2 -$ increasing IF strongly ζ continuous function $f : (X, \tau_1, \tau_2, \leq) \to I(I)$ such that $B \subseteq f^{-1}(\overline{L_1}) \subseteq f^{-1}(R_0) \subseteq A$.

4. TIETZE EXTENSION THEOREM FOR PAIRWISE ORDERED INTUITIONISTIC FUZZY ζ –EXTREMALLY DISCONNECTED SPACE

Notation 4.1. Let $(X, \tau_1, \tau_2 \leq)$ be an ordered IF bitopological space and $A \subset X$. Then an IFS ψ^*_A is of the form $< x, \psi_A(x), 1 - \psi_A(x) >$.

Proposition 4.2. Let $(X, \tau_1, \tau_2 \leq)$ be a pairwise ordered intuitionistic fuzzy ζ extremally disconnected space and let $A \subset X$ such that ψ^*_A is τ_1 and $\tau_2 -$ increasing $IF\zeta OS$ in $(X, \tau_1, \tau_2 \leq)$. Let $f : (A, \tau_1 / A, \tau_2 / A) \to I(I)$ be τ_1 and $\tau_2 -$ increasing IF strongly ζ continuous function. Then f has an τ_1 and $\tau_2 -$ increasing IF strongly ζ continuous extension over (X, ζ).

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