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SOME MORE RESULTS ON FUZZY CONTINUITY

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ABSTRACT

In this peice of work we define α^*-semicontinuous, $R\alpha$- semicontinuous and $R\alpha^*$-semicontinuous functions as a generalization of F-semicontinuous and F-irresolute functions. By these concepts and the concept of an α-continuous functions, we improve and generalize (in fuzzy setting) some results previously obtained by Malghan and Benchalli [11,12] and Sivaraj [17].

1. INTRODUCTION

In 1978, Gantner, et al. [9] introduced the concept of α-compact and strong locally α-compact fuzzy spaces. In 1979 Gameron [8] introduced for the first the concept of I-compact spaces. In 1980 and 1984, the concept of countably α-compact and locally α-compact fuzzy spaces were introduced by Malghan and Benchalli [11,12]. In 1986 and 1987 the concepts of α-continuity α-irresolute functions and S-closed spaces were introduced by Mashhour et al. [13,15].

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Theorem A [17]. If a function $f:X \longrightarrow Y$ is irresolute and $A \subset X$ is I-compact relative to X, then f(A) is αS-closed relative to Y.

Corollary B [17]. If a function $f:X \longrightarrow Y$ is irresolute, Y is an FED-space and $A \subset X$ is I-compact relative to X, then f(A) is I-compact relarive to Y.

Corollary C [17]. If a function $f:X \longrightarrow Y$ is semiopen and semicontinuous, Y is an ED-space and $A \subset X$ is I-compact relative to X, then f(A) is I-compact relative to Y.

Theorem D [11]. Let $f:X \longrightarrow Y$ be an F-continuous function. If X is countably α-compact, then f(X) is countably α-compact subspace Of Y.

Theorem E [11]. Let $f:X \longrightarrow Y$ be an F-continuous, F-open surjection. If X is locally α-compact, then Y is locally α-compact.

Corollary F [12]. Let f be an F-open, F-continous function from an fts X onto a 1*-Hausdorff fts Y such that Supp(Cl(A)) = Cl(Supp(A)) for each fuzzy open set A in Y. If X is strong locally α-compact, then so is Y.

Let S be a fuzzy subset of a fuzzy topological space (an fts, for short) (X,τ), we denote the closure of (resp. interior of S, semiclosure of S) with respect to τ by Cl(S) (resp. Int(S), Scl(S)). The family of all fuzzy semiopen (resp. fuzzy regular semiopen) sets in X are denoted by SO(X) (resp. RSO(X)).

Definition 1.1 . A fuzzy subset S of an fts X is called:

(i) fuzzy semiopen [2,5] if $S \leq Cl(Int(S))$,

(ii) fuzzy semiclosed [2,5] if $S \geq Int(Cl(S))$,

(iii) fuzzy preopen [7] if $S \leq Int(Cl(S))$,

(iv) fuzzy regular open [5] if $S = Int(Cl(S))$,

(v) fuzzy regular-semiopen [13] if there is a fuzzy regular open set U such that $U \leq S \leq Cl(U)$.

Definition 1.2 [16]. A fuzzy point x_r is said to be quasicoincident with A, denoted by $x_r qA$ if $r > A''(x) > 1$. A fuzzy set A is quasi-concident with a fuzzy set B or AqB if there is $x \quad X$, $A(x) + B(x) > 1$. A fuzzy set A in an fts (X, τ) is called a Q-neighbourhood of x_r iff there is $B \in \tau$ such that $x_r qB \leq A$.

Theorem 1.3. [16]. A fuzzy point $x_r \in Cl(A)$ iff each q-neighbourhood of x_r is quasi-coincident with A.

The following Propositions have been stated in [10].

Proposition 1.4. (i) If $A \wedge B = 0$, then $A \not{q} B$ (A is not quasi-coincident with B),

(ii) $A \leq B$ iff $x_r qB$ for each $x_r qA$,

(iii) $x_r \not{q} A$ iff $x_r \quad A''$ (A'' is the complement of A),

(iv) $A \not{q} B$ iff $A \leq B''$,

(v) $x_r q(\bigvee_{j \quad J} A_j)$ iff there is $j_o \quad J$ such that $x_r qA_{j_o}$

<u>Proposition 1.5</u>. Let (X, τ) be an fts and $V \in \tau$, then $VqA \Longleftrightarrow VqCl(A)$ for each fuzzy set A in X.

<u>Theorem 1.6</u>. [14]. A fuzzy point $x_r \in Scl(A)$ iff each fuzzy semiopen set U with $x_r qU$, UqA.

<u>Theorem 1.7</u> [12]. If $f: X \longrightarrow Y$ is a function from a set X into a set Y, A is a fuzzy subset in X and B is a fuzzy subset in Y, then

(i) $f(S(A)) = S(f(A))$, where S(A) means support of A.

(ii) $f^{-1}(S(B)) = S(f^{-1}(B))$.

<u>Definition 1.8.</u> Let $f: X \longrightarrow Y$ be a function from an fts X into an fts Y. Then f is called:

(i) F-continuous [6] if $f^{-1}(V)$ is fuzzy open in X for each fuzzy open set in Y,

(ii) F-open [6], if f(U) is fuzzy open in Y for each fuzzy open set U in X.

(iii) F-irresolute [14] if $f^{-1}(V)$ SO(X) for each V SO(Y).

(iv) F-semicontinuous [2,5] if $f^{-1}(V) \in SO(X)$ for each fuzzy open set V in Y.

(v) α-continuous [13], if for each $x \in X$ and for each fuzzy open set V in Y with $V(f(x)) > \alpha$, there is a fuzzy open set U in X with $U(x) > \alpha$ and $f(U) \leq V$, $0 \leq \alpha < i$.

(vi) α-semicontinous (resp. α-irresolute) [15], if for $x \in X$ and for each fuzzy open set V in Y (resp. $V \in SO(Y)$) with $V(f(x)) > \alpha$, there is $U \in SO(X)$ with $U(x) > \alpha$ and $f(U) \leq V$.

Definition 1.9. [9]. Let X be an fts and $\alpha \in [0,1]$. A collection ν of fuzzy sets is called α-shading of X if for each $x \in X$, there is $U \in \nu$ with $U(x) > \alpha$. A subcollection of an α-shading ν which is also an α-shading is called an α-subshading of ν.

Definition 1.10. An fts X is called;

(i) Countably α-compact [11], if every countable open α-shading of X has a finite α-subshading.

(ii) α-compact [9] (resp. α-almost compact [1]) if every open α-shading of X has a finite α-subshading (resp. has a finite subfamily the closure of whose members are an α-shading of X).

(iii) Locally α-compact [12] (resp. strong locally α-compact [9]) if for each $x \in X$, there is a neighbourhood U of x (resp. an open neighbourhood) of x such that $U(x) = 1$ and $S(U)$(resp. $S(Cl(U))$) is α-compact.

(iv) α S-closed [13] (resp. α I-compact [4]) if for each semiopen α-shading of X. there is a finite subfamily the closure (resp. the interior of the closure) of whose members are an α-shading of X.

Definition 1.11. A fuzzy subset A of an fts X is called:

(i) α S-closed [3] (resp. α I-compact [4]) relative to X if for each α-shading of $S(A)$ by fuzzy semiopen sets of X; there is a finite subfamily the closure (resp. the interior of the closure) of whose members are an α-shading of S(A).

(ii) α-almost compact relative to X if for each α-shading of S(A) by fuzzy open set of X, there is a finite subfamily the closure of whose members are an shading of S(A).

Definition 1.12. [13]. An fts X is called fuzzy extremely disconnected space (an FED-space, for short) if the closure of each fuzzy open set in X is fuzzy open in X.

2. α*-semicontinuity Rα*-semicontinuity and αI-compactness.

Definition 2.1. Let $f:(X,\tau) \longrightarrow (Y,\theta)$ be a function from an fts (X,τ) to an fts (Y,θ) . For $0 \leq \alpha < 1$, f is called:

(i) α*-semicontinuous if for each $x \in X$ and for each $V \in \theta$, with $V(f(x)) > \alpha$, there is $U \in SO(X)$ such that $U(x) > \alpha$ and $f(Int(Cl(U)) \leq 1$ (V).

(ii) Rα-semicontinuous (resp. Rα*-semicontinuous) if for each $x \in X$ and for each $V \in RSO(Y)$ with $V(f(x)) > \alpha$, there is $U \in SO(X)$ such that $U(x) > \alpha$ and $f(U) \leq V$ (resp. $f(Int(Scl(U))) \leq Scl(V)$).

Remark 2.2. It is clear that an F-semicontinuous (resp. F-irresolute) function is an α*-semicontinuous (resp. Rα-semicontinuous and Rα*-semicontinuous) function. That the converses need not be true as shown by Examples 2.3 and 2.4, below.

Example 2.3. Let $X=\{a,b\}$, U_1, U_2 and U_3 be fuzzy subsets of X defined as

$U_1(a) = 0.6$ $\qquad$ $U_1(b) = 0.55,$

$U_2(a) = 0.4$ $\qquad$ $U_2(b) = 0.30,$

$U_3(a) = 0.7$ $\qquad$ $U_3(b) = 0.8.$

Consider the following fuzzy topologies $=\{0,U_1,1\}$ & $\theta=\{0,U_2,U_3,1$ on X and the function $i:(X,\tau) \longrightarrow (X,\theta)$ defined by $i(x)=x$ for each $V_j(a) = r_j \geq 0.6$, $V_j(b)= S_j \geq 0.55$; it is obvious that i is α^*-semicontinous which is not F-semicontinuous when $0.4 < \alpha < 0.5$.

<u>Example 2.4.</u> Let $X = \{a , b\}$, V_1, V_2 and V_3 be fuzzy substs of X defined as

$V_1(a) = 0.45$ $\qquad$ $V_1 (b) = 0.51$

$V_2(a) = 0.4$ $\qquad$ $V_2 (b) = 0.45$

$V_3(a) = 0.6$ $\qquad$ $V_3 (b) = 0.5$

Consider the fuzzy topologies $\tau = \{0, V_1, 1\}$ and $\theta = \{o,V_2, V_3$ on X and the function $i : (X , \tau) \longrightarrow (Y , \theta)$ defined by $i(x) = x$ for each $x \in X$. It is clear that all fuzzy semiopen sets in τ are U_j where $U_j(a) = r_j \geq 0.45$, $U_j(b) = S_j \geq 0.51$. Also, the only fuzzy regular semiopen sets in θ are H_j and

M_j where $H_j(a) = 0.4$, $0.45 \leq H_j(b) \leq 0.5$, $M_j(a) = 0.6$ and $0.5 \leq M_j(b) \leq 0.55$. It is obvious that i is R_α-semicontinuous and R_α* - semicontinuous but not F-irresolute when $\alpha = 0.53$.

<u>Lemma 2.5.</u> Let X be an fts and U be a fuzzy subset of X, then $Int(Cl(U)) \leq Scl(U)$.

<u>Proof</u>: Let $x_r \notin Scl(U)$, then there is $V \in So(X)$ with $x_r qV$ such that $V \not q U$ and hence $Int(V) \not q U$. By Proposition 1.5. $Int(V) \not q Cl(U)$ and hence $Cl(Int(V)) \not q Int(Cl(U))$. By Proposition 1.4, $Cl(Int(V)) \leq 1 - Int(Cl(U))$. Since V SO(X) and $x_r qV$, then $x_r q Cl(Int(V))$ and hence $x_r q\ (i - Int(Cl(U)))$. By Proposition 1.4, $x_r \notin Int(Cl(U))$. This show that $Int(ClU)) \leq Scl(U)$.

<u>Lemma 2.6.</u> Let X be an fts,then $Scl(U) \leq Int(Cl(U))$ for each fuzzy preopen set U of X.

<u>Proof</u>: Let $x_r \notin Int(Cl(U))$, then $x_r q(1 - Int(Cl(U))$.Put $1 - Int(Cl(U)) = V \in SO(X)$. Then $x_r qV$. Since U is fuzzy preopen,

then $U < Int(Cl(U))$, which implies $U \not q (1-Int(Cl(U)) = V$. Hence, there is $V \in SO(X)$ with $x_r q V$ such that $V \not q U$. Then $x_r \notin Scl(U)$. This show that $Scl(U) \leq Int(Cl(U))$.

Lemma 2.7. A fuzzy subset U of an fts X is fuzzy regular semiopen if and only if U is fuzzy semiopen and fuzzy semiclosed.

Proof: Let $U \in RSO(X)$, then there is a fuzzy regular open set V of X such that $V \leq U \leq Cl(V)$ and hence $Int(Cl(U)) = Int(Cl(V)) = V \leq U$. Therefore U is fuzzy semiclosed and fuzzy semiopen. Conversely, let U be fuzzy semiopen and fuzzy semiclosed in X, then $Int(Cl(U)) \leq U \leq Cl(Int(U)) \leq Cl(Int(Cl(U$ Put $Int(Cl(U)) = V$. Which is fuzzy regular open in X. Hence there exists a fuzzy regular open set V of X such that $V \leq U \leq Cl(V)$. Then U is fuzzy regular semiopen.

Theorem 2.8. If (Y,θ) is an FED-space and a function $f:(X,\tau) \longrightarrow (Y,\theta)$ is α-semicontinuous, then f is $R\alpha$-semicontinuous.

Proof: Let $x \in X$ and $V \in RSO(Y)$ with $V(f(x)) > \alpha$. Since Y is an FED-space, then $V \leq Cl(Int(V)) = Int(Cl(Int(V)))$ 0, with $Int(Cl(Int(V)))(f(x)) > \alpha$, Since f is α-semicontinuous, there is $U \in SO(X)$ such that $U(x) > \alpha$ and $f(U) \leq Int(Cl(Int(V)))$. By Lemma 2.5 and 2.7, $Int(Cl(V)) \leq Scl(V) = V$ and hence $f(U) \leq V$. then f is $R\alpha$ -semicontinuous.

<u>Theorem 2.9.</u> If (Y,θ) is an FED-space and a function $f: (X,\tau) \longrightarrow (Y,\theta)$ is α^*-semicontinuous, then f is $R\alpha^*$-semicontinuous.

<u>Proof</u>: Let $x \in X$ and $V \in RSO(Y)$ with $V(f(x)) > \alpha$. Similar to that of Theorem 2.8., there is $U \in SO(X)$ such that $U(x) > \alpha$ and semiclosed, then $Int(Scl(U)) = Int(Cl(Scl(U))) = Int(Cl(U))$. Since $V \in RSO(Y)$, then $Cl(V) = Cl(Int(V)) = Int(Cl(Int(V))) \leq Scl(V)$. Hence $f(Int(Scl(U)) \leq Scl(V)$. Therefore f is $R\alpha^*$-semicontinuous.

<u>Theorem 2.10.</u> If a function $f:X \longrightarrow Y$ is α^*-semiconuous and A is α I-compact relative to X, then f(A) is α-almost compact relative to Y.

<u>Proof</u>: Let ν be a fuzzy open α-shading of S(f(A)). Thus for $y \in S(f(A))$, there is $V_y \in \nu$ such that $V_y(y) > \alpha$. Since f is α^*-semicontinuous, then for $x \in S(A)$ with $f(x)=y$, there is $U \in SO(X)$ such that $U_x(x) > \alpha$ and $f(Int(Cl(U_x))) < Cl(V_y$ ..

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Hence $\{U_x : x \quad S(A)\}$ is an α-shading of $S(A)$ by fuzzy semiopen sets of X. Since A is α I-compact relative to X, then there is a finite subfamily $\{U_{x_i} : i = 1,2,3,\ldots,n\}$ such that $\{Int(Cl(U_{xi})) \; : i=1,2,3,\ldots,n\}$ is an α-shading of S(A). For $y_i \in S(f(A))$, there is $x_i \in S(A)$ such that $f(x_i)=y_i$ and hence there is $Int(Cl(U_{x_i}))$ such that $Int(Cl(U_{x_i}))(x_i) > \alpha$. But $f(Int(Cl(U_{x_i})))(y_j) = \sup_{X_i \in f^{-1}(y_i)} (Int(Cl(U_{x_i})))(x_i) > \alpha$, which implies for $y_i \quad S(f(A))$, $Cl(V_{yi})(y_i) > \quad$. Then $\{Cl(V_{y_i}) : i= 1,2,3, \ldots,n\}$ is an α-shading of $S((f(A)))$. Therefore f(A) is α-almost compact relative to Y.

In an fts X, it is easy to see that if A is α I-compact relative to X, then A is α S-closed relative to X, and α-almost compact relative to X, but not the converse. Also by the following Theorem we show that, in an FED-space X if A is α-almost compact relative to X, then A is α I-compact relative to X.

<u>Theorem 2.11.</u> If X is an FED-space and A is α-almost comact relative to X, then A is α I-compact relative to X.

Proof: Let $\{F_i: i \in I\}$ be an α-shading of S(A) by fuzzy regular closed sets in X. Since X is an FED-space, then for each i I, $F_i = Cl(Int(F_i))$, which is fuzzy open in X. Since A is α-almost compact relative to X, then there is a finite subset I_o of I such that $\{Cl(F_i) : i \; I_o\}$ is an α-shading of S(A) since X is an FED-space, then $Int(F_i) = F_i = Cl(F_i)$ and hence $\{Int(F_i): i \in I_o\}$ is an α-shading of S(A). Then A is α I-compact relative to X.

The following corollary may be considered as a generalization (in fuzzy seting) and an improvement of Corollaries B and C.

Corollary 2.12. If a function $f:X \longrightarrow Y$ is α^*-semi-continuous, Y is an FED-space and A is α I-compact relative to X, then f(A) is αI-compact relative to Y.

Proof: If follows that from Theorems 2.10 and 2.11. The following Theorem may be considered as a generalization (in fuzzy setting) and an improvement of Theorem A.

Theorem 2.13. If a function $f:X \longrightarrow Y$ is R *-semi-continuous and A is α I-compact relative to X, then f(A) is α S-closed relative to Y.

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Proof: Let $\mathcal{V}$ be an α-shading of $S(f(A))$ by fuzzy regular semiopen sets of Y. Thus for $y \in S(f(A))$, there is $V_y \in \mathcal{V}$ such that $V_y(y) > \alpha$. Since f is $R\alpha^*$-semicontinuous, then for $x \in S(A)$, with $f(x)=y$, there is $U_x \in SO(X)$ such that $U_x(x) > \alpha$ and $f(Int(Scl(U_x))) < Scl(V_y)$. One can obtain as in Theorem 2.11., for $y_i \in S(f(A))$, there is $x_i \in S(A)$ with $f(x_i)=y_i$ and hence, there is $Int(Cl(U_{x_i}))$ such that $Int(Cl(U_{x_i}))(x_i) > \alpha$. But $Int(Cl(U_{x_i}))=Int(Scl(U_{x_i}))$, then $f(Int(Scl(U_{x_i})))(y_i)=(Int(Cl(U_{x_i})))(y_i)= \sup_{x_i \in f^{-1}(y_i)} (Int(Cl(U_{x_i})))(x_i) > \alpha$ which implies for $y_i \in S(f(A))$, $Scl(V_{y_i})(y_i) > \alpha$. Then $\{Cl(V_{y_i}): i=1,2,3, \ldots,n\}$ is an α-shading of $S(f(A))$. Therefore f(A) is α S-closed relative to Y.

Corollary 2.14. If a function $f:X \longrightarrow Y$ is $R\alpha^*$-semicontinuous, Y is an FED-space and A is αI-compact relative to X, then f(A) is αI-compact relative to Y.

The following corollary may be considered as a generalization (in fuzzy setting) and an improvement of Corollaries B and C.

Corollary 2.15. If a function $f:X \longrightarrow Y$ is α^*-semicontinuous, Y is an FED-space and A is αI-compact relative to X, then f(A) is α I-compact relative to Y.

Proof: If follows that from Theorem 2.9 and Corollary 2.14.

In 1986, Mashhour, et al. [13], show that every F-continuous function is an α-continuous function, but not the converse. Since it is so, then theorems 2.16, 2.17 and Corollary 2.18 may be considered as an improvement of Theorems D, E and Corollary F, respectively.

Theorem 2.16. If a function $f: X \longrightarrow Y$ is α-continuous and X is countably α-compact, then f(X) is countably α-compact.

Proof: Assume that $f(X)=Y$. Let $\mathcal{V}$ be a countable open α-shading of Y. Thus for $y \in Y$, there is $U_y \in \mathcal{V}$ such that $Y_y(y) > \alpha$. Since f is α-continuous, then for $x \in X$ with $f(x)=y$, there is a fuzzy open set V_x of X such that $V_x(x) > \alpha$ and $f(V_x) \leq U_y$. Hence $\mathcal{U}=\{V_x : x \in X\}$ is countable open α-shading of X. Since X is countable α-compact, then $\mathcal{U}$ has a finite α-subshading $\{V_{x_i} : i=1,2,3,\ldots,n\}$. For $y_i \in Y$, there is $x_i \in X$ with $f(x_i) = y_i$ and hence there is V_{x_i} such that $V_{x_i}(x_i) > \alpha$. But $f(V_{x_i})(y_i) = \sup_{x_i \in f^{-1}(y_i)} V_{x_i}(x_i)$, which $U_{y_i}(y_i) > \alpha$. Hence $\{U_{y_i} : i=1,2,3,\ldots,n\}$ is a finite α-shading of . Then f(X) is countably α-compact.

Theorem 2.17. Let $f:X \longrightarrow Y$ be an α-continuous, F-open surjection. If X is locally α-compact, then Y is also locally α-compact.

Proof: Let $y \in Y$ and let $f(x) = y$. Since $x \in X$, there is a neighbourhood U of x such that $U(x)=1$ and $S((U))$ is α-compact. Since f is F-open, then $f(U)$ is a neighbourhood of y such that $(f(U))(y) = \sup_{x \in f^{-1}(y)} U(x) = 1$ and since of is α-continuous $f(S(U)) = S(f(U))$ is α-compact [13 Corollary 4.9]. Hence Y is locally α-compact.

Corollary 2.18. Let f be an α-continuous, F-open function from an fts X onto a 1*-Hausdorff fts Y such that $S(Cl(U) = Cl(S(U))$ for each fuzzy open set U in Y. If X is strongly locally α-compact, then so is Y.

Proof: It follows that from Theorem 2.17 and Theorem 5.5 of [12].

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بعض النتائج الاضافية على الاتصال الغازى

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فى هذا البحث عرفنا مفاهيم شبه الاتصال الغازى من النوع α^* وشبه الاتصال الغازى من النوع $R\alpha$ والنوع $R\alpha^*$ كتعميم لشبه الاتصال الغازى. باستخدام تلك المفاهيم ومفهوم الاتصال من النوع α تم تحسين وتعميم بعض النتائج فى [11,12,17]