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Almost δ^* - Pre-I-Continuous Multifunctions

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Abstract

In this paper we introduce and investigate a new type of weaker class namely δ^*-pre-I-continuous and almost δ^*-pre-I-continuous multifunctions in ideal topological space. Some characterizations of almost δ^* - pre-I-continuous multifunctions are obtained.

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1.Introduction

Mashhour et al. [9] introduced the concept of preopen sets and pre-continuous functions in topological spaces. In 1968, Velicko [18] introduced the notion of δ-open sets which are stronger than open sets.Many authors like [1], [5], [12] have researched and studied several forms of continuous functions and multi functions. Let X be a topological space. Recall that a subset A of X is said to be preclosed if cl(int(A)) $\subset$ A. The preclosure of A is denoted by pclA, is the smallest preclosed set in X containing A. Complement of preclosed sets are called preopen sets. S.Raychaudhuri and M.N. Mukherjee[17] introduced the notion of δ-continuity and δ-preopen sets. Erdal Ekici[5] introduced the concept of almost δ-precontinuous multifunction. Some of the other continuities are semi-continuity[11], α-continuity [10,16], precontinuity [15] and β-continuity [16].

Here we introduce a new type of continuous multifunctions namely almost δ^* - pre-I-continuity in ideal topological space. Some properties and several characterizations are studied and the relationships between other continuous

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multifunctions are also determined.

2. Preliminaries

In this paper, spaces (X,τ) and (Y,υ) always mean topological spaces on with no separation axioms are assumed unless explicitly stated. Let A be a subset of a space X. For a subset A of (X,τ), cl(A) and int(A) represent the closure of A with respect to τ and interior of A with respect to τ, respectively. An ideal is defined as a nonempty collection I of subsets of X satisfying the following two conditions: (1) If A $\in$ I and B $\subset$ A, then B $\in$ I. (2) If A $\in$ I and B $\in$ I, then A $\cap$ B $\in$ I. Let (X,τ) be any topological space and I an ideal of subsets of X. An ideal topological space denoted by (X,τ,I) is a topological space (X,τ) with an ideal I on X. For a subset A of X, A^*(I)={ x $\in$ X : U $\cap$ A $\in$ I for each neighbourhood U of x } is called the local function[6] of A with respect to I and τ. Additionally, $cl^*(A) = A \cup A^*$ defines a Kuratowski closure operator for τ^*(I). δ-cl(A) = $\{x \in$ X: A $\cap$ int(cl(A))$\neq \phi$, U $\in \tau$ and x $\in$ U$\}$,if A = δ-cl(A) then A is said to be δ-closed set. The δ-interior of a subset A of X is denoted by δ-int(A). A subset A is called δ-open if A = δ-int(A). The complement of δ-closed is δ-open.

Definition.2.1. A subset A of a space X is said to be α-open [17] if A $\subset$ int(cl(int(A))), pre-open [9] if A $\subset$ int(cl(A)), δ-preopen [17] if A $\subset$ int(δ-cl(A)), semi-open [8] if A $\subset$ cl(int(A)), b-open [2] if A $\subset$ cl(int(A)) $\cup$ int(cl(A)), β-open [1] if A $\subset$ cl(int(cl(A))).

The family of all α-open sets, β-open sets, preopen sets, δ-preopen sets, δ-open sets are denoted by αO(X,τ), βO(X,τ), PO(X,τ), δPO(X,τ), δO(X,τ) respectively.

By a multifunction F : X $\rightarrow$ Y , we mean a point-to-set correspondence from X into Y and always assume that F(x) $\neq \phi$ for all x $\in$ X. For a multifunction F: X$\rightarrow$ Y, following [3,4] we shall denote the upper and lower inverse of a set B of Y by F^+(B) and F^-(B) respectively, that is, $F^+(B) = \{x \in X : F(x) \subset B\}$ and $F^-(B) = \{x \in X : F(x) \cap B \neq \phi\}$. In particular, $F^-(y) = \{x \in X : y \in F(x)\}$ for each point y $\in$ Y. For each A $\subset$ X, F(A) = $\cup_{x\in X}$F(x), then F is said to be a surjection if F(X) = Y, or equivalently if for each y $\in$ Y there exists an x $\in$ X such that y $\in$ F(x). Moreover, F : X $\rightarrow$ Y is called upper semi continuous(resp. lower semi continuous) if F^+(V) (resp. F^-(V)) is semi open in X for every open set V of Y [11].

Definition.2.2. A multifunction F :X $\rightarrow$ Y, is said to be: 1) upper almost continuous [13,14] or upper precontinuous [14] (upper α continuous, upper β-continuous[15] , upper δ-precontinuous [11]) at x $\in$ X if for each open set V of Y containing F(x), there exists U $\in$ PO(X,τ), (U $\in$ αO(X,τ), U $\in$ βO(X,τ), U $\in$ δPO(X,τ)) such that F(U) $\subset$ V.

2) lower almost continuous [13,14] or lower precontinuous [14] (lower α continuous, lowerβ-continuous[15] , lower δ-precontinuous [11]) at x $\in$ X if for each open set V of Y such that F(x) $\cap$ V $\neq \phi$, there exists U $\in$ PO(X,τ), (U $\in$ αO(X,τ),U $\in \beta$O(X,τ), U $\in \delta$PO(X,τ)) such that F(u) $\cap$ V $\neq \phi$ for every u $\in$ U.
3) upper (lower) almost continuous or upper (lower) precontinuous, (upper (lower) α-continuous, (upper (lower) precontinuous, upper(lower) δ-precontinuous) if it has this property at each point of X.

3. Almost δ^*- pre-I-continuous multifunctions

The δ^*-interior of a subset A of X is denoted by δ^*-int(A). A subset A is called δ^*-open if A = δ^*-int(A). A point x of X is called a δ^*-cluster point of A if , δ^*-cl(A) = $\{x \in$ X: A $\cap$ int(cl*(U)) $\neq \phi$, whenever $x \in U$, U $\in \tau\}$ equivalently if A $\cap$ V $\neq \phi$ for every IR open set V containing x, where V is said to be IR open[7] if int(cl*(V)) = V. If δ^*-cl(A) = A, then A is said to be δ^*-closed. The complement of δ^*-closed is δ^*-open.
Definition.3.1. A subset A of a space X is said to be δ^*-pre-I-open if A $\subset$ int(δ^*-cl(A)).

The complement of a δ^*-pre-I-open is said to be δ^*-pre-I-closed. The intersection of all δ^*-pre-I-closed sets of X containing A is called the δ^*-pre-I-closure of A and is denoted by δ^*-pIcl(A).The union of all δ^*-pre-I-open sets of X contained in A is called the δ^*-pre-I-interior of A and is denoted by δ^*-pIint(A). The subset U of X is called a δ^*-pre-I-neighbourhood of a point x $\in$ X if there exists a δ^*-pre-I-open set V such that x $\in$ V $\subset$ U. The family of all δ^*-pre-I-open sets, δ^*-pre-I-closed sets of X is denoted by δ^*PIO(X), δ^*PIC(X).
Theorem.3.2. For a subset A of a topological space (X,τ,I), the following properties hold: 1) Every δ-open is δ^*-open. 2) Every δ^*pre-I-open is δ preopen. But the converses is not true for both in general.
Proof. It is clear from the definitions.
Example.3.3. Let X = $\{a, b, c\}, \tau = \{\phi, X, \{a\}\}$, A = $\{a\}$ and I = $\{\phi, \{a\}\}$ then we get A is δ^* open set but it is not a δ open set.
Example.3.4. Let X = $\{a, b, c\}, \tau = \{\phi, X, \{a\}\}, A = \{b, c\}$ and I = $\{\phi, \{a\}\}$ then we get $\{b, c\}$ is δ preopen set but it is not a δ^* pre-I-open set.
Definition.3.5. A multifunction F: X $\rightarrow$ Y is said to be: 1) upper δ^*-pre-I-continuous at a point x $\in$ X if for each open set V of Y containing F(x), there exists a U $\in \delta^*$PIO(X,τ), such that F(U) $\subset$ V,
2)lower δ^*-pre-I-continuous at a point x $\in$ X if for each open set V of Y such that F(x) $\cap$ V $\neq \phi$, there exists a U $\in \delta^*$PIO(X,τ), such that F(U) $\cap$ V $\neq \phi$,
3) lower almost δ^*-pre-I-continuous at a point x $\in$ X if for each open set V of Y such that x $\in$ F$^-$(V), there exists a U $\in \delta^*$PIO(X,τ) such that U $\subset$ F$^-$(int(cl*(V))),

4) upper almost δ^*-pre-I-continuous at a point x $\in$ X if for each open set V of Y such that x $\in$ F^+(V), there exists a U $\in$ δ^*PIO(X,τ) such that U $\subset$ F^+(int(cl*(V))),

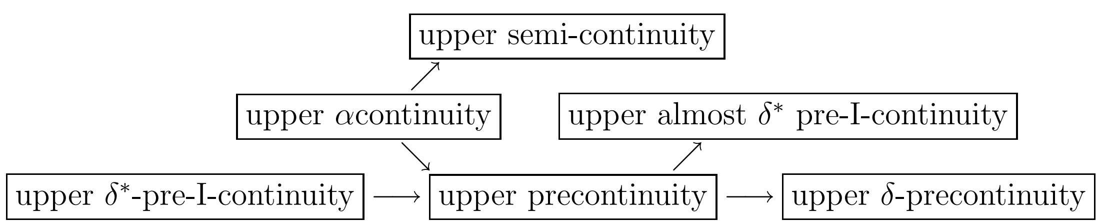
5) lower (upper) almost δ^*-pre-I-continuous if F has this property at each point of X.

Example.3.6. Let F: (X,τ,I) $\rightarrow$ (Y,υ,I), where X=$\{a, b, c, d\}$, τ =$\{\phi, X, \{a, c\}$,$\{a, c, d\}\}$, $I = \{\phi, \{a\}\}$, Y = $\{a, b\}$ and = $\{\phi, Y, \{a\}\}$. The function is defined as follows: F(a) = F(b) = F(c) = a and F(d) = b. Let a $\in$ X ,then V=$\{a\}$ be the open set containing F(a) in Y, then there exists a δ^*pre-I-open set U=$\{a, c\}$ in X such that U $\subset$ F^+ (int(cl*(V))).

Theorem.3.7. For a multifunction F : X $\rightarrow$ Y from a topological space (X,τ) to a topological space (Y,υ), the following implications hold: 1) Every upper α-continuous is upper semicontinuous. 2) Every upper α-continuous is upper precontinuous. 3) Every upper δ^*-pre-I-continuous is upper precontinuous. 4) Every upper precontinuous is upper δ-precontinuous. 5) Every upper δ^*-pre-I-continuous is upper almost δ^*-pre-I-continuous.

Proof. It is clear from the definitions.

Remark.3.8. The above theorem.3.7. is shown diagramatically.



Note that none of these implications is reversible. We give an example for the almost upper δ^*-pre-I-continuous but not upper δ^*-pre-I-continuous.

Example.3.9. Let X=$\{a, b, c, d\}$, $\tau = \{\phi, X, \{a, c\}$,$\{a, c, d\}\}$,I=$\{\phi, \{a\}, \{c\}, \{a, c\}\}$, Y=$\{a, b\}$, υ=$\{\phi, X, \{a\}\}$ and J=$\{\phi, \{b\}\}$. Let F: (X,τ,I) $\rightarrow$ (Y,υ,J) be a function defined as F(a)=F(b)=F(d)=a and F(c)=b. Let b $\in$ X then V = $\{a\}$ be the open set containing F(b), then there exists a δ^*-pre-I-open set U=$\{b, c\}$ such that U $\subset$ F^+(int(cl*(V)) but not F(U) $\subset$ V. (i.e) F is almost upper δ^*-pre-I-continuous but not upper δ^*-pre-I-continuous.

The following theorem gives some characterizations of an upper almost δ^*-pre-I-continuous multifunction.

Theorem.3.10. Let F: X $\rightarrow$ Y be a multifunction from a topological space (X,τ) to a topological space (Y,σ). Then the following statements are equivalent: 1) F is a upper almost δ^*-pre-I-continuous multifunction, 2) for each x $\in$ X and for each open set V such that F(x) $\subset$ V, there exists a U $\in$ δ^*PIO(X,τ) such that if y $\in$ U, then F(y) $\in$ int(cl*(V)), 3) for each x $\in$ X and for each closed set K such that x $\in$ $F^+(Y\backslash K)$, there exists a δ^*pre-I-open set H such that x $\in X\backslash H$ and F^- (cl(int*(K))) $\subset$ H, 4) F^+(int(cl*(V))) $\in \delta^*$PIO(X,τ) for any open set V $\subset$ Y, 5) F^- (cl(int*(K))) $\in \delta^*$PIC(X,τ) for any closed set K $\subset$ Y, 6) for each point x $\in$ X and each neighbourhood V of F(x), F^+(int(cl*(V)))) is a δ^*- pre-I- neighbourhood of x, 7) for each point x $\in$ X and each neighbourhood V of F(x) , there exists a δ^*- pre-I-neighbourhood U of x such that F(U) $\subset$ int(cl*(V)), 8) δ^*-pIcl(F^-(cl(int*(H))) $\subset$ F^-(cl(int*(cl(H)))) for every subset H of Y, 9) F^+(int(cl*(int(N)))) $\subset$ δ^*-pIint(F^+(int(cl*(N)))) for every subset N of Y.

Proof. (1) $\leftrightarrow$ (2): obivious.

(2) $\rightarrow$ (3): Let x $\in$ X and K be a closed set of Y such that x $\in F^+(Y\backslash K)$. By (2), there exists a U $\in \delta^*$PIO(X,τ) such that F(U) $\subset$ (int(cl*(Y$\backslash$ K))). We have (int(cl*($Y\backslash$K))) = Y$\backslash$ (cl(int*(K) and U $\subset$ F^+(Y$\backslash$ (cl(int*(K))) = X$\backslash$ F^-(cl(int*(K)))). Thus we obtain F^-(cl(int*)(K)))) $\subset X\backslash$ U. Take H = X$\backslash$ U, then x $\in$ X$\backslash$ H and H is a δ^* pre-I-closed set.

(3) $\rightarrow$ (2): It can be obtained similarly as (2) $\rightarrow$(3).

(1) $\rightarrow$ (4): Let V be any open set of Y and x $\in F^+$(V). By (1), there exists $U_X \in \delta^*$PIO (X,τ) such that $U_X \subset F^+$(int(cl*(V)))). Therefore, we obtain F^+(int(cl*(V)))) = $\cup$ U_X. Hence, F^+(int(cl*(V))) $\in \delta^*$PIO(X,τ).

(4) $\rightarrow$ (1): Let V be any open set of Y and x $\in$ F^+(V). By (4),F^+(int(cl*(V)) $\in \delta^*$PIO(X). Take U = F^+(int(cl*(V))). Then, F(U) $\subset$ int(cl*(V)). Hence , F is upper almost δ^*-pre-I-continious.

(4) $\rightarrow$ (5): Let K be any closed set of Y. Then, Y$\backslash$ K is a open set of Y. By (4), F^+(int(cl*(Y$\backslash$ K)))) $\in \delta^*$PIO(X,τ). Since (int(cl*(Y $\backslash$ K) = Y$\backslash$(cl(int*(K))), it follows that F^+(int(cl*($Y\backslash K$)))) = F^+(Y$\backslash$ (cl(int*(K)))) = X$\backslash F^-$((cl(int*(K)))). We obtain that F^-(cl(int*(K))) is δ^*pre-I-closed in X.

(5) $\rightarrow$ (4): It can be obtained similarly as (4) $\rightarrow$ (5).$_0$

(4) $\rightarrow$ (6) Let x $\in$ X and V be a neighbourhood of F(x). Then there exists an open set G of Y such that F(x) $\in$ G $\subset$ V. Therefore, we obtain x $\in$ F^+(G) $\subset$ F^+(V). Since F^+(int(cl*(G))) $\in \delta^*$PIO(X,τ), F^+(int(cl*(V))) is a δ^*- pre-I-neighbourhood of x.

(6) $\rightarrow$ (7): Let x $\in$ X and V be a neighbourhood of F(x). By (6), F^+(int(cl*(V)))) is a δ^*- pre-I- neighbourhood of x. Take U = F^+(int(cl*(V))). Then F(U) $\subset$ (int(cl*(V))).

(7) $\rightarrow$ (1): Let x $\in$ X and V be any open set of Y such that F(x) $\in$ V. Then V is a neighbourhood of F(x). By (7), there exists a δ^*- pre-I-neighbourhood of x such that F(U) $\subset$ (int(cl*(V))). Therefore, there exists G $\in \delta^*$PIO(X,τ) such that x $\in$ G $\subset$ U and F(G) $\subset$ F(U) $\subset$ (int(cl*(V))). We obtain upper almost δ^*-pre-I-continuous.

(5) $\rightarrow$ (8) For any subset H of Y, cl(H) is closed in Y. By (5), F^-(cl(int*(cl (H)))) is δ^*pre-I-closed in X. Therefore, we obtain δ^*-pcl(F^-(cl(int*(H)))) $\subset$ F^-cl(int*(cl(H)))).

(8) $\rightarrow$ (5) Let K be any closed set of Y. Then we have δ^*-pcl(F^-(cl(int*(K)))) $\subset$

$F^-(cl(int^*(cl(K))))$ $=F^-(cl(int^*(K)))$. Thus, $F^-(cl(int^*(K)))$ is δ^*-pre-I-closed in X.
(4) → (9) For any subset N of Y, int(N) is open in Y. By (4), $F^+(int(cl^*(int(N))))$ is δ^*pre-I-open in X. Therefore, we obtained $F^+(int(cl^*(int(H)))) \in \delta^*$-pint($F^+(int(cl^*(H))))$.
(9) → (4) Let V be any open set of Y. Then we have $F^+(int(cl^*(V))) \in \delta^*$-pint($F^+$ $(int(cl^*(V))))$. Thus, $F^+(int(cl^*(V)))$ is δ^*-pre-I-open in X.
Theorem.3.11. Let F: X → Y be a multifunction from a ideal topological space (X,τ,I) to a topological space (Y,σ,I). Then the following statements are equivalent: 1) F is a lower almost δ^*-pre-I-continuous multifunction, 2) for each x ∈ X and for each open set V such that $F(x) \cap V \neq \phi$, there exists a U ∈ δ^*PIO(X,τ) such that if y ∈ U, then $F(y) \cap int(cl^*(V)) \neq \phi$, 3) for each x ∈ X and for each closed set K such that $x \in F^-(Y\setminus K)$, there exists a U ∈ δ^*pre-I-closed set H such that $x \in X\setminus H$ and F^+ $(cl(int^*(K))) \subset H$, 4) $F^-(int(cl^*(V))) \in \delta^*$PIO(X,$\tau$) for any open set V ⊂ Y, 6) $F^+(cl(int^*(K))) \in \delta^*$PIC(X,$\tau$) for any closed set K ⊂ Y, 7) δ^*-pIcl($F^+(cl(int^*(H))) \subset F^+(cl(int^*(cl(H))))$ for every subset H of Y, 8) $F^-(int(cl^*(int(N)))) \in \delta^*$-pIint($F^-(int(cl^*(N))))$ for every subset N of Y.
Proof. It can be obtained similarly as the previous theorem.
Lemma.3.12. Let A and X_0 be subsets of a space (X,x). If A ∈ δ^*PIO(X,τ) and $X_0 \in \delta^*O(X)$,then $A \cap X_0 \in \delta^*PIO(X)$.
Proof. Let A∈ δ^*PIO(X,τ) and $X_0 \in \delta^*O(X)$, which implies A ∈ (int(δ^*-cl(A)). $A \cap X_0 \subset (int(\delta^*\text{-}cl(A))) \cap X_0 \subset (int(\delta^*\text{-}cl(A)) \cap X_0) \subset (int(\delta^*\text{-}cl(A) \cap X_0)))$ $\subset (int(\delta^*\text{-}cl(A \cap X_0)))$. Therefore $A \cap X_0 \in \delta^*PIO(X,\tau)$.
Lemma.3.13. Let A and X_0 be subsets of a space (X,τ). If A ∈ δ^*PIO(X,τ) and $X_0 \in \delta^*O(X)$,then $A \cap X_0 \in \delta^*PIO(X_0)$.
Proof. Let A ∈ δ^*PIO(X,τ) and $X_0 \in \delta^*O(X)$ by lemma 3.12 $A \cap X_0 \in \delta^*PIO(X)$,Now $A \cap X_0 \cap X_0 \subset X_0 \cap (int(\delta^*\text{-}cl(A \cap X_0))) \subset (X_0 \cap int(\delta^*\text{-}cl(A \cap X_0)))$,$\subset (int_{X_0}(X_0 \cap \delta^*\text{-}cl(A \cap X_0)))) \subset (int_{X_0}(\delta^*\text{-}cl_{X_0}(A \cap X_0))))$. Therefore $A \cap X_0 \in \delta^*PIO(X_0)$.
Lemma.3.14. Let $A \subset X_0 \subset X$. If $X_0 \in \delta^*O(X)$ and $A \in \delta^*PIO(X_0)$,then A ∈ δ^*PIO(X).
Proof. Let $A \in \delta^*PIO(X_0)$ and $X_0 \in \delta^*O(X)$. Since $X_0 \subset X$, which implies A ∈ δ^*PIO(X).
Theorem.3.15. Let F: X → Y be a multifunction and let U be a δ^*-open set in X. If F is a lower(upper) almost δ^* pre-I-continuous, then the restriction multifunction, F | U : U → Y is a lower (upper) almost δ^* pre-I-continuous.
Proof. Suppose that V is a open set in Y. Let x ∈ U and $x \in (F \mid U)^-(V)$. Since F is a lower almost δ^* pre-I-continuous multifunction, it follows that there exists a δ^* pre-I- open set G such that $x \in G \subset F^-(int(cl^*(V)))$. By Lemma 3.13 we obtain that $x \in G \cap U \in \delta^*PO(U)$ and $G \cap U \subset (F \mid U)^-$ $(int(cl^*(V))))$.Thus, we show that the restriction multifunction F | U is a lower

almost δ^*-pre-I-continuous. The proof of the upper almost δ^*-pre-I-continuous of F | U is similar to the above.

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