International Conference on Applied Mathematics and Computing (ICAMC2023) – Proceedings, Organized by PG and Research Department of Mathematics, Dwaraka Doss Goverdhan Doss Vaishnav College, Chennai, Tamilnadu, ISBN: 978-93-90956-07-4

δJ-CONTINUOUS FUNCTIONS

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Abstract:
Different kinds of δJ-continuous function are introduced.

Keywords: δJ- continuous, Strongly δJ- continuous, super continuous, totally-continuous .

Introduction

In 1968, Velico proposed δ-open sets which are stronger than open sets. Levine has brought generalized closed sets in 1970. Later in 2016, Meenakshi P L has introduced a new sets namely η*open sets, a union of r*open sets, which is placed between δ open set and open set. Then a new class of sets namely J-closed sets was introducing η*open sets in topological spaces. This class of J-closed sets is placed between that of generalized closed(g-closed) sets and generalized δ-closed sets. In the year 2020,Meenakshi P L has introduced the concept of J-continuous Functions. In 2022, Vethavarna K P has introduced δJ closed sets. In this chapter , δJ continuous functions, different kinds of δJ-continuous functions namely Quasi δJ –continuous functions, Totally δJ –continuous functions, Strongly δJ-continuous functions and Contra δJ –continuous functions are introduced. In section 1, a topological space is represented by (g,τ).

1.Preliminaries

Definition 1.1: Let (g,τ) be a topological space. If D is a non-empty subset of (g,τ) then the intersection of all closed sets containing D is called closure of D and is denoted by Cl(D).
The union of all open sets contained in D is called interior of D and is denoted by int(D).

Definition 1.2: Let (g,τ) be a topological space. A subset D of space is called
Regular closed set (Stone, 1937) if D=Cl(int(D))
Semi-closed set (Levine, 1963) if int(Cl(D)) ⊆ D
α-closed set (Njastad, 1965) if Cl(int(Cl(D))) ⊆ D
π-closed set (Zaitsav, 1968) if it is the finit union of regular closed sets
Pre-closed set (Mashhour et al., 1982) if Cl(int(D)) ⊆ D
Semi pre-closed set (Andrijevic, 1986) if int(Cl(int(D))) ⊆ D
The complements of the above mentioned sets are called **regular open, semi-open, α-open, π-open and pre-open, semi pre-open sets** respectively.
The intersection of all **regular closed** (resp. **semi-closed, α-closed, π-closed, pre-closed and semi pre-closed**) subsets of (g,τ) containing D is called the **regular closure (**resp. **Semi-closure, α-closure, π-closure, preclosure and semi pre-closure)** of D and is denoted by rCl(D) (resp. sCl(D), αCl(D), πCl(D), pCl(D) and spCl(D)).

Definition 1.3: The **δ-interior** (Velicko, 1968) of a subset D of Y is the union of all regular open sets of Y contained in D and is denoted by intδ(D). The subset D is called **δ-open** if D= intδ(D), i.e. a set is δ-open if it is the union of regular open sets, the complement of δ-open is called **δ-closed.**
Alternatively, a set D ⊆ Y is δ-closed if D = δCl(D), where **δCl(D)** is the intersection of all regular closed sets of (g,τ) containing D.

Definition 1.4: A subset D of a topological space (g,τ) is called **generalized Closed** (briefly **g-closed**) (Levine, 1970) if Cl(D) ⊆ M whenever D ⊆ M and M is open in (g,τ). The complement of g-closed is a **g-open set.**

Definition 1.5 [Pious Annalakshmi, 2016]: Let (Y,ζ) be a topological space. A subset D of (Y,ζ) is called **regular*-open (or r*-open)** if D=int(Cl*(D)). The complement of regular*-open set is called **regular*-closed set.** The union of all regular*-open sets of Y contained in D is called **regular*-interior** and is denoted by r*int(D). The intersection of all regular*-closed sets of Y containing D is called **regular*-closure** is denoted by r*Cl(D).

Definition 1.6 [Meenakshi PL, 2019): A subset D of a topological space (g,τ) is called **η*-open set** if it is a union of regular*-open sets (r*-open sets). The complement of a η*-open set is called a **η*-closed set.** A subset D of a topological space (g,τ) is called **η*-Interior** of D is the union of a η*-open sets of Y contained in D. We denote the symbol by η*-Int(D). The intersection of all η*-closed sets of Y containing D is called **η*-closure** is denoted by η*-Cl(D).

Definition 1.7: A subset D of a topological space (g,τ) is called
1) **generalized semi-closed** (briefly **gs-closed**) (Arya et al., 1990) if sCl(D) ⊆ M whenever D ⊆ M and M is open in (g,τ).
2) **regular generalized closed** (briefly **rg-closed**) (Palaniappan, et. al.,1993) if Cl(D) ⊆ M whenever D ⊆ M and M is regular open in (g,τ).
3) **regular weakly generalized closed** (briefly **rwg-closed**) (Nagaveni, 1999) if Cl(int(D)) ⊆ M whenever D ⊆ M and M is regular open in (g,τ).
4) ***π*-generalized closed** (briefly ***π*g-closed**) (Dontchev et.al.,2000) if Cl(D) ⊆ M whenever D ⊆ M and M is π-open in (g,τ).
5) **generalized δ-closed** (briefly **gδ-closed**) (Dontchev, 2000) if sCl(D) ⊆ M whenever D ⊆ M and M is δ-open in (g, τ).
6) ***π*-generalized semi-closed** (briefly ***π*gs-closed**) (Aslim et.al.,2006) if sCl(D) ⊆ M whenever D ⊆ M and M is π-open in (g, τ).
7) ***π*-generalized pre-closed** (briefly ***π*gp-closed**) (Park, 2006) if pCl(D) ⊆ M whenever D ⊆ M and M is π-open in (g, τ).
8) ***π*-generalized α-closed** (briefly ***π*gα-closed**) (Janaki, 2009) if αCl(D) ⊆ M whenever D ⊆ M and M is π-open in (g, τ).
9) ***π*-generalized semi pre-closed** (briefly ***π*gsp-closed**) (Sarsak,2010) if spCl(D) ⊆ M whenever D ⊆ M and M is π-open in (g, τ).
10) **generalized semi pre regular-closed** (briefly **gspr-closed**) (Sarsak et.al.,2010) if spCl(D) ⊆ M whenever D ⊆ M and M is regular open in (g, τ).
11) **generalized pre regular-closed** (briefly **gpr-closed**) (Gnanambal, 1998) if pCl(D) ⊆ M whenever D ⊆ M and M is regular open in (g, τ).
12) **J-closed** [Meenakshi PL,2021] if Cl(D) ⊆ M whenever D ⊆ M and M is η*-open in (g, τ).
13) **δ generalized -closed** (briefly **δg-closed**) (Dontchev, 1996) if δCl(D) ⊆ M whenever D ⊆ M and M is open in (g, τ).
14) **δ generalized star -closed** (briefly **δg*-closed**) (Sudha, 2014) if δCl(D) ⊆ M whenever D ⊆ M and M is g-open in (g, τ).
15) **g*-closed** (Veerakumar, 2000) if Cl(D) ⊆ M whenever D ⊆ M and M is g-open in (g, τ).
16) **ĝ -closed** (Veerakumar, 2003) if Cl(D) ⊆ M whenever D ⊆ M and M is semi-open in (g, τ).
17) **#gs -closed** (Veerakumar, 2005) if sCl(D) ⊆ M whenever D ⊆ M and M is *g-open in (g, τ).
18) ***g-closed** (Veerakumar, 2006) if Cl(D) ⊆ M whenever D ⊆ M and M is ĝ-open in (g, τ).
19) **g*s-closed** (Pushpalatha et al., 2000) if Cl(D) ⊆ M whenever D ⊆ M and M is gs-open in (g, τ).
20) **δg‡-closed** (Dontchev, 2000) if δCl(D) ⊆ M whenever D ⊆ M and M is δ-open in (g, τ).
21) **J*-closed** [Meenakshi PL,2021] if η*-Cl(D) ⊆ M whenever D ⊆ M and M is η*-open in (g, τ).
22) **J**-closed** [Meenakshi PL,2021] if η*-Cl(D) ⊆ M whenever D ⊆ M and M is η*-open in (g, τ).
The complements of the above mentioned sets are called their respective open sets.

Remark 1.8 :
(i) π-closed(open) regular closed(open) δ-closed(open) η*-closed(open) closed(open) semi-closed(open) semi preclosed(open).
(ii) π-closed(open) regular closed(open) δ-closed(open) η*-closed(open) closed(open)closed(open) α-closed(open).
(iii) π-closed(open) regular closed(open) δ-closed(open) η*-closed(open) closed(open) g-closed(open).
(iv) π-closed(open) regular closed(open) δ-closed(open) η*-closed(open) closed(open) pre-closed(open).

Definition 1.9 . Afunction f: g → h is said to be
- **J -Continuous (** Levine,1970) if for every closed set U in (h,σ),$f^{-1}(U)$ is a closed set in (g,τ).
- *s***trongly J- continuous (**Levine,1960) if the inverse image of every subset of (h,σ) is clopen in (g, τ).

- δ **−continuous** (Noiri,1980) if for every δ-closed set U of (h,σ),f^{-1}(U) is a δ-closed set of (g,τ).
- **Totally J- continuous** (Jain,1980) if the inverse image of every open set of (h,σ) is δ clopen in(g,τ)
- **Super J- continuous** (Munshi,1982) if for every closed set U of (h, σ),f^{-1}(U) is a δ closed set of (g, τ).
- **g-continuous**(Balachandran et al.,)if for every closed set U in (h,σ),f^{-1}(U) is a g closed set in (g, τ)
- r**g-continuous**(Palaniappan,et.al.,)if f^{-1}(U) is a rg closed set in (g, τ) for every closed set U in (h, σ)
- **gs-continuous**(Devi et.al., 1993)if f^{-1}(U) is a gs closed set in (g, τ) for every closed set U in (h, σ)
- **Contra J-continuous**(Dontchev,1996)if the inverse image of every closed set of (h,σ) is δ open set in(g,τ)
- δ**g-continuous**(Dontchev,1996)if f^{-1}(U) is a δ g closed set in (g, τ) for every closed set U in (h, σ)
- **gpr-continuous**(Gnanambal,1997)if f^{-1}(U) is a gpr closed set in (g, τ) for every closed set U in (h, σ)
- **rwg-continuous**(Nagaveni , 1999) if f^{-1}(U) is a rwg closed set in (g, τ) for every closed set U in (h, σ)
- **gδ-continuous**(Dontchev,2000) iff^{-1}(U) is a gδ closed set in (g, τ) for every closed set U in (h, σ)
- **ĝ-continuous**(Veerakumar,2003)if f^{-1}(U) is a ĝ open set in (g, τ) for every open set U in (h, σ)
- π**gp-continuous**(Park,2004) if f^{-1}(U) is a πgp closed set in (g, τ) for every closed set U in (h, σ)
- π**gs-continuous**(Aslim,2006)if f^{-1}(U) is a πgs closed set in (g, τ) for every closed set U in (h, σ)
- π**gα-continuous**(Park,2004) if f^{-1}(U) is a πgα closed set in (g, τ) for every closed set U in (h, σ)
- π**g-continuous**(Ekici et.al.,2007) if f^{-1}(U) is a πg closed set in (g, τ) for every closed set U in (h, σ)
- π**gp-continuous**(Park,2004) if f^{-1}(U) is a πgp closed set in (g, τ) for every closed set U in (h, σ)
- π**gsp-continuous**(Park,2004) if f^{-1}(U) is a πgsp closed set in (g, τ) for every closed set U in (h, σ)
- **gspr-continuous**(Devi et.al., 1993)if f^{-1}(U) is a gspr closed set in (g, τ) for every closed set U in (h, σ)
- **g*s-continuous**(Pushpalatha et.al.,)if f^{-1}(U) is a g*s closed set in (g, τ) for every closed set U in (h, σ).
- δ**g*-continuous**(Pushpalatha et.al.,)if f^{-1}(U) is a δg* closed set in (g, τ) for every closed set U in (h, σ)

2.2.δJ -continuous Function in Topological Spaces

2.2. δJ-continuous Function

The properties of δJ-continuous functions in topological spaces are introduced and some of their related properties are analysed here.

DEFINITION2.2.1 : A function f(g,τ)→ (h,σ) is said to be δJ –continuous function if the inverse image of every closed set in (h,σ) is δJ closed in (g,τ).

Example 2.2.2 : Let f: (g,τ)→(h,σ) be the many one into fun ction defined by f(a)={b},f(b)={c},f(c)={a}.Consider g=h={a,b,c} with τ={g,$\emptyset$,{a}} and σ ={h,$\emptyset$,{a},{b,c}}, τ^c={g, ,$\emptyset$,{b,c}}, σ^c={h, ,$\emptyset$,{b,c},{a}}.Then f is δJ- Continuous as δJC(g,τ)={g,$\emptyset$,{b},{c},{a,b},{a,c},{b,c}}.

Proposition 2.2.3: A δJ-continuous function f:(g,τ)→(h,σ) is a J- continuous function but the converse is not true.

Proof Given f: (g,τ)→(h,σ) is a δJ –continuous function . Let U be any closed set in (h,σ) .Since f is a δJ continuous, f^{-1} inverse of (U) is δJ closed in (g,τ).Then f^{-1}(U) is J closed in (g,τ).Hence f is J-continuous .

Counter Example 2.2.4: Let f:(g,τ)→(h,σ) be the function defined by f(a)={a},f(b)={c},f(c)={b}Let g=h={a,b,c,} with τ={g,$\emptyset$,{a},{b},{a,b}} and σ={h,$\emptyset$,{a},{b,c}}.Here τ^c ={g,$\emptyset$, {b,c},{a,c},{c}},σ^c ={h,$\emptyset$, {a},{b,c}} and $\delta\delta$ J (g, τ)={g, ,$\emptyset$,{c},{b, c},{a ,c}} .Then f is J- continuous as JC=P(g) but not δJ continuous. Because for the closed sets {a} in (h,σ) the inverse image are not δJ closed in (g,τ).

Proposition 2.2.5: A δJ-continuous function f: (g,τ)→(h,σ) is a gs -continuous function but the converse is not true.

Proof Given f:(g,τ) → (h,σ) is a δJ-continuous function. Let U be an$y$ closed set in (h,σ) .Since f is a δJ continuous,f^{-1}(U) is δJ closed in (g,τ).Then f^{-1}(U) is gs closed in (g,τ).Hence f is gs- continuous .

CounterExample2.2.6: let f(g,τ) → (h,σ) be the function defined by f(a)={c},f(b)={a},f(c)={b} then f^{-1}(a)={b},f^{-1}(b)={c},f^{-1}(c)={a}.Consider g=h={a,b,c} with τ={g,ϕ,{a},{b,c}} and σ={h,ϕ,{a,b}}.Here σ^c={h,$\emptyset$,{c}}, δc (h, σ)={h,$\emptyset$,{a},{b,c}} and δJ closed(g, τ)={g,$\emptyset$,{b},{c},{a,b},{a,c}}.Then f is gs-continuous as gs(g,τ)=P(g) but not δJ -continuous. Because for the closed set {c} in(h,σ),f^{-1}(c)={a} is not δJ closed in(g,τ).

Proposition 2.2.7:A δJ- continuous function f:((g,τ)→ (h,σ) is a πg-continuous function but the converse is not true.

Proof Given f:(g,τ) → (h,σ) is a δJ-continuous function. Let U be any closed set in (h,σ) .Since f is a δJ-continuous,f^{-1}(U) is δJ closed in (g, τ).Then f^{-1}(U) is πg closed in (g,τ).Hence f is πg − continuous .

CounterExample 2.2.8: Let f:(g,τ)→(h,σ) be the function defined by f(a)={b},f(b)={c},f(c)={a} then f^{-1}(a)={c},f^{-1}(b)={a},f^{-1}(c)={b}.Consider g=h={a,b,c} with τ={g,$\emptyset$,{a},{b},{a,b},{a,c}} and σ={h, ,$\emptyset$,{a,b}}.Here τ^c={g, ,$\emptyset$,{b,c},{a,c},{c},{b}},σ^c={h, ,$\emptyset$,{c},δc (h, σ) ={h, ,$\emptyset$,{b},{a,c}} and δJ(g, τ)={g, ,$\emptyset$}. Then f is πg- continuous as πg(g, τ)=P(g) but not δJ - continuous. Because for the closed set {b} in (h, σ) f^{-1}(b)={a} is not δJ closed in (g, τ).

Proposition 3.2.9: A δJ-continuous function f:(g,τ)→ (h,σ) is a πgs – continuous function but the converse is not true.

Proof Given f:(g,τ) → (h,σ) is a δJ-continuous function. Let U be any closed set in (h,σ) .Since f is a δJ-continuous,f^{-1}(U) is δJ closed in (g,τ).Then f^{-1}(U) is πgs closed in (g,τ).Hence f is πgs -continuous .

Counter Example 2.2.10: Let f:(g,τ)→(h,σ) be the function defined by f(a)={a},f(b)={c},f(c)={b} then f^{-1}(a)={a},f^{-1}(b)={c},f^{-1}(c)={b}.Consider g=h={a,b,c} with τ={g,$\emptyset$,{a},{b},{a,b}} and σ={h, ,$\emptyset$,{a,b}}.Then τ^c={g, ,$\emptyset$,{b,c},{a,c},{c}}, σ^c={h, ,$\emptyset$,{c}}, δc (h,σ)={h, ,$\emptyset$,{c},{a,c},{b,c}} and δJ(g, τ)={g,$\emptyset$,{c},{a,c},{b,c}}.Then f is πgs-continuous as πgs(g, τ)={g,$\emptyset$,{a},{b},{c},{a,c},{b,c}} but not δJ-continuous. Because for the closed set {c} in (h,σ) f^{-1}(c)={b} is not δJ closed in (g, τ)

Preposition 2.2.11: A δJ-continuous function f:(g,τ)→ (h,σ) is a gspr-continuous function but the converse is not true.

Proof Given f:(g,τ) → (h,σ) is a δJ-continuous function. Let U be any closed set in (h,σ) .Since f is a δJ-continuous,f^{-1}(U) is δJ closed in (g,τ).Then f^{-1}(U) is gspr closed in (g,τ).Hence f is gspr- continuous .

Counter Example 2.2.12: Let f:(g,τ)→(h,σ) be theidentity function defined by f(a)={a},f(b)={b},f(c)={c} then f^{-1}(a)={a},f^{-1}(b)={b},f^{-1}(c)={c}.Consider g=h={a,b,c} with τ={g,$\emptyset$,{a},{b,c}} and σ={h,$\emptyset$,{a,b}}.Then τ^c={g, ,$\emptyset$,{a},{b,c}}, σ^c={h,$\emptyset$,{c}}, δc (h,σ)={h,$\emptyset$,{a},{b,c}} and δJ(g, τ)={g, ,$\emptyset$,{b},{c},{a,b},{a,c},{b,c}}.Then f is gspr -continuous as gspr(g, τ)=P(g) but not δJ- continuous. Because for the closed set {a} in (h,σ) f^{-1}(a)={a} is not δJ closed in (g, τ).

Proposition2.2.13: A δJ-continuous function f:(g,τ)→ (h,σ) is a gδ-continuous function but the converse is not true.

Proof Given f:(g,τ) → (h,σ) is a δJ-continuous function. Let U be any closed set in (h,σ) .Since f is a δJ-continuous,f^{-1}(U) is δJ closed in (g,τ).Then f^{-1}(U) is $g\delta$ closed in (g,τ).Hence f is $g\delta$ -continuous .

Counter Example 2.2.14:Let f:(g,τ)→(h,σ) be the identity function defined by f(a)={a},f(b)={b},f(c)={c} then f^{-1}(a)={a},f^{-1}(b)={b},f^{-1}(c)={c}.Consider g=h={a,b,c} with τ={g,$\emptyset$,{a},{b},{a,c},{a,b}} and σ={h,$\emptyset$,{a,b}}.Then τ^c={g, ,$\emptyset$,{b,c},{a,c},{b},{c}}, σ^c={h,$\emptyset$,{c}}, δc (h,σ)={h, ,$\emptyset$,{b},{a,c}} and δJ(g, τ)={g,$\emptyset$}.Then f is $g\delta$ -continuous as $g\delta$ (g, τ)=P (g) but not δJ –continuous. Because for the closed set {b} in (h,σ) f^{-1}(b)={b} is not δJ closed in (g, τ).

Theorem 2.2.15: A δJ - function f:(g,τ)→ (h,σ) is a

1. **πgα continuous function**
2. **gpr -continuous function**
3. **rwg -continuous function**
4. **$gspr$ -continuous function**
5. **πg-continuous function**
6. **πgp-continuous function**
7. **πgs-continuous function**

Proof Obvious

Remark 2.2.16 The converse of the above theorem 2.2.14 is not true. It can be seen from the following counter example.

Counter Example 2.2.17 In the above **counterexample2.2.14**πgα (g,τ)=gpr(g, τ)=rwg(g, τ)=gspr(g, τ)= πg(g, τ)=πgp(g, τ)=πgs(g, τ)=P(g).Then f is πgα-contiuous, gpr-continuous, gspr-continuous, πg-continuous, πgp-continuous, πgs-continuous but not δJ-continuous. Because for the closed set {b} in (h,σ),f^{-1}(b)={b} is not δJ closed in(g, τ).

Theorem 2.2.18 A function f:(g,τ)→ (h,σ) is a δJ-continuous if and only if the inverse image of every closed set in (h,σ) is δJ-open in (g, τ).

Proof Necessity Letf:(g,τ)→(h, σ) be δJ continuous and U be an$y$ open set in (h, σ).Then h-U is closed in (h, σ).Since f δJ continuous,f^{-1}(h-U)=h-f^{-1}(U) is δJ closed in (g, τ) and hence f^{-1}(U) is δJ open in (g, τ).

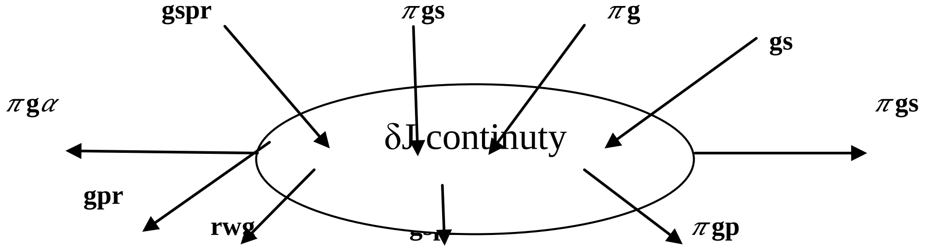
Sufficiency Assume that f^{-1}(V) is δJ open in (g, τ) for each open set V in (h, σ).Let V be a δ closed set in (h, σ).Then h-V is δ open in (h, σ).By assumption f^{-1}(h-V)=h-f^{-1}(V) is δJ open in (g, τ) which implies that f^{-1}(V) is δJ closed in (g, τ).Hence f is δJ-continuous.

Proposition 2.2.19 A super continuous function f:(g,τ)→ (h,σ) is a δJ - continuous function but the converse is not true.

Proof Given f:(g,τ) → (h,σ) is a super continuous function. Let U be any closed set in (h, σ).Since f is a super continuous function ,f^{-1}(U) is δ closed in (g,τ).Then f^{-1}(U) is a δJ closed in (g, τ).Hence f is δJ-continuous.

Counter Example 2.2.20 Let f:(g, τ) → (h, σ) be the function defined by f(a)={b},f(b)={c},f(c)={b} then f^{-1}(c)={b},f^{-1}(b)={a,c}.Consider g=h={a,b,c} with τ={g,$\emptyset$,{a},{a,b}} and σ={h,$\emptyset$,{a,b}}.Here τ^c={g,,$\emptyset$,{c},{b,c}}, σ^c={h,$\emptyset$,{c}}, δc (h,σ)={h, ,$\emptyset$,{a}} and δJ (g, τ)={g,$\emptyset$,{b},{c},{a,b},{a,c}}.Then f is δJ continuous as δC (g, τ)={g, ,$\emptyset$,} but not super continuous. Because for the closed set {c} in (h, σ),f^{-1}(c)={b} is not δ closed in (g, τ)

Remark 2.2.21 From the above discussions, we have the following diagram



Proposition 2.2.22 A totally continuous function f:(g,τ)→(h,σ) is a δJ- continuous function but the converse is not true.

Proof Given f:(g,τ) → (h,σ) is a totally continuous function. Let U be any open set in (h,σ).Since f is a totally continuous,f^{-1}(U) is clopen in (g, τ).We know that "Every clopen is δJ open set".Then f^{-1}(U) is δJ open in (g, τ).Hence f is δJ- continuous.

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