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27th October 2021

Jointly Organized by

Department of Biological Science, Physical Science and Computational Science

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ABOUT THE INSTITUTION

A nations's growth is in proportion to education and intelligence spread among the masses. Having this idealistic vision, two great philanthropists late. S.P. Nallamuthu Gounder and Late. Arutchelver Padmabhushan Dr.N.Mahalingam formed an organization called Pollachi Kalvi Kazhagam, which started NGM College in 1957, to impart holistic education with an objective to cater to the higher educational needs of those who wish to aspire for excellence in knowledge and values. The College has achieved greater academic distinctions with the introduction of autonomous system from the academic year 1987-88. The college has been Re-Accredited by NAAC and it is ISO 9001 : 2015 Certified Institution. The total student strength is around 6000. Having celebrated its Diamond Jubilee in 2017, the college has blossomed into a premier Post-Graduate and Research Institution, offering 26 UG, 12 PG, 13 M.Phil and 10 Ph.D Programmes, apart from Diploma and Certificate Courses. The college has been ranked within Top 100 (72nd Rank) in India by NIRF 2021.

ABOUT CONFERENCE

The International conference on “Emerging Trends in Science and Technology (ETIST-2021)” is being jointly organized by Departments of Biological Science, Physical Science and Computational Science - Nallamuthu Gounder Mahalingam College, Pollachi along with ISTE, CSI, IETE, IEE & RIYASA LABS on 27th OCT 2021. The Conference will provide common platform for faculties, research scholars, industrialists to exchange and discus the innovative ideas and will promote to work in interdisciplinary mode.

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Stronger form of δP_S-Continuous Functions

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ABSTRACT. The purpose of this paper is to introduce a new concept of functions called Almost δP_S-continuous functions. This class of functions is defined using new class of sets called δP_S- open sets in topological spaces. Some propertiesand characterizations of this function areobtained.

Keywords.δP_S-continuous, precontinuous, almost precontinuous functions.

1. INTRODUCTION

Velicko [23]was the first who introduced δ-open sets in 1968, which plays an important role in study of various topological spaces. Considering this many authorsdefined a new class of sets in topological spaces. Vidhyapriya et al [24] introduceda new concept called δP_S-open sets in topological spaces. In this paper almost δP_S-continuous functions isdefined by which various properties are obtained.

2. PRELIMINARIES

In a topological space X mean a topological space without anyseparation axiom. We recall the following definitions, notations and terminology.

Definition 2.1.A subset A of X is said to be

a) preopen**[12]** if$A \subseteq IntClA$
b) semi-open **[10]** if$A \subseteq ClIntA$
c) α-open **[15]** if $A \subseteq IntClIntA$
d) β-open **[1]** if $A \subseteq ClIntClA$
e) regular open **[22]**if$A = IntClA$
f) regular semi-open**[5]** if $A = s\ IntsClA$
g) δ-preopen **[20]** if $A \subseteq Int(\delta Cl(A))$

- The complement of a preopen (resp. semi-open, α-open, β-open, regular openand regular semi-open) set is said to be preclosed(resp. semi-closed, α-closed, β-closed,regular closed, δ-preclosed and regular semi-open).
- The family of all preopen (resp. semi-open, α-open, regular open, regular semi-open, δ-preopen and regular closed) subsets of a topological space X is denotedbyPO(X)(resp.SO(X),αO(X),RO(X),RSO(X), δPO(X)andRC(X)).

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- The closure (resp. interior) of a subset A of X is denoted by Cl A (resp. Int A).

Definition 2.2: Afunction$f: (X, \tau) \to (Y, \sigma)$is said to be

a) precontinuous**[12]**(resp., δ-precontinuous)if the inverse image of each open subset ofY is preopen (resp., δ-preopen) in X.
b) super continuous **[13]** if the inverse image of each open subset of Y is δ-open in X.

- A function $f: (X, \tau) \to (Y, \sigma)$is said to be almost precontinuous**[14]**(resp. almost continuous in the sense of Singal and Singal**[21]**) if the inverse image of each regular open subset of Y is preopen (resp., opensets) in X.
- A function $f: (X, \tau) \to (Y, \sigma)$is said to be δ-continuous **[16]**(resp., almost strongly θ-continuous **[18]**) if for each x ∈ X and each open set V of Y containing f (x), there exists an open set U of X containing x such that f (IntClU) ⊆IntClV (resp., f(ClU) ⊆sClV).

Definition 2.3.A function $f: (X, \tau) \to (Y, \sigma)$is said to be irresolute **[7]** if the inverse imageof each semi-open subset of Y is semi-open in X.

Definition 2.4. A function $f: (X, \tau) \to (Y, \sigma)$ is said to be weakly quasi- continuous**[8]**(resp.S-continuous**[26]**)ifforevery$F \in RC(Y), f^{-1}(F) \in SO(X)$ (resp $f^{-1}(F)$is the union of regular closed sets of X).

Definition2.5[24].A δ- preopen subset A of a space X is called a δP_S-open set if for each x ϵ A, there exists a semi-closed set F such that x ϵ F⊆ A.

Definition2.6[23]. AsubsetAofaspaceXiscalledδ-open(resp.,θ-open)ifforeachx∈A, thereexistsanopensetG suchthat$x \in G \subseteq IntCl(G) \subseteq A$(resp$x \in G \subseteq ClG \subseteq A$).

- The intersection of all δP_S-closed (resp. preclosed, semi-closed, α-closed, δ-preclosed and δ-closed) sets of X containing A is called the δP_S-closure (resp. preclosure, semi-closure, α-closure, δ-preclosure and δ-closure) of A and is denoted by δP_SCl A (resp. pCl A, sCl A, αCl A,δpcl(A) and Cl_δ A).

- The union of all δP_S-open (resp. preopen, semi-open, α-open, δ-preopen and δ-open) sets of X contained in A is called the δP_S-interior (resp. preinterior, semi-interior, α-interior, δ-preinterior and δ-interior) of A and is denoted by δP_SInt A (resp. p Int A, s Int A, αInt A,δpInt(A) and Int_δ A).

Proposition 2.7[24].A subset A of a space X is δP_S-open if and only if A is a δ-preopen set and A is a union of semi-closed sets.

Definition 2.8. A space X is s-regular**[3]**(resp., semi-regular**[19]**) if for each$x \in X$ and each opensetGcontainingx,thereexistsasemi-open(resp.,regularopen)setHsuchthat$x \in H \subseteq sclH \subseteq G$ (resp., $x \in H \subseteq G$).

Theorem 2.9[21]. For a mapping $f: (X, \tau) \to (Y, \sigma)$, the following statements are equivalent:

a) f is almost continuous at $x \in X$
b) For each regularly-open neighborhood$M$ of $f(x)$, there is a neighborhood N of x such that $f(N) \subseteq M$.
c) For each net $\{x_\lambda\}_{\lambda \in D}$ converging to x, the net $\{f(x_\lambda)\}_{\lambda \in D}$ is eventually in every regular open set containing $f(x)$.

Definition 2.10. A space X is said to be:

a) Hyperconnected **[6]** if every non-empty open subset of X is dense.

b) Locally indiscrete **[6]** if every open subset of X isclosed.

c) Semi-T_1**[11]** if to each pair of distinct points x, y of X, there exists a pair of semi-open sets, one containing x but not y and the other containing y butnot x.

Proposition 2.11. The following statements are true:

a) AspaceXissemi-T_1ifandonlyifforanypointx∈X,thesingletonset{x}issemiclosed**[11]**.

b) If a space X is semi-T_1, then$\delta P_S O(X) = \delta PO(X)$**[24]**.

c) Ifatopologicalspace(X,τ) is locally indiscrete space, $\delta P_S O(X) = \tau$**[24]**.

d) Ifatopologicalspace(X, τ) is s-regular, then$\tau \subseteq \delta P_S O(X)$**[24]**.

Lemma 2.12[6]. a). If R ∈ RO(X) and P ∈ PO(X), then R ∩P ∈ RO(P).

b). Let Y be a dense subspace of X. If O is regular open in Y, then $O = Y \cap int(cl(O))$.

Proposition2.13[24]. The following properties are true:

a) Let (Y, τ_Y) be a subspace of a space (X, τ). If $A \in \delta P_S O(X, \tau)$ and $Y \in RO(X, \tau)$ then$A \in \delta P_S O(Y, \tau_Y)$.

b) If either$B \in RSO(X)$ or B is an δ-open subspace of a space X and$A \in \delta P_S O(X)$, then$A \cap B \delta P_S O(B)$.

c) Let (Y,τ_Y) be a subspace of a space (X,τ). If A ϵ $\delta P_S O(Y, \tau_Y)$ and Y ϵ RO(X, τ), then A ϵ $\delta P_S O(X, \tau)$.

d) Let A and B be any subsets of a space X. If A ϵ $\delta P_S O(X)$ and B ϵ RSO(X), then A ∩ B ϵ $\delta P_S O(B)$.

Lemma 2.14. The following statements are true:

a) LetAbeasubsetofaspace(X,τ).ThenA∈PO(X,τ)ifandonlyif sClA=IntClA**[7]**.

b) AsubsetAofaspace(X,τ)isβ-openifandonlyifClAisregularclosed.**[4]**.

Lemma 2.15. Let A be a subset of a topological space (X , τ), then the following statement are true:

a) For each $A \in SO(X), Cl_\delta A = Cl(A) = \delta P_S Cl(A) = pCl(A) = \alpha Cl(A)$**[25]**.

b) If$A \in \beta O(X)$, then $\alpha Cl(A) = Cl(A)$**[2]**.

Definition 2.16[24].A function $f: (X, \tau) \to (Y, \sigma)$is called δP_S- continuous at a point $x \in$ X if for each $x \in$ X and each open set V of Y containing $f(x)$, there exists a δP_S-open set U of X containing x such that$f(U) \subseteq V$. If f is δP_S-continuous at every point of X, then it is calledδP_S-continuous. Equivalently,a function $f: (X, \tau) \to (Y, \sigma)$is δP_S-continuous if and only if $f^{-1}(V)$is δP_S-open set in X for each open set V in Y.

Lemma 2.17[14]. The following results can be proved easily:

a) If $f: (X, \tau) \to (Y, \sigma)$is almost precontinuous and Y is semi-regular, then $f$is precontinuous.

b) If $f: (X, \tau) \to (Y, \sigma)$is almost continuous and Y is semi-regular, then f iscontinuous.

c) A function $f: (X, \tau) \to (Y, \sigma)$is is almost precontinuous if and only if $f^{-1}(V)$ is preopen set in X , for every δ-open set V in Y .

Theorem 2.18 [24]. If $f: (X, \tau) \to (Y, \sigma)$ is a continuous and open function and V is a δP_S-open set of Y, then$f^{-1}(V)$ is a δP_S-open set of$X$.

Theorem 2.19 [7]. A function $f: (X, \tau) \to (Y, \sigma)$ is preopen if and only if$f^{-1}(ClV) \subseteq Cl(f^{-1}(V))$,for each semi-open set V of Y.

Definition 2.20[9]. A function $f:(X,\tau)\to(Y,\sigma)$ is called almost P_S-continuous at a point x ∈ X if for each open set V of Y containing f (x), there exists a P_S-open set U of X containing x such that f (U) ⊆IntClV. If f is almost P_S-continuous at every point of X, then it is called almost P_S-continuous.

Lemma 2.21[21]. Let A be a subset of a topological space (X, τ). Then δ-sCl(δ-Int(A)) = Int(Cl(δ-Int(A)), or equivalently, δ-sCl(U) = Int(Cl(U)) for each δ-open set U of X.

Proposition 2.22[9]: If a function $f:(X,\tau)\to(Y,\sigma)$ is δ-continuous, then f isalmost P_S-continuous.

3.Almost δPs-Continuous Functions

Definition 3.1: A function $f:(X,\tau)\to(Y,\sigma)$is called almost δP_S-continuous function at a point $x \in$ X if for each open set V of Y containing $f(x)$, there exists a δP_S-open set U of X containing x such that f(U) ⊆ Int(Cl(V)). If f is almost δP_S-continuous at every point of X, then it is called almost δP_S-continuous.

Note 3.2. For an open set $\delta Cl(V) = Cl(V)$ [23]. Hence in the definition $f(U) \subseteq intcl(V)$.

Proposition 3.3: The following results supervene from their definitions directly:

a) Every δP_S-continuous functionsis almost δP_S-continuous.

b) Every almost P_S-continuous function is almost δP_S-continuous.

Proof: (a) Let $f:(X,\tau)\to(Y,\sigma)$ be δP_S-continuous. Then for $x \in X$ and $V \in \sigma$ containing $f(x)$ there exists a δP_S-open set U in X containing x such that $f(U) \subseteq V$ (1)→

Then $V \subseteq \delta cl(V)$. Since V is open, $V = int\, V \subseteq int\, \delta\, cl(V)$ (2)→

∴ From (1) & (2) $V \subseteq int(\delta Cl(V))$

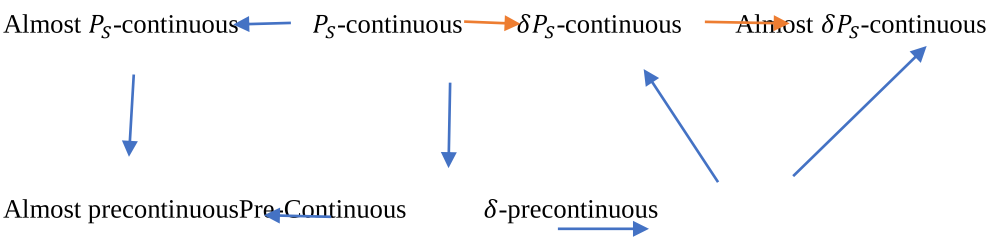
Hence from definition 3.1, f is almost δP_S-continuous function.

(b). Every almost P_S-continuous function is almost δP_S-continuous function

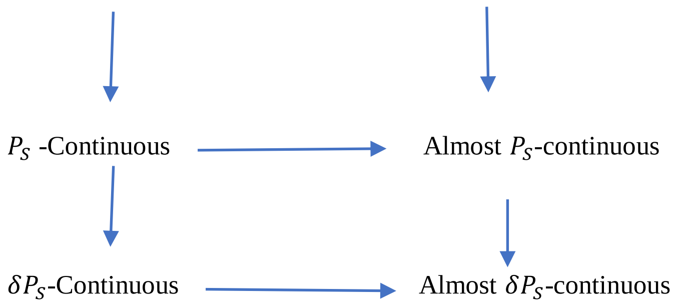
Let $f:(X,\tau)\to(Y,\sigma)$ be almost P_S-continuous function. Then for $x \in X$ and $V \in \sigma$ containing $f(x)$ there exists a δP_S-open set U in X containing x such that $f(U) intcl(V)$. Since every P_S-open set is δP_S-open,from Definition 3.1, f is almost δP_S-continuous.

Proposition 3.4: If a function $f:(X,\tau)\to(Y,\sigma)$is δ-continuous, then f is almost δP_S-continuous.

Proof. From Proposition 2.22, Every δ-continuous is almost δP_S-continuous. From Proposition 3.3(b) every almost δP_S-continuous functions is almost δP_S-continuous. Therefore, every δ-continuous function is almost δP_S-continuous functions.



And we have



The following examples substantiate the converse of Proposition 3.3(a) is generally not true.

Example 3.5. Let $X = \{a, b, c\}$ with the two topologies$\tau = \{X, \emptyset, \{a\}, \{b\}, \{a, b\}, \{a, c\}\}$ and $\sigma = \{X, \emptyset, \{a\}, \{a, b\}\}$; then the $\delta P_S O(X) = \{X, \emptyset, \{b\}, \{c\}, \{a, c\}, \{b, c\}\}$ with respect to τ. Let$f: (X, \tau) \to (X, \sigma)$betheidentityfunction, with $f(a) = a, f(b) = b$ and $f(c) = c$, for $a \in V = \{a\}$ or $\{a, b\}$, then there exists $U = \{a, c\}$ such that $f(U) = \{a, c\} = int(cl(\{a, c\}) = X$.Then f is almost δP_S-continuous, but it is not δP_S-continuous, because $f(U) = \{a, c\} = intcl \subseteq X$ but $f(U) \nsubseteq \{a\}$ or $\{a, b\}$.

The following example substantiate the Proposition 3.3(b) is not true in general.

Example3.6. Let$X = \{a, b, c, d\}$ withthetwotopologies$\tau = \{X, \emptyset, \{a, b\}, \{a, b, c\}, \{a, b, d\}$ and$\sigma = \{X, \emptyset, \{a\}, \{c\}, \{a, b\}, \{a, c\}, \{a, b, c\}, \{a, c, d\}\}$.Let$f: (X, \tau) \to (X, \sigma)$ be defined by $f(a) = f(b) = f(c) = c$ and $f(d) = d$, there exists $\delta P_S O(X, \tau) = \{c\} \subseteq x$ such that $f(U) \subseteq intcl(V)$.but there exists no$P_S O(X, \tau)$ in τ, such that $f(U) \subseteq intcl(V)$. Hence$f$ is almost δP_S-continuous but not almost P_S-continuous.

The following example shows that almost δP_S-continuous but not δ-continuous.

Example3.7. Let$X = \{a, b, c, d\}$withthetwotopologies $\tau = \{X, \emptyset, \{a\}, \{b\}, \{a, b\}\}and\sigma = \{X, \emptyset, \{a\}, \{a, b\}, \{a, b, c\}, \{a, b, d\}\}$;Let$f: (X, \tau) \to (X, \sigma)$beidentityfunctions for $b \in X$ and $V = \{b\} \in \sigma$ there exists $U = \{a, b\}$ containing b which is δP_S-open in X such that $f(U) = \{a, b\} \subseteq int(\delta Cl(V) = int(X) = X$. Here f is almost δP_S-continuous but not δ-continuous.Since $f(int(Cl(U)) = f(int(Cl\{a, b\}) = f(X) = Y \nsubseteq int(Cl(V)) = int(Cl(\{b\}) = int\{b, c, d\} = \emptyset$.

Lemma 3.8. Let A be subset of a space (X, τ). Then $A \in \delta PO(X, \tau)$ if and only if $\delta\ sCl(A) = int(\delta Cl(A))$.

Proof: Let $A \in \delta PO(X, \tau)$. Then

$A \subseteq int(\delta Cl(A) \Rightarrow \delta sCl(A) \subseteq \delta sCl(int(\delta Cl(A))$ $\longrightarrow$ (*)

Claim: $int(\delta Cl(A)) \in \delta Sc(X, \tau)$

Proof: Let $B = int(\delta Cl(A))$

Then $int(B) = int(int(\delta Cl(A)) = int(\delta Cl(A) = B$ (1) $\longrightarrow$

Now $B \subseteq \delta Cl(B) = \delta Cl(int(B))$ [from (1)]. Hence $B \in \delta Cc(X, \tau)$. Hence the claim

Substitute claim in (*), we get, $\delta sCl(A) \subseteq \delta sCl(int(\delta Cl(A)) = int(\delta Cl(A))$

In general, $int(\delta Cl(A) = \delta sCl(A)$. Hence $\delta(sCl(A)) = int(\delta Cl(A))$.

Proposition 3.9. For a function : $(X, \tau) \to (Y, \sigma)$, the following statements are equivalent:

a) f is almost δP_S-continuous.

b) For each$x \in X$ and each δ-open set V of Y containing$f(x)$there exists a δP_S-open set U in X containingxsuchthat$f(U) \subseteq \delta sClV$.

c) Foreach $x \in X$ andeachregularopensetVofYcontaining $f(x)$,thereexists a δP_S-openset U in X containing x such that $f(U) \subseteq V$.

d) For each $x \in X$ and each δ-open set V of Y containing $f(x)$, there exists a δP_S-open set U in X containing x such that $f(U) \subseteq V$.

Proof. (a) ⇒ (b). Let $x \in X$ and let V be any δ-open set of Y containing f (x). By (a), there exists a δP_S-open set U of X containing x such that f (U) ⊆IntδCl V. Since V is δ-open, hence V is δ -preopen set. Therefore, by Lemma 3.8, f (U) ⊆δsClV.

$(b) \Rightarrow (c)$. Let $x \in X$ and let V be any regular open set of Y containing f (x). Then V is a δ-open set of Y containing f (x). By (b), there exists a δP_S-open set U in X containing x such that $f(U) \subseteq \delta sCl(V)$.SinceVisregularopenandhenceisδ-openset.Therefore,byLemma 2.21,$f(U) \subseteq Int(Cl(V))$. SinceVisregularopen,then$f(U) \subseteq V$.

$(c) \Rightarrow (d)$. Let $x \in X$ and let V be any δ-open set of Ycontaining $f(x)$. Then for each$f(x) \in V$, there exists an open set G containing $f(x)$such that$G \subseteq Int(Cl(G)) \subseteq V$. Since$Int(Cl(G))$ is a regular open set of Y containing f (x), by (c), there exists a δP_S-open set U in X containing x such that$f(U) \subseteq Int(Cl(G)) \subseteq V$.

$(d) \Rightarrow (a)$. Let $x \in X$and let V be any open set of Y containing $f(x)$. Then$Int(Cl(V))$ is δ-open set of Y containing f (x). By (d), there exists a δP_S-open set U in X containing x such that$f(U) \subseteq Int(Cl(V))$.But$intCl(V) \subseteq int\delta Cl(V)$ [$\because Cl(V) \subseteq \delta Cl(V)andA \subseteq B \Rightarrow int(A) \subseteq int(B)$]. Therefore, f is almostδP_S-continuous.

Proposition3.10. For a function $f:(X,\tau) \to (Y,\sigma)$, the following statements are equivalent:

a) f is almost δP_S-continuous.
b) $f^{-1}(Int(Cl(V))$ is δP_S-open in X, for each open set V in Y.
c) $f^{-1}(Cl(Int(F))$ is δP_S-closed set in X, for each closed set F in Y.
d) $f^{-1}(F)$ is δP_S-closed set in X, for each regular closed set F of$Y$.
e) $f^{-1}(V)$ is δP_S-open set in X, for each regular open set V of Y.

Proof. (a) ⇒ (b). Let V be any open set in Y. We have to show that$f^{-1}(Int(Cl(V))$ is aδP_S-open set in X. Let$x \in f^{-1}(Int(Cl(V))$and $Int\big(Cl(V)\big)$ is a regular open set in Y. Since f is almost δP_S-continuous, by Proposition 3.9, there exists a δP_S-open set U of X containing x such that$f(U) \subseteq Int(Cl(V))$,which implies that$x \in U \subseteq f^{-1}(Int(Cl(V))$. Therefore,$f^{-1}(Int(Cl(V))$is δP_S-open set in X.

$(b) \Rightarrow (c)$. Let F be any closed set of Y. Then $Y - F$ is an open set of Y. By (b),$f^{-1}(Int(Cl(Y\backslash F))$ is δP_S-open set in X and$f^{-1}(Int\big(Cl(Y\backslash F)\big) = f^{-1}\big(Int(Y\backslash F)\big) = f^{-1}(Y\backslash Cl\big(Int(F)\big) = X\backslash f^{-1}(Cl(Int(F))$ isδP_S-opensetinXandhence$f^{-1}(Cl(Int(F))$isδP_S-closed set in$X$.

$(c) \Rightarrow (d)$. Let$F$beanyregularclosedsetof$Y$.Then$F$isaclosedsetof$Y$.By (c),$f^{-1}(Cl(Int(F))$is δP_S-closed set in X. Since F is regular closed set, then$f^{-1}(Cl\big(Int(F)\big) = f^{-1}(F)$. Therefore,$f^{-1}(F)$is δP_S -closed set in X.

$(d) \Rightarrow (e)$. Let V be any regular open set of Y. Then$Y\backslash V$ is regular closed set of
Y and by (d), wehave$f^{-1}(Y\backslash V = X\backslash f^{-1}(V)$ is δP_S-closed set in X and hence $f^{-1}(V)$ is δP_S-open in X.

$(e) \Rightarrow (a)$. Let $x \in X$and let V be any regular open set of Y containing $f(x)$. Then$x \in f^{-1}(V)$.By (e), we have$f^{-1}(V)$ is aδP_S-open set in X. Therefore, we obtain$f(f^{-1}(V)) \subseteq V$. Hence by Proposition 3.9, f is almost

δP_S-continuous.

The following result can be proved easily from the above Proposition.

Proposition 3.11. If f is almost δP_S-continuous then $f^{-1}(F)$ is a δP_S-closed set for each clopen set F.

Proof: Let $f:(X,\tau)\to(Y,\sigma)$ be almost δP_S-continuous and F be a clopen set. By (c) of Proposition 3.10, $f^{-1}(Cl(int(F)))$ is δP_S-closed. Since every clopen set is open, $int(F)=F$ and since F is closed we get $Cl\big(int(F)\big)=Cl(F)=F$.

$\therefore f^{-1}(F)$ is a δP_S-closed in X.

Proposition3.12. For a function $f:(X,\tau)\to(Y,\sigma)$, the following statements are equivalent:

a) f is almost δP_S-continuous.
b) $f(\delta P_S Cl(A))\subseteq Cl_\delta f(A)$, for each $A\subseteq X$.
c) $\delta P_S Cl f^{-1}(B)\subseteq f^{-1}Cl_\delta(B)$, for each $B\subseteq Y$.
d) $f^{-1}(F)$ is δP_S-closed in X, for each δ-closed set F of Y.
e) $f^{-1}(V)$ is δP_S-open set in X, each δ-open set V of Y.
f) $f^{-1}(Int_\delta B)\subseteq \delta P_S f^{-1}(B)$, for each $B\subseteq Y$.

Proof. (a) ⇒ (b). Let A be a subset of X. Since $Cl_\delta f(A)$ is δ-closed set in δP_S, so $Cl_\delta f(A)=\cap\{F_\alpha : F_\alpha\in RC(Y),\alpha\in\Lambda\}$, where Λ is an index set. Then $A\subseteq f^{-1}\big(Cl_\delta f(A)\big)=f^{-1}(\cap\{F_\alpha:\alpha\in\Lambda\})=\cap\{f^{-1}(F_\alpha):\alpha\in\Lambda\}$. By (a) and Proposition 3.10, $f^{-1}\big(Cl_\delta f(A)\big)$ is δP_S-closed set of X. Hence $\delta P_S Cl(A)\subseteq f^{-1}\big(Cl_\delta f(A)\big)$. Therefore, we obtain that f $(f(\delta P_S Cl(A)\subseteq \big(Cl_\delta f(A)\big)$.

(b)⇒(c). Let B be any subset of Y. Then f^{-1}(B) is a subset of X. By (b), we have $f(\delta P_S Cl f^{-1}(B))\subseteq Cl_\delta(f\big(f^{-1}(B)\big)=Cl_\delta(B)$. Hence $\delta P_S Cl(f^{-1}(B)\subseteq f^{-1}(Cl_\delta(B))$.

(c)⇒ (d). Let F be any δ-closed set of Y. By (c), we have $\delta P_S\big(Cl f^{-1}(F)\big)\subseteq f^{-1}(Cl_\delta F)=f^{-1}(F)$ and hence $f^{-1}(F)$ is δP_S-closed set in X.

(d)⇒(e). Let V be any δ-open set of Y. Then Y \ V is δ-closed set of Y and by (d), we have $f^{-1}(Y \setminus V) = X \setminus f^{-1}(V)$ is δP_S-closed set in X. Hence $f^{-1}(V)$ is δP_S -open set in X.

(e)⇒ (f). For each subset B of Y. We have $Int_\delta B\subseteq B$. Then $f^{-1}(Int_\delta B)\subseteq f^{-1}(B)$. By(e), $f^{-1}(Int_\delta B)$ is δP_S-open set in X. Then $f^{-1}(Int_\delta B)\subseteq\delta P_S Int\, f^{-1}(B)$.

(f)⇒ (a). Let x ∈ X and V be any regular open set of Y containing x. Hence V is δ-open.

$\therefore \delta int(V)=V \longrightarrow (1)$

Moreover, by (f), $f^{-1}(\delta int(V))\subseteq \delta P_S int(f^{-1}(V)$ (2) ⟶

From (1) & (2), $f^{-1}(V)\subseteq\delta P_S int f^{-1}(V)$

$\therefore f^{-1}(V)$ is a δP_S-open set in X which contains x and we know $f(f^{-1}(V))\subseteq V$. Hence by Proposition 3.9 (c) we get f is almost δP_S-continuous.

Proposition3.13. For a function $f:(X,\tau)\to(Y,\sigma)$, the following statements are equivalent:

a) f is almost δP_S-continuous.
b) $\delta P_S Cl f^{-1}(V)\subseteq f^{-1}(ClV)$, for each β-open set V of Y.
c) $f^{-1}(IntF)\subseteq\delta P_S Int f^{-1}(F)$, for each β-closed set F of Y.
d) $f^{-1}(IntF)\subseteq\delta P_S Int f^{-1}(F)$, for each semi-closed set F of Y.

e) δP_SClf^{-1}(V)⊆f^{-1}(ClV),foreachsemi-opensetVofY.

Proof. (a) ⇒ (b). Let V be any β-open set of Y. It follows from Lemma 2.14(b) that Cl V is regular closed set in Y. Since f is almostδP_S -continuous, by Proposition3.10(d), f^{-1}(Cl V) isδP_S-closed set in X. Therefore, we obtain $f^{-1}(Cl(V) = \delta P_S f^{-1}Cl(V)$ ⟶ (1)

Now$V \subseteq Cl(V) \Rightarrow f^{-1}(V) \subseteq f^{-1}\big(Cl(V)\big) \Rightarrow \delta P_S Cl\big(f^{-1}(V)\big) = \delta P_S Cl\big(f^{-1}Cl(V)\big) = f^{-1}Cl(V))$ [From (1)]

Hence $\delta P_S Cl(f^{-1}(V) \subseteq f^{-1}(Cl(V))$.

(b)⇒ (c). Let F be any β-closed set of Y. Then Y \ F is β-open set of Y and by (b), we have δP_SCl f^{-1}(Y \ F) ⊆ f^{-1}(Cl (Y \ F)) and δP_SCl (X \ f^{-1}(F)) ⊆ f^{-1}(Y \ Int F) and hence, X \ δP_SIntf^{-1}(F)⊆X\f^{-1}(IntF).Therefore,f^{-1}(IntF)⊆δP_SIntf^{-1}(F).

(c)⇒ (d). Obvious since every semi-closed set isβ-closed.

(d)⇒ (e). Let V be any semi-open set of Y. Then Y \ V is semi-closed set in Y and by (d), wehavef^{-1}(Int(Y\V))⊆δP_SIntf^{-1}(Y\V)andf^{-1}(Y\ClV)⊆δP_SInt(X\f^{-1}(V))andhence, X\f^{-1}(ClV)⊆X\$\delta P_S$Clf^{-1}(V).Therefore,$\delta P_S$Clf^{-1}(V)⊆f^{-1}(ClV).

(e)⇒ (a). Let F be any regular closed set of Y. Then F is a semi-open set of Y. By (e), we have δP_SClf^{-1}(F)⊆ f^{-1}(ClF)=f^{-1}(F)[Since every regular closed set is closed].Thisshowsthatf^{-1}(F)isaδP_S-closedsetinX.Therefore,by Proposition3.10(d), f is almostδP_S-continuous.

Corollary 3.14. For a function $f:(X,\tau) \to (Y,\sigma)$, the following statements are equivalent:

a) f is almost δP_S-continuous.

b) $\delta P_S Cl(f^{-1}(V) \subseteq f^{-1}(\alpha Cl(V))$,foreachβ-opensetVofY.

c) $\delta P_S Cl(f^{-1}(V) \subseteq f^{-1}(Cl_\delta(V))$, for each β-open set V of Y.

d) $\delta P_S Cl(f^{-1}(V) \subseteq f^{-1}(\delta P_S Cl(V))$,foreachsemi-opensetVofY.

e) $\delta P_S Cl(f^{-1}(V) \subseteq f^{-1}(pCl(V))$,foreachsemi-opensetVofY.

Proof. (a) ⇒ (b). Follows from Proposition 3.13and Lemma 2.15[b]

(b)⇒ (c). Follows from the fact that αCl V ⊆Cl_δV.

(c)⇒ (d) and (d) ⇒ (e). Follows from Proposition 3.13and Lemma2.15[a].

(e) ⇒ (f). Follows from Proposition 3.13and Lemma 2.15[a].

The following result also can be concluded directly.

Corollary 3.15. For a function $f:(X,\tau) \to (Y,\sigma)$, the following statements are equivalent:

a) f is almost δP_S-continuous.

b) f^{-1}(αIntF)⊆δP_SIntf^{-1}(F),foreachβ-closedsetFofY.

c) f^{-1}(Int$_\delta$F)⊆δP_SIntf^{-1}(F),foreachβ-closedsetFofY.

d) f^{-1}(δP_SIntF)⊆δP_SIntf^{-1}(F),foreachsemi-closedsetFofY.

e) f^{-1}(pIntF)⊆δP_SIntf^{-1}(F),foreachsemi-closedsetFofY.

Proposition3.16. A function $f:(X,\tau) \to (Y,\sigma)$ is almost δP_S-continuous if and only if f^{-1}(V) ⊆δP_SInt f^{-1}(IntCl V)for each preopen set V of Y.

Proof. Necessity. Let V be any preopen set of Y. Then V ⊆IntCl V and IntCl V is a regular open set in Y. Since f is almost δP_S-continuous, by Proposition 3.10(e), f^{-1}(IntCl V) is δP_S-open set in X and hence we obtain that f^{-1}(V) ⊆ f^{-1}(IntCl V)= δP_SIntf^{-1}(IntCl V).

Sufficiency. Let V be any regular open set of Y. Then V is a preopen set of Y. By hypothesis, we have f $^{-1}$(V) ⊆δP_SInt f $^{-1}$(IntClV) = δP_SInt f $^{-1}$(V). Therefore, f $^{-1}$(V) is δP_S-open set in X and hence by Proposition 3.10(e), fis almostδP_S-continuous.

We obtain the following corollary.

Corollary 3.17. The following statements are equivalent for a function $f: (X, \tau) \to (Y, \sigma)$:

a) f is almost δP_S-continuous.
b) f^{-1}(V)⊆δP_SIntf^{-1}(sClV)foreachpreopensetVofY
c) δP_SClf^{-1}(ClIntF)⊆f^{-1}(F)foreachpreclosedsetFofY.
d) δP_SClf^{-1}(sIntF)⊆f $^{-1}$(F)foreachpreclosedsetFofY.

Corollary 3.18. For a function $f: (X, \tau) \to (Y, \sigma)$, the following statements are equivalent:

a) f is almost δP_S-continuous.
b) For eachneighborhoodVof f(x),x∈δP_SIntf^{-1}(sClV).
c) For eachneighborhoodVoff(x), x∈δP_SIntf^{-1}(IntClV).

Proof. Follows from Proposition3.16 andCorollary3.17.

Proposition3.19. Let $f: (X, \tau) \to (Y, \sigma)$ be an almost δP_S-continuous function and let V be any open subset of Y. If x ∈δP_SCl f $^{-1}$(V) \ f $^{-1}$(V), then f (x) ∈δP_SCl V.

Proof. Let x ∈ X be such that x ∈δP_SCl f $^{-1}$(V) \ f $^{-1}$(V) and suppose $f(x) \notin \delta P_S Cl(V)$. Then there exists a δP_S-open set H containing f (x) such that H ∩ V = ∅. Then Cl H ∩ V =∅ implies IntClH ∩V = ∅ and IntClH is a regular open set. Since f is almost δP_S-continuous, by Proposition3.9(c), there exists a δP_S-open set U in X containing x such that f (U)⊆IntClH . Therefore, f (U) ∩ V = ∅. However, since $x \in \delta P_S Cl\big(f^{-1}(V)\big), U \cap f^{-1}(V) \neq \emptyset$for every δP_S-open set U in X containing x, so that$f(U) \cap V \neq \phi$. We have a contradiction. It follows that $f(x) \in \delta P_S Cl(V)$.

Proposition3.20. If a function $f: (X, \tau) \to (Y, \sigma)$ is almost precontinuous. Then the following statements are equivalent:

a) f is almost δP_S-continuous.
b) For each x ∈ X and each open set V of Y containing f (x), there exists a semi-closed set F in X containing x such that f (F) ⊆IntδClV.
c) For each x ∈ X and each open set V of Y containing f (x), there exists a semi-closed set F in X containing x such that f (F) ⊆sClV.
d) Foreachx∈XandeachregularopensetVofYcontainingf(x),thereexistsasemi-closed set F in X containing x such that f (F) ⊆ V.
e) For each x ∈ X and each δ-open set V of Y containing f (x), there exists a semi-closed set F in X containing x such that f (F) ⊆ V.

Proof. (a) ⇒ (b). Let x ∈ X and let V be any open set of Y containing f (x). By (a), there exists a δP_S-open set U of X containing x such that f (U) ⊆IntδCl V. Since U is δP_S-open set, so for each x ∈ U there exists a semi-closed set F in X such that x ∈ F ⊆ U.Therefore, we havef (F)⊆IntδClV.

(b)⇒ (c).Obvious as $intCl(V) \subseteq sCl(V)$.

(c)⇒ (d). Let x ∈ X and let V be any regular open set of Y containing f (x). Then V is an open set of Y containing f (x). By (c), there exists a semi-closed set F in X containing x such that f (F) ⊆sClV. Since V is regular open and hence is preopen. Therefore, by Lemma 2.14[a],f (F)⊆IntClV.SinceVisregular open,thenf (F)⊆V.

(d)⇒ (e). Let x ∈ X and let V be any δ-open set of Y containing f (x). Then for each f (x) ∈ V, there exists an open set G containing f (x) such that G ⊆IntClG⊆ V. Since IntClGis a regular open set of Y containing f (x), by (d), there exists a semi-closed set F in X containing x such that f (F) ⊆IntClG⊆V. This completes the proof.

(e)⇒(a).LetVbeanyδ-opensetofY.Wehavetoshowthatf^{-1}(V)isδP_S-opensetinX.Since f is almost precontinuous, by Proposition 2.17(c), f $^{-1}$(V) is preopen set in X. Since every preopen set is δ-preopen we get $f^{-1}(V)$ is δ-preopen. Let x ∈ f $^{-1}$(V), then f (x) ∈ V. By (e), there exists a semi-closed set F of X containing x such that f(F)⊆V.Whichimpliesthatx∈F⊆f^{-1}(V).Therefore,f^{-1}(V)isδP_S-opensetinX.Henceby Proposition3.12(e), f is almostδP_S-continuous.

Proposition3.21. A function $f:(X,\tau)\rightarrow(Y,\sigma)$is almost δP_S-continuous if and only if $f:(X,\tau)\rightarrow(Y,\sigma_s)is\delta P_S$-continuous.

Proof. Necessity. Let H ∈σ_s, then H is a regular open set in (Y, σ). Since $f:(X,\tau)\rightarrow(Y,\sigma)$ is almost δP_S-continuous, by Proposition3.10(e), f $^{-1}$(H) is δP_S-open set in X. Therefore, $f:(X,\tau)\rightarrow(Y,\sigma_s)is\delta P_S$-continuous.

Sufficiency. Let G be any regular open set in (Y, σ). Then$G\in\sigma_s$. Since $f:(X,\tau)\rightarrow(Y,\sigma_s)$ is δP_S-continuous, by Definition 2.16, f $^{-1}$(G) is δP_S-open set in X. Therefore, by Proposition3.10(e), $f:(X,\tau)\rightarrow(Y,\sigma)$isalmost$\delta P_S$-continuous.

Proposition3.22. Let X be a locally indiscrete space. Then the function $f:(X,\tau)\rightarrow(Y,\sigma)$ is almost δP_S -continuous if and only if $f:(X,\tau)\rightarrow(Y,\sigma_s)$is continuous.

Proof. Necessity. Let $H\in\sigma_s$, then H is a regular open set in (Y, σ). Since $f:(X,\tau)\rightarrow(Y,\sigma)$ is almost δP_S-continuous, by Proposition3.10(e), f^{-1}(H) is δP_S -open set in X. Since X is locally indiscrete space, by Proposition2.11(c), f^{-1}(H) is open set in X. Therefore, $f:(X,\tau)\rightarrow(Y,\sigma_s)$is continuous.

Sufficiency. Let G be any regular open set in (Y, σ). Then G ∈σ_S . Since $f:(X,\tau)\rightarrow(Y,\sigma_s)$is continuous, so f $^{-1}$(G) is open set in X. Since X is locally indiscrete space, by Proposition 2.11(c), f $^{-1}$(G) is δP_S-open set in X.Therefore, by Proposition 3.10(e), $f:(X,\tau)\rightarrow(Y,\sigma)$is almost δP_S-continuous.

Corollary 3.23. If $f:(X,\tau)\rightarrow(Y,\sigma)$is almost δP_S-continuous function if and only if f is almost continuous where X is locally indiscrete space.

The following is the pasting lemma for almostδP_S-continuity

Proposition 4.7. Let X = R_1∪ R_2, where R_1 and R_2 are regular open sets in X. Let f : R_1 → Y and g : R_2 → Y be almost δP_S-continuous. If f (x) = g (x) for each x ∈ R_1 ∩ R_2. Then h : R_1∪ R_2 → Y such that h(x) = f (x) for x ∈ R_1 and h(x) = g (x) for x ∈ R_2 is almost δP_S-continuous.

Proof. Let O be a regular open set of Y. Now h^{-1}(O) = f $^{-1}$(O) ∪ g $^{-1}$(O). Since f and g are almost δP_S-continuous, by Proposition 3.10(e), f $^{-1}$(O) and g $^{-1}$(O) are δP_S-open set in $R_1$and R_2respectively. But $R_1$and $R_2$are both regular open sets in X. Then by Lemma 2.13(c),f $^{-1}$(O) and g $^{-1}$(O) are δP_S-open sets in X. Since union of two δP_S-open sets isδP_S-open, so h^{-1}(O) is a δP_S-open set in X. Hence by Proposition 3.10(e), h is almost δP_S-continuous.

Proposition 4.8. Let $f:(X,\tau)\rightarrow(Y,\sigma)$ be almost δP_S-continuous surjection and A be either δ-open or regular semi-open subset of X. If f is an open function, then the function g : A → f (A), defined by g (x) = f (x) for each x ∈ A, is almost δP_S-continuous.

Proof. Suppose that H = f (A). Let x ∈ A and V be any open set in H containing $g(x)$. Since H is open in Y and V is open in H, so V is open in Y. Since f is almost δP_S-continuous, hence there exists a δP_S-open set U in X containing x such that $f(U)\subseteq Int(\delta Cl(V))$. Taking $W=U\cap A$, since A is either open or regular semi-open subset of X, by Lemma 2.13(d), W is a δP_S-open setinAcontainingx and $g(W)\subseteq Int_YCl_Y(V)\cap H=Int_HCl_H(V)$. Then $g(W)\subseteq Int_HCl_H(V)$. This shows that g is almost δP_S-continuous.

Proposition 4.9. Let $f:(X,\tau)\rightarrow(Y,\sigma)$Y be almost δP_S-continuous. If Y is a preopen subset of Z, then $f:(X,\tau)\rightarrow(Z,\eta)$is almost$\delta P_S$-continuous.

Proof. Let V be any regular open set of Z. Since Y is preopen, by Lemma 2.12(a), V ∩ Y is a regular open set in Y. Since f: X → Y is almost δP_S-continuous, by Proposition 3.10(e), f^{-1}(V ∩ Y) is a δP_S-open set in X. But f (x) ∈ Y for each x ∈ X. Thus $f^{-1}(V)=f^{-1}(V\cap Y)$ is a δP_S-open set of X. Therefore, by Proposition 3.10, $f:(X,\tau)\rightarrow(Z,\eta)$is almost$\delta P_S$-continuous.

Proposition 4.10. Let $f:(X,\tau)\rightarrow(Y,\sigma)$and $g:(Y,\sigma)\rightarrow(Z,\eta)$be functions.Then the composition function $g\circ f:(X,\tau)\rightarrow(Z,\eta)$ is almost δP_S-continuous if f and g satisfy one of the followingconditions:

a) f is δP_S-continuous and g is almostcontinuous.
b) f is almost δP_S-continuous and g isδ-continuous.
c) f is continuous and open and g is almost δP_S-continuous.

Proof. (a). Let W be any regular open subset of Z. Since g is almost continuous, (so g) $^{-1}$(W) is open subset of Y. Since f is δP_S-continuous, by Definition 2.17, $(gof)^{-1}(W)=f^{-1}(g^{-1}(W))$ is δP_S-open subset in X. Therefore, by Proposition 3.10(e), gof is almost δP_S-continuous.

(b). Let W be any δ-open subset of Z. Since g is δ-continuous, sog^{-1}(W) is δ-open subset of Y. Since f is almost δP_S-continuous, by Proposition 3.12(e), $(gof)^{-1}(W)=f^{-1}(g^{-1}(W))$ is δP_S-open subset in X . Therefore, by Proposition 3.12(e), gof is almost δP_S-continuous.

(c). Let W be any regular open subset of Z. Since g is almost δP_S-continuous, by Proposition 3.10(e), g^{-1}(W) is δP_S-open subset of Y. Since f is continuous and open, by Proposition 2.22, $f^{-1}(g^{-1}(W))=(gof)^{-1}(W)$ is a δP_S-open set in X . Hence by Proposition 3.10(e),$g\circ f$ is almost δP_S- continuous.

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