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ALEKSANDROV URYSOHN COMPACTNESS CRITERION ON INTUITIONISTIC FUZZY $S*$ STRUCTURE SPACE

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Abstract

In this paper, the intuitionistic fuzzy S^* maximal compact extension $\beta(S)$ (Cech extension) of an arbitrary intuitionistic fuzzy S^* completely regular space using the method of intuitionistic fuzzy S^* centred systems and the Aleksandrov Urysohn compactness criterion on intuitionistic fuzzy $S*$ structure space has been studied and discussed as in [8].

Key words

Intuitionistic fuzzy $S*$ structure space $(S, S*)$, intuitionistic fuzzy $S*$ centred system, a maximal intuitionistic fuzzy $S*$ centred system, intuitionistic fuzzy $S*H$-closed, intuitionistic fuzzy $S*$ compact, intuitionistic fuzzy S^* completely regular space, intuitionistic fuzzy S^* maximal compact extension $\beta(S)$.

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1.Introduction

After the introduction of the concept of fuzzy sets by Zadeh [11], several researches were conducted on the generalizations of the notion of fuzzy set. The concept of "Intuitionistic fuzzy sets" was first published by Atanassov [1] and many works by the same author and his colleagues appeared in the literature [2-4]. Later this concept was generalized to "Intuitionistic L-fuzzy sets" by Atanassov and stoeva [5]. An introduction to intuitionistic fuzzy topological space was introduced by Dogan Coker [6]. Fuzzy continuity in intuitionistic fuzzy topological spaces was introduced by Gurcay. H, Coker, D., and Haydar, Es. A., [7]. The method of centered system in the theory of topological spaces was introduced by Iliadis. S, Fomin.S [8]. The method of centered system in fuzzy topological spaces was introduced by M.K.Uma, E.Roja and Balasubramanian.G [10]. In this paper, the intuitionistic fuzzy S^* maximal compact extension $\beta(S)$ (Cech extension) of an arbitrary intuitionistic fuzzy S^* completely regular space using the method of intuitionistic fuzzy S^* centred systems and the Aleksandrov Urysohn compactness criterion on intuitionistic fuzzy S^* structure space has been studied and discussed as in [8]. Some interesting properties and characterizations are studied.

2.Preliminaries

Definition 2.1[3] Let X be a non empty fixed set. An intuitionistic fuzzy set (*IFS* for short) A is an object having the form $A=\{\langle x,\mu_A(x),\gamma_A(x)\rangle : x\in X\}$ where the functions $\mu_A : X\to I$ and $\gamma_A : X\to I$ denote the degree of membership (namely $\mu_A(x)$) and the degree of non membership (namely $\gamma_A(x)$) of each element $x\in X$ to the set A, respectively, and $0\le\mu_A(x)+\gamma_A(x)\le 1$ for each $x\in X$.

Remark 2.1[6] For the sake of simplicity, we shall use the symbol $A=\langle x,\mu_A,\gamma_A\rangle$.

Definition 2.2[6] Let X be a non empty set and let $\{A_i : i\in J\}$ be an arbitrary family of *IFSs* in X . Then (a) $\bigcap A_i=\{\langle x,\wedge\mu_{A_i}(x),\vee\gamma_{A_i}(x)\rangle : x\in X\}$;

(b) $\bigcup A_i=\{\langle x,\vee\mu_{A_i}(x),\wedge\gamma_{A_i}(x)\rangle : x\in X\}$.

Definition 2.3[6] Let X be a non empty fixed set. Then, $0_\sim=\{\langle x,0,1\rangle : x\in X\}$ and $1_\sim=\{\langle x,1,0\rangle : x\in X\}$.

Definition 2.4[6] Let X and Y be two non empty fixed sets and $f : X\to Y$ be a function. Then

(a) If $B=\{\langle y,\mu_B(y),\gamma_B(y)\rangle : y\in Y\}$ is an *IFS* in *Y*, then the pre image of B under f, denoted by $f^{-1}(B)$, is the *IFS* in X defined by $f^{-1}(B)=\{\langle x, f^{-1}(\mu_B)(x), f^{-1}(\gamma_B)(x)\rangle : x\in X\}$.

(b) If $A=\{\langle x,\lambda_A(x),\nu_A(x)\rangle : x\in X\}$ is an *IFS* in X , then the image of A under f, denoted by $f(A)$, is the *IFS* in *Y* defined by

$f(A)=\{\langle y, f(\lambda_A)(y),(1-f(1-\nu_A))(y)\rangle : y\in Y\}$ where,

$$f(\lambda_A)(y)=\begin{cases}\sup\limits_{x\in f^{-1}(y)}\lambda_A(x) & if \quad f^{-1}(y)\neq 0\\ 0, & otherwise,\end{cases}$$

$$(1-f(1-\nu_A))(y)=\begin{cases}\inf\limits_{x\in f^{-1}(y)}\nu_A(x) & if \quad f^{-1}(y)\neq 0\\ 1, & otherwise.\end{cases}$$

for the *IFS* $A=\{\langle x,\mu_A(x),\gamma_A(x)\rangle : x\in X\}$.

Definition 2.5[6] Let X be a non empty set. An intuitionistic fuzzy topology (*IFT* for short) on a non empty set X is a family τ of intuitionistic fuzzy sets (*IFSs* for short) in X satisfying the following axioms: (T_1) $0_\sim, 1_\sim \in \tau$, (T_2) $G_1 \cap G_2 \in \tau$ for any $G_1, G_2 \in \tau$, (T_3) $\bigcup\limits_{\subseteq \tau} G_i \in \tau$ for any arbitrary family $\{G_i : i \in J\}$.

In this case the pair (X, τ) is called an intuitionistic fuzzy topological space (*IFTS* for short) and any *IFS* in τ is known as an intuitionistic fuzzy open set (*IFOS* for short) in X.

Definition 2.6[6] Let X be a non empty set. The complement $\overline{A}$ of an *IFOS* A in an *IFTS* (X, τ) is called an intuitionistic fuzzy closed set (*IFCS* for short) in X.

Definition 2.7[6] Let (X, τ) be an *IFTS* and $A = \langle x, \mu_A, \gamma_A \rangle$ be an *IFS* in X. Then the fuzzy interior and fuzzy closure of A are defined by

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

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

Remark 2.2[6] Let (X, τ) be an *IFTS*. $cl(A)$ is an *IFCS* and $\text{int}(A)$ is an *IFOS* in X, and (a) A is an *IFCS* in X iff $cl(A) = A$; (b) A is an *IFOS* in X iff $\text{int}(A) = A$.

Proposition 2.1[6] Let (X, τ) be an *IFTS*. For any *IFS* A in (X, τ), we have

(a) $cl(\overline{A}) = \overline{\text{int}(A)}$, (b) $\text{int}(\overline{A}) = \overline{cl(A)}$.

Definition 2.8[6] Let (X, τ) and (Y, φ) be two *IFTSs* and let $f : X \to Y$ be a function. Then f is said to be fuzzy continuous iff the pre image of each *IFS* in ϕ is an *IFS* in τ.

Definition 2.9[6] Let (X, τ) and (Y, φ) be two *IFTSs* and let $f : X \to Y$ be a function. Then f is said to be fuzzy open(resp.closed) iff the image of each *IFS* in τ (resp.(1- τ)) is an *IFS* in ϕ (resp.(1-ϕ)).

Definition 2.10[9] A fuzzy topological space (X, T) is called fuzzy Hausdorff space iff for any two distinct fuzzy points $p, q \in X$, there exists $U, V \in T$ such that $U \cap V = 0$ with $p \in U$ and $q \in V$.

Definition 2.11[10] Let R be a fuzzy Hausdorff space. A system $p = \{U_\alpha\}$ of fuzzy open sets of R is called fuzzy centred if any finite collection of the sets of the system has a non empty intersection. The system p is called a maximal fuzzy centred system or a fuzzy end if it cannot be included in any larger fuzzy centred system of fuzzy open sets.

Definition 2.12[8] An centred system $p = \{U\}$ of open sets of R is called completely regular if for any $U \in p$ there exists a $V \in p$ and an continuous function f on R such that $f(r) = 1$ for $r \in R \setminus U$, $f(r) = 0$ for $r \in V$ and $0 \le f(r) \le 1$ for any $r \in R$. In this case V is completely regular in U. A completely regular system is called completely regular end if it is not contained in any larger completely regular system.

Definition 2.13[8] A Hausdorff space $\delta(R)$ is called an extension of a Hausdorff space R if R is contained in $\delta(R)$ as an everywhere dense subset. R is called H - closed if every extension coincides with R itself. An extension $\delta(R)$ is called H-closed if $\delta(R)$ is H- closed and compact if $\delta(R)$ is compact.

3. CONSTRUCTION OF THE CECH EXTENSION BY MEANS OF CENTRED SYSTEMS.

In this section, the intuitionistic fuzzy S^* maximal compact extension $\beta(S)$ (Cech extension) of an arbitrary intuitionistic fuzzy S^* completely regular space has been constructed by using the method of intuitionistic fuzzy S^* centred systems. Some of its properties and characterizations are discussed.

Definition 3.1 Let X be a non empty set. Let S be a collection of all intuitionistic fuzzy sets of X. An intuitionistic fuzzy S^* structure on S is a collection S^* of subsets of S having the following properties

(a) ϕ and S are in S^*.

(b) The union of the elements of any sub collection of S^* is in S^*.

(c) The intersection of the elements of any finite sub collection of S^* is in S^*.

The collection S together with the structure S^* is called intuitionistic fuzzy S^* structure space. A subset U of S is an intuitionistic fuzzy S^* open set if $U \in S^*$. Its complement is said to be an intuitionistic fuzzy S^* closed set.

Definition 3.2 Let A be a member of S. An intuitionistic fuzzy S^* open set U in (S,S^*) is said to be an intuitionistic fuzzy S^* neighbourhood of A if $A \in G \subset U$ for some intuitionistic fuzzy S^* open set G in (S,S^*).

Definition3.3 Let (S,S^*) be an intuitionistic fuzzy S^* structure space and $A = \langle x, \mu_A, \gamma_A \rangle$ be an intuitionistic fuzzy set in X. Then the intuitionistic fuzzy S^* closure and intuitionistic fuzzy S^* interior of A are respectively defined and denoted by

$$IF\,S^*cl(A) = \bigcap\{ K : K \text{ is an intuitionistic fuzzy } S^* \text{closed sets in } S \text{ and } A \subseteq K\},$$

$$IF\,S^*\operatorname{int}(A) = \bigcup\{ G : G \text{ is an intuitionistic fuzzy } S^* \text{open sets in S and } G \subseteq A\}.$$

Definition 3.4 The ordered pair (S,S^*) is called an intuitionistic fuzzy S^* Hausdorff space if for each pair A_1, A_2 of disjoint members of S, there exist disjoint intuitionistic fuzzy S^* open sets U_1 and U_2 such that $A_1 \subseteq U_1$ and $A_2 \subseteq U_2$.

Definition 3.5 Let (S_1, S_1^*) and (S_2, S_2^*) be any two intuitionistic fuzzy S^* structure spaces and let $f:(S_1,S_1^*) \to (S_2,S_2^*)$ be a function. Then f is said to be an intuitionistic fuzzy S^* continuous iff the pre image of each intuitionistic fuzzy S_2^* open set in (S_2,S_2^*) is an intuitionistic fuzzy S_1^* open set in (S_1,S_1^*).

Definition 3.6 Let (S_1,S_1^*) and (S_2,S_2^*) be two intuitionistic fuzzy S^* structure spaces and let $f:(S_1,S_1^*) \to (S_2,S_2^*)$ be a bijection function. If both the function f and the inverse function $f^{-1}:(S_2,S_2^*) \to (S_1,S_1^*)$ are intuitionistic fuzzy S^* continuous, then f is called a intuitionistic fuzzy S^* homeomorphism.

Note 3.1 Throughout this paper let $U_\alpha : \alpha = 1, 2, 3, \ldots .n$ be an intuitionistic fuzzy $S*$ open set in $\boldsymbol{(S, S*)}$.

Definition 3.7 Let $(S, S*)$ be an intuitionistic fuzzy $S*$ Hausdorff space. A system $p = \{U_\alpha : \alpha = 1, 2, 3, \ldots .n\}$ of intuitionistic fuzzy $S*$ open sets is called an intuitionistic fuzzy $S*$ centred system if any finite collection of the sets of the system has a non empty intersection. The intuitionistic fuzzy $S*$ centred system p is called a maximal intuitionistic fuzzy $S*$ centred system or an intuitionistic fuzzy $S*$ end if it cannot be included in any larger intuitionistic fuzzy $S*$ centred system of intuitionistic fuzzy $S*$ open sets.

Note 3.2 Throughout this chapter let $U_\alpha : \alpha = 1, 2, 3, \ldots .n$ be an intuitionistic fuzzy $S*$ open set in $\boldsymbol{(S, S*)}$.

Proposition 3.1 Let $(S, S*)$ be an intuitionistic fuzzy $S*$ Hausdorff space and $p = \{U_\alpha\}$ is an intuitionistic fuzzy $S*$ centred system in $\boldsymbol{(S, S*)}$. Then the following properties hold

1. If $U_i \in p \quad (i = 1, 2, \ldots n)$, then $\bigcap_{i=1}^{n} U_i \in p.$
2. If $\phi \neq U \subseteq H,\ U \in p$ and H is intuitionistic fuzzy $S*$ open set, then $H \in p$.
3. If H is an intuitionistic fuzzy $S*$ open set, then $H \notin p$ iff there exists $U \in p$ such that $U \cap H = \phi.$
4. If $U_1 \bigcup U_2 = U_3 \in p$, U_1 and U_2 are intuitionistic fuzzy $S*$ open sets and $U_1 \bigcap U_2 = \phi,$ then either $U_1 \in p$ or $U_2 \in p.$
5. If $IFS*cl(U) = S,$ then $\phi \neq U \in p$ for any intuitionistic fuzzy $S*$ end *p*.

Definition 3.8 Let $\theta(S)$ denote the collection of all intuitionistic fuzzy $S*$ ends belonging to $S.$ An intuitionistic fuzzy $S*$ topology is introduced into $\theta(S)$ in the following way. Let O_U be the set of all intuitionistic fuzzy $S*$ ends that contains U as an element, where U is an intuitionistic fuzzy $S*$ open set of $S.$ Therefore O_U is an intuitionistic fuzzy $S*$ neighbourhood of each intuitionistic fuzzy $S*$ end contained in O_U .

Definition 3.9 A subset *A* of an intuitionistic fuzzy $S*$ structure space $(S, S*)$ is said to be an everywhere intuitionistic fuzzy $S*$ dense subset in $(S, S*)$ if $IFS{*}cl(A) = S.$

A subset of an intuitionistic fuzzy $S*$ structure space $(S, S*)$ is said to be an nowhere intuitionistic fuzzy $S*$ dense subset in $(S, S*)$ if $X \setminus \overline{A}$ is everywhere intuitionistic fuzzy $S*$ dense subset.

Definition 3.10 Let (S,S^*) be an intuitionistic fuzzy S^* structure space and *Y* be an intuitionistic fuzzy S^* open set in (S,S^*). Then the intuitionistic fuzzy S^* relative topology $T_Y=\{G\bigcap Y : G\in S^*\}$ is called the intuitionistic fuzzy S^* relative (or induced or subspace) topology on *Y*. The ordered pair (Y,T_Y) is called an intuitionistic fuzzy S^* subspace of the intuitionistic fuzzy S^* space (S,S^*).

Definition 3.11 Let (S,S^*) be an intuitionistic fuzzy S^* structure space. Then

(a) If a family $\{U_\alpha : i\in\Lambda\}$ of intuitionistic fuzzy S^* open sets in (S,S^*) satisfies the condition $S=\bigcup\{U_\alpha : i\in\Lambda\}$, then it is called an intuitionistic fuzzy S^* open cover of *S*. A finite subfamily of the intuitionistic fuzzy S^* open cover $\{U_\alpha : i\in\Lambda\}$ of *S*, which is also an intuitionistic fuzzy S^* open cover of *S*, is called a finite subcover of $\{U_\alpha : i\in\Lambda\}$.

(b) An intuitionistic fuzzy S^* structure space (S,S^*) is called intuitionistic fuzzy S^* compact iff every intuitionistic fuzzy S^* open cover of S has a finite subcover.

Definition 3.12 An intuitionistic fuzzy S^* Hausdorff space $\delta(S)$ is called an extension of an intuitionistic fuzzy S^* Hausdorff space S if S is contained in $\delta(S)$ as an everywhere intuitionistic fuzzy S^* dense subset. S is called an intuitionistic fuzzy S^*H -closed if every extension coincides with S itself. An extension $\delta(S)$ is called an intuitionistic fuzzy S^*H -closed if $\delta(S)$ is an intuitionistic fuzzy S^*H -closed and an intuitionistic fuzzy S^* compact if $\delta(S)$ is an intuitionistic fuzzy S^* compact.

Definition 3.13 Let (S,S^*) be an intuitionistic fuzzy S^* structure space. A system $\mathcal{B}$ of intuitionistic fuzzy S^* open sets of an intuitionistic fuzzy S^* structure space S is called an intuitionistic fuzzy S^* base(or basis) for (S,S^*) if each member of (S,S^*) is a union of members of $\mathcal{B}$. A member of $\mathcal{B}$ is called an intuitionistic fuzzy S^* basic open set.

Definition 3.14 Let (S,S^*) be an intuitionistic fuzzy S^* structure space. A system of intuitionistic fuzzy S^* open sets of an intuitionistic fuzzy S^* structure space S is called an intuitionistic fuzzy S^* sub-base if it together with all possible finite intersections of members of the system forms a base of S .

Definition 3.15 Let $\left(S_1,S_1^*\right)$ and $\left(S_2,S_2^*\right)$ be two intuitionistic fuzzy S^* structure spaces. An intuitionistic fuzzy S^* structure space $\left(S_1,S_1^*\right)$ is said to be topologically embedded in another intuitionistic fuzzy S^* structure space $\left(S_2,S_2^*\right)$ if $\left(S_1,S_1^*\right)$ is an intuitionistic fuzzy S^* homeomorphism to an intuitionistic fuzzy S^* subspace of $\left(S_2,S_2^*\right)$.

Definition 3.16 An intuitionistic fuzzy S^* centred system $p=\{U_\alpha\}$ of intuitionistic fuzzy S^* open sets of S is called intuitionistic fuzzy S^* completely regular system if for any $U_\alpha\in p$ there exists a $V_\alpha\in p$ and an intuitionistic fuzzy S^* continuous function f on S such that $f(A)=1$ for

$A \in S \setminus U_\alpha$, $f(A) = 0$ for $A \in V_\alpha$ and $0 \le f(A) \le 1$ for any $A \in S$. In this case V_α is intuitionistic fuzzy S^* completely regularly contained in U_α.

Definition 3.17 An intuitionistic fuzzy S^* completely regular system is called an intuitionistic fuzzy S^* completely regular end if it is not contained in any larger intuitionistic fuzzy S^* completely regular system.

The absolute $w(S)$ of intuitionistic fuzzy S^* structure space

The maximal intuitionistic fuzzy S^* centred systems of intuitionistic fuzzy S^* open sets (intuitionistic fuzzy S^* ends), regarded as elements of the intuitionistic fuzzy S^* space $\theta(S)$, fall into two classes: those intuitionistic fuzzy S^* ends each of which contains all the intuitionistic fuzzy S^* neighbourhoods of one (and obviously only one) member of S, and the intuitionistic fuzzy S^* ends not containing such systems of intuitionistic fuzzy S^* neighbourhoods. The intuitionistic fuzzy S^* ends of the first type can be regarded as representing the members of the original intuitionistic fuzzy S^* space S, and those of the second type as corresponding to "holes" in S. The collection of all the intuitionistic fuzzy S^* ends of the first type in $\theta(S)$, an intuitionistic fuzzy S^* completely regular space and it is also called the intuitionistic fuzzy S^* absolute of S which is denoted by $w(S)$. In $w(S)$, each member $V \in S$ is represented by intuitionistic fuzzy S^* ends containing all intuitionistic fuzzy S^* neighbourhoods of S. It is obvious that $w(S) = \bigcup_{V \in S} B(V)$, where $B(V)$ are the intuitionistic fuzzy S^* ends *p* of *S* that contain all the intuitionistic fuzzy S^* neighbourhoods of *V*. The subset $w(S)$ is mapped in a natural way onto S. If $p \in w(S)$, then by definition $\pi_S(p) = V$, where V is the member whose intuitionistic fuzzy S^* neighbourhoods all belong to p and π_S the natural function of $w(S)$ onto S.

Lemma 3.1 An intuitionistic fuzzy S^* system $\{U_\alpha\}$ of all intuitionistic fuzzy S^* neighbourhoods of a member A in an intuitionistic fuzzy S^* completely regular space S is an intuitionistic fuzzy S^* completely regular end.

Now we construct an intuitionistic fuzzy S^* structure space which is denoted by $\alpha'(S)$. Its members are all intuitionistic fuzzy S^* completely regular ends of S, and its intuitionistic fuzzy S^* topology is defined as follows: Choose an arbitrary intuitionistic fuzzy S^* open set U in S and the collection O_U of all intuitionistic fuzzy S^* centred completely regular ends of S that contain U as a member is to be an intuitionistic fuzzy S^* neighbourhood of each of them.

Lemma 3.2 An intuitionistic fuzzy S^* completely regular end $p = \{U_\alpha\}$ of an intuitionistic fuzzy S^* structure space S has the following properties:

(a) if $U_\beta \supseteq U_\alpha \in p$, then $U_\beta \in p$;

(b) the intersection of any finite number of members of p belongs to p.

Corollary 3.1 $O_U \cap O_V = O_{U \cap V}$

Lemma 3.3 $\alpha'(S)$ is an intuitionistic fuzzy S^* Hausdorff extension of S.

Note 3.3 In an intuitionistic fuzzy S^* completely regular space the intuitionistic fuzzy S^* canonical neighbourhoods form a base.

Lemma 3.4 An intuitionistic fuzzy S^* structure space $\alpha'(S)$ can be continuously mapped onto every intuitionistic fuzzy S^* compact extension of S in such a way that the members of S remain fixed.

Lemma 3.5 The intuitionistic fuzzy S^* structure space $\alpha'(S)$ is intuitionistic fuzzy S^* completely regular space.

Lemma 3.6 The intuitionistic fuzzy S^* structure space $\alpha'(S)$ is intuitionistic fuzzy S^* compact.

Proposition 3.2 For any intuitionistic fuzzy S^* completely regular space S, the intuitionistic fuzzy S^* structure space $\alpha'(S)$ coincides with the Cech extension $\beta(S)$ up to an intuitionistic fuzzy S^* homeomorphism leaving the members of S fixed.

The proof of Proposition 3.2 follows immediately from Lemmas 3.4 and 3.6 and the uniqueness of an maximal intuitionistic fuzzy S^* compact extension.

4.THE ALEKSANDROV-URYSOHN COMPACTNESS CRITERION

In this section the concept of intuitionistic fuzzy S^* absolute is applied to establish the Aleksandrov-Uryson compactness criterion:

Definition 4.1 Let (S_1, S_1^*) and (S_2, S_2^*) be two intuitionistic fuzzy S^* structure spaces. An function $f:(S_1, S_1^*)\to(S_2, S_2^*)$ of an intuitionistic fuzzy S^* structure space (S_1, S_1^*) onto an intuitionistic fuzzy S^* structure space (S_2, S_2^*) is an intuitionistic fuzzy S^* quotient function (or intuitionistic fuzzy S^* natural function) if, whenever *V* is an intuitionistic fuzzy S_1^* open set of (S_2, S_2^*), $f^{-1}(V)$ is an intuitionistic fuzzy S_2^* open set in (S_1, S_1^*) and conversely.

Theorem 4.1 (Aleksandrov-Urysohn compactness criterion)

An intuitionistic fuzzy S^* Hausdorff space S is an intuitionistic fuzzy S^* compact space if and only if each of its intuitionistic fuzzy S^* closed subset is intuitionistic fuzzy S^*H -closed.

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