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SUPRA bT-SET CONNECTED FUNCTIONS IN SUPRA TOPOLOGICAL SPACES

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Abstract. In this paper, we came out with the new approach of functions called bT^{μ}-set connected functions and studied its properties. Also, we have retrieve separation axioms using bT^{μ}-set connected functions in supra topological spaces.

1. Introduction

Function play an necessary role in Mathematics. The latest growth of simulating and universality of continuous function, compactness, disconnectedness and separation axioms etc., are used by many topologist. The idea of clopen functions was introduced by Reilly and Vamanamurthy in the year 1983([14]). In the year 1999, Dontchev, Ganster and Reilly came out with a new function called regular set- connected([3]). The concept of regular set-connected functions is extended to almost clopen functions by Ekici in the year 2005[5]). The concept of supra topology were introduced by Mashhour et.al.([13]) and also studied S-continuous maps and S^{*}- continuous maps in Supra topological spaces. Also Mashhour et.al ([13]) discussed that many results of topological spaces, whereas some become false. Also the authors remarked that the intersection of two supra open sets need not be supra open and also the intersection of an open set and supra open set need not be supra open. They were also introduced S-T_0, S-T_1,S-T_2,S-$T_2^{;}$spaces and discussed their relationship with the topological spaces T_0, T_1, T_2, $T_2^{;}$ spaces. In 2008,R.Devi, S.Sampath kumar and M. Caldas([2]) introduced supraα-open sets and sα-continuous functions and investigate some of the basic properties of this function. Sayed and Takashi Noiri([15]) studied the approach of b-open set and supra b continuity in supra topological space in 2010 and also discussed about the

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relation between supra b-continuous maps and supra b-open maps. E. Ekici and M. Caldas([4]) introduced and discussed some properties of slightly-γcontinuous functions. Ganes M. Pandya, C. Janaki and I. Arockiarani([6]) introduced a new class of set connected functions called π-set connected and also investigated the relationship between π-set connected function, separation axioms and covering properties. Supra b-compact and supra b-Lindelof spaces were introduced by Jamal M. Mustafa.et.al([7]) and also discussed about the compactness and Lindelof spaces. The authors([8]) came out with a new concept of supra bT closed set and studied some of its properties.

The idea of this paper is to come out with the new theory of bT^μ-set connected functions and also to bring out new separation axioms utilized bT^μ-set connected functions in supra topological spaces. We define this class of functions by the requirement that the inverse image of each supra clopen (that is, supra open and supra closed) set in the codomain is bT^μ- clopen (that is, bT^μ-open and bT^μ- closed) in the domain. Also we investigate the fundamental properties of bT^μ-set connected functions.

In the present paper, (X, τ) and (Y, σ) represent supra topological spaces on which no separation axioms are assumed unless otherwise mentioned. Let A be a subset of X. We denote the supra interior and supra closure of a set by int^μ(A) and cl^μ(A) respectively.

2. Preliminaries

Definition 2.1. [13, 15] *A subfamily of μ of X is said to be a supra topology on X, if*

(i) *X, $\phi \in \mu$*

(ii) *if $A_i \in \mu$ for all i$\in$ J then $\cup A_i \in \mu$.*

The pair (X, μ) is called supra topological space. The elements of μ are called supra open sets in (X, μ) and complement of a supra open set is called a supra closed set.

Definition 2.2. [13, 15]

(i) *The supra closure of a set A is denoted by $cl^\mu(A)$ and is defined as $cl^\mu(A) = \cap\{B :$ B is a supra closed set and $A \subseteq B\}$.*

(ii) *The supra interior of a set A is denoted by $int^\mu(A)$ and defined as $int^\mu(A) = \cup\{B : B$ is a supra open set and $A \supseteq B\}$.*

Definition 2.3. [8] *A subset A of a supra topological space (X, τ) is called bT^μ-closed set if $bcl^\mu(A) \subset U$ whenever $A \subset U$ and U is T^μ- open in (X,τ).*

Definition 2.4. [8] *Let (X, τ) and (Y, σ) be two supra topological spaces. A function f:(X, τ) $\rightarrow$(Y, σ) is called bT^μ-continuous if $f^{-1}(V)$ is bT^μ-closed in (X, τ) for every supra closed set V of (Y, σ).*

Definition 2.5. [11] *A function f:(X, τ) $\rightarrow$(Y, σ) is called contra bT^{μ}-continuous if $f^{-1}(V)$ is bT^{μ}-closed in (X, τ) for every supra open set V of (Y, σ).*

Definition 2.6. [10] *A function f:(X, τ) $\rightarrow$(Y, σ) is called perfect bT^{μ}-continuous if the inverse image of every bT^{μ} - closed in (Y, σ) is both supra closed and supra open set V of (X, τ).*

Definition 2.7. [13] *A function f:(X, τ) $\rightarrow$(Y, σ) is called S^{*}-continuous if $f^{-1}(V)$ is supra closed in (X, τ) for every supra closed set V of (Y, σ).*

Definition 2.8. [9] *A map f:(X, τ) $\rightarrow$(Y, σ) is said to be a bT^{μ}-closed map (bT^{μ}-open map) if the image f(A) is bT^{μ}-closed(bT^{μ} -open) in (Y, σ) for each supra closed (supra open) set A in (X, τ).*

Definition 2.9. [10] *Let (X, τ) and (Y, σ) be two supra topological spaces. A function f:(X, τ) $\rightarrow$(Y, σ) is called Strongly bT^{μ}-continuous if $f^{-1}(V)$ is supra closed in (X, τ) for every bT^{μ}-closed set V of (Y, σ).*

Definition 2.10. [12] *A space X is called supra normal (resp. mildly normal)if for any pair of disjoint supra closed (resp. supra regular closed) subsets A and B of X, then there exist disjoint supra open sets U and V such that $A \subset U$, $B \subset V$.*

Definition 2.11. [12] *A space X is called almost supra normal if for each disjoint supra closed set A and supra regular closed set B of X, there exist disjoint supra open sets U and V such that $A \subset U$, $B \subset V$.*

Definition 2.12. [10] *Let (X,τ) and (Y,σ) be two supra topological spaces. A function f:(X,τ) $\rightarrow$(Y, σ) is called perfectly bT^{μ}-continuous if the inverse image of every bT^{μ}-closed in Y is both supra closed and supra open in X.*

Definition 2.13. [4] *A supra topological space X is said to be supra clopen T_1 space if for each pair of distinct points x and y of X, there exist supraopen sets U and V containing x and y respectively such that $x \in U, y \notin U$ and $x \notin V, y \in V$.*

Definition 2.14. [4] *A supra topological space X is said to be supra ultra Hausdroff space if every two distinct points of X can be separated by disjoint supra clopen sets.*

Definition 2.15. [4] *A supra topological space X is said to be supra clopen T_0 if for each pair of distinct points in X ,there exist a supra clopen set containing one point but not the other.*

Definition 2.16. [4] *A supra topological space X is said to be supra ultra regular if for each supra closed set F of X and each $x \notin F$, there exist disjoint supra clopen sets U and V such that $F \subset U$ and $x \in V$.*

Definition 2.17. [5] *A space X is said to be*

(*i*) *clopen T_1, if for each pair of distinct points x and y of X, there exist clopen sets U and V contaning x and y respectively such that $y \notin U$ and $x \notin V$.*

(*ii*) *clopen* T_2*, if for each pair of distinct points x and y of X, there exist disjoint clopen sets U and V in X such that* $x\in U$ *and* $y\in V$*.*

Definition 2.18. [12] *A space X is said to be strongly* bT^{μ}*-normal if for every pair of disjoint* bT^{μ}*- closed sets A and B, then their exist disjoint* bT^{μ}*-open sets U and V such that* $A \subset U$ *and* $B \subset V$*.*

Definition 2.19. [6] *A function f:*$(X,\tau) \rightarrow (Y, \sigma)$ *is said to be set connected if* $f^{-1}(V)$ *is clopen in X for every* $V\in CO(Y)$*.*

3. bT^{μ}- SET CONNECTED FUNCTION

Definition 3.1. *A function f:*$(X,\tau) \rightarrow (Y, \sigma)$ *is called supra set connected function if* $f^{-1}(V)$ *is supra clopen in* (X,τ) *for every* $V \epsilon$ *supra clopen* (Y, σ)*.*

Definition 3.2. *A function f:*$(X,\tau) \rightarrow (Y, \sigma)$ *is called* bT^{μ}*-set connected function if* $f^{-1}(V)$ *is* bT^{μ} *clopen in* (X,τ) *for every supra clopen set V in* (Y, σ)*.*

Example 3.3. *Let* $X = Y = \{a,b,c\}$ *with* $\tau = \{X, \phi, \{a\}, \{a,c\}, \{b,c\}\}$ *and* $\sigma = \{Y, \phi, \{b\}, \{b,c\}, \{a,c\}\}$*. A function f:*$(X,\tau) \rightarrow (Y,\sigma)$ *is defined as f(a) = b, f(b) = a, f(c) = c. The supra clopen set of* (Y,σ) *are* $\{Y, \phi, \{b\}, \{a,c\}\}$ *and the* bT^{μ} *clopen of* (X,τ) *are* $\{X, \phi, \{a\}, \{c\}, \{a,b\}, \{b,c\}\}$*. Here f is* bT^{μ}*- set connected function.*

Theorem 3.4. *A function f:*$(X,\tau) \rightarrow (Y, \sigma)$ *is perfectly* bT^{μ}*-continuous function then f is* bT^{μ}*-set connected functions.*

Proof. Let V be supra clopen in (Y,σ). Since f is perfectly bT^{μ}-continuous function, f^{-1}(V) is supra clopen in (X,τ). We know that every supra clopen set is bT^{μ} clopen. Therefore f^{-1}(V) is bT^{μ} clopen in (X,τ). Hence f is bT^{μ}-set connected functions. □

Definition 3.5. *A supra topological space* (X,τ) *is said to be* bT^{μ} *locally indiscrete if every* bT^{μ} *open set of* (X,τ) *is* bT^{μ} *closed set in* (X,τ)*.*

Theorem 3.6. *For a function f:*$(X,\tau) \rightarrow (Y, \sigma)$ *is perfectly* bT^{μ}*-continuous function and* (X,τ) *is* bT^{μ} *locally indiscrete then f is* bT^{μ}*-set connected function.*

Proof. Let V be supra clopen in (Y,σ). Since f is perfectly bT^{μ}-continuous and (X,τ) is bT^{μ} locally indiscrete, f^{-1}(V) is bT^{μ}-open and bT^{μ}-closed in (X,τ). Therefore f^{-1} (V) is bT^{μ} clopen in (X,τ). Hence f is bT^{μ}-set connected functions. □

Theorem 3.7. *Let f:*$(X,\tau) \rightarrow (Y, \sigma)$ *and g:*$(Y,\sigma) \rightarrow (Z, \gamma)$*. The following properties hold.*

(*i*) *If f and g are* bT^{μ}*-set connected functions then g∘f:*$(X,\tau) \rightarrow (Z,\gamma)$ *is* bT^{μ}*-set connected functions.*

(*ii*) *If f is* bT^{μ}*-set connected functions and g is perfectly* bT^{μ}*-continuous function then g∘f:*$(X,\tau) \rightarrow (Z, \gamma)$ *is* bT^{μ}*-set connected functions.*

(*iii*) *If f is supra set connected and g is* bT^{μ}*-set connected functions then g∘f:*$(X,\tau) \rightarrow (Z, \gamma)$ *is* bT^{μ}*-set connected functions.*

Proof. (i) Let V is supra clopen in (Z, γ). By hypothesis, g^{-1}(V) is bT^{μ} clopen in (Y,σ). Since, f is bT^{μ}-set connected functions, f^{-1}(g^{-1}(V)) = $(g \circ f)^{-1}$(V) is bT^{μ} clopen . Therefore g∘f is bT^{μ}-set connected functions.
(ii) Let V is supra clopen in (Z, γ). By hypothesis, g^{-1}(V) is supra clopen in (Y,σ). Since, f is bT^{μ}-set connected functions, f^{-1}(g^{-1}(V)) = $(g \circ f)^{-1}$(V) is bT^{μ} clopen . Therefore g∘f is co bT^{μ} set connected functions.
(iii) Let V is supra clopen in (Z, γ). By hypothesis, g^{-1}(V) is bT^{μ} clopen in (Y,σ). Since, f is supra set connected functions, f^{-1}(g^{-1}(V)) = $(g \circ f)^{-1}$(V) is supra clopen. Since, we know that every supra clopen set is bT^{μ} clopen. Therefore g∘f is bT^{μ}-set connected functions. □

Theorem 3.8. *If f:(X,τ) →(Y,σ) is a surjective bT^{μ}-open and bT^{μ}-closed function and g:(Y,σ) →(Z, γ) is a function such that g∘f : (X,τ) → (Z,γ) is bT^{μ}-set connected , then g is bT^{μ}-set connected functions.*

Proof. Let V be a supra clopen in (Z,γ). By hypothesis, $(g \circ f)^{-1}$(V) is bT^{μ} clopen in (X,τ), f^{-1}(g^{-1}(V)) is bT^{μ} clopen in (X,τ). Since, f is surjective bT^{μ}-open and bT^{μ}-closed. f(f^{-1}(g^{-1}(V))) = g^{-1}(V) is bT^{μ} clopen. Therefore g is bT^{μ}-set connected functions. □

Definition 3.9. *A function f:(X,τ) →(Y, σ) is called co bT^{μ}-irresolute function if the inverse image of each bT^{μ} clopen set in Y is a bT^{μ} clopen set in (X,τ).*

Example 3.10. *Let $X = Y = \{a, b, c\}$ with $\tau = \{X, \phi, \{a\}, \{a, c\}, \{b, c\}\}$ and $\sigma = \{Y, \phi, \{b\}, \{b, c\}, \{a, c\}\}$. A function f:(X,$\tau$) → (Y,$\sigma$) is defined as f(a) = b, f(b) = a, f(c) = c. The bT^{μ} clopen set of (Y,σ) are $\{Y, \phi, \{b\}, \{c\}, \{a, c\}, \{a, b\}, \}$ and the bT^{μ} clopen of (X,τ) are $\{X, \phi, \{a\}, \{c\}, \{a, b\}, \{b, c\}\}$. Here f is co bT^{μ}-irresolute function.*

Theorem 3.11. *Let f:(X,τ) →(Y, σ) and g:(Y,σ) → (Z, γ) be a function. Then the following properties hold.*
(i) If f is co bT^{μ}-irresolute and g is bT^{μ}-set connected, then g∘f is bT^{μ}-set connected .
(ii) If f is bT^{μ}-set connected and g is co bT^{μ}-irresolute, then g∘f is perfectly bT^{μ}-continuous.

Proof. (i) Let V be any supra clopen set in (Z, γ). Since, g is bT^{μ}-set connected, g^{-1}(V) is bT^{μ} clopen. Since, f is co bT^{μ}-irresolute, f^{-1}(g^{-1}(V)) = $(g \circ f)^{-1}$(V) is bT^{μ} clopen. Therefore g∘f is bT^{μ}-set connected .
(ii) Let V be any supra clopen set in (Z, γ). By the co bT^{μ}-irresolute of g, g^{-1}(V) is bT^{μ} clopen. Since,f is bT^{μ}-set connected , f^{-1}(g^{-1}(V)) = $(g \circ f)^{-1}$(V) is bT^{μ} clopen. Since we know that every bT^{μ} clopen set is bT^{μ}-closed. Therefore g∘f is perfectly bT^{μ}-continuous. □

4. Separation axioms

Definition 4.1. *A supra topological space X is said to be co bT^{μ} T_1 if for each pair of distinct points x and y of X, there exist bT^{μ} clopen sets U and V containing x and y respectively such that x∈U, y∉U and x∉V, y∈V.*

Example 4.2. *Let $X = \{a, b, c, d\}$ with $\tau = \{X, \phi, \{a\}, \{c\}, \{a, c\}, \{a, d\}, \{a, c, d\}\}$. The bT^{μ} clopen sets are $\{X, \phi, \{c\}, \{a, d\}, \{b, c\}, \{a, b, d\}, \}$. Let $U = \{a, b, d\}$ and $V = \{b, c\}$. Let a and c be the point in X and a∈U, c∉ U and c∈V, a∉V. Hence X is co bT^{μ} T_1 space.*

Theorem 4.3. *If f:(X,τ) →(Y, σ) is bT^{μ}-set connected injective and Y is supra clopen T_1 space, then X is co bT^{μ} T_1 space.*

Proof. Let x and y be any two distinct points in (X,τ). Since f is injective, we have f(x) and f(y) such that f(x)≠f(y). Since (Y,σ) is supra clopen T_1, there exist a supra clopen sets U and V in (Y,σ) such that f(x) ∈ U, f(y) ∉ U, f(y) ∈ V and f(x)∉V. Therefore we have x ∈ f^{-1} (U), y∉ f^{-1} (U), y ∈ f^{-1}(V) and x∉ f^{-1}(V), where f^{-1}(U) and f^{-1}(V) are bT^{μ} clopen subsets of (X,τ) because, f is bT^{μ}-set connected functions. This shows that (X,τ) is co bT^{μ} T_1 space. □

Definition 4.4. *A supra topological space (X,τ) is said to be co bT^{μ} T_0 if for each pair of distinct points in (X,τ), there exist a bT^{μ} clopen set containing one point but not the other.*

Example 4.5. *Let $X = \{a, b, c, d\}$ with $\tau = \{X, \phi, \{a\}, \{c\}, \{a, c\}, \{a, d\}, \{a, c, d\}\}$. The bT^{μ} clopen sets are $\{X, \phi, \{c\}, \{a, d\}, \{b, c\}, \{a, b, d\}\}$. Let the distinct point be a and c in (X,τ). Let the bT^{μ} clopen set $\{a, b, d\}$ containing the point a but not the point c. Hence X is co bT^{μ} T_0 space.*

Definition 4.6. *A supra topological space (X,τ) is said to be co bT^{μ} T_2 space if every two distinct points of (X,τ) can be separated by disjoint bT^{μ} clopen sets.*

Example 4.7. *Let $X = \{a, b, c, d\}$ with $\tau = \{X, \phi, \{a\}, \{c\}, \{a, c\}, \{a, d\}, \{a, c, d\}\}$. The bT^{μ} clopen sets are $\{X, \phi, \{c\}, \{a, d\}, \{b, c\}, \{a, b, d\}, \}$. Let a and c be the two distinct point in (X,τ). Let $U = \{a, d\}$ and $V = \{b, c\}$, a∈U, c∈V and $U \cap V = \phi$. Hence (X,τ) is a co bT^{μ} T_2 space.*

Theorem 4.8. *If f:(X,τ) → (Y,σ) is bT^{μ}-set connected injection on Y is clopen T_0, then (X,τ) is co bT^{μ} T_2 space.*

Proof. Let x and y be any pair of distinct points of (X,τ) and f be injective. Then f(x) ≠ f(y) in (Y,σ). Since (Y,σ) is clopen T_0, there exist a supra clopen set containing f(x) but not f(y). Then we have x ∈ f^{-1} (U) and y∉ f^{-1}(U). Since f is bT^{μ}-set connected, f^{-1}(U) is bT^{μ} clopen in (X,τ). Also x∈ f^{-1}(U) and y∈ X - f^{-1}(U). This implies every pair of distinct points of (X,τ) can be separated by disjoint bT^{μ} clopen sets in (X,τ). Therefore (X,τ) is co bT^{μ} T_2 space. □

Theorem 4.9. *If f:(X,τ) $\rightarrow$(Y, σ) is perfectly bT^μ-continuous injection on (Y,σ) is co bT^μ T_0, then X is supra ultra Hausdorff space.*

Proof. Let a and b be any pair of distinct points of (X,τ) and f be injective. Then f(a) $\neq$ f(b) in (Y,σ). Since (Y,σ) is co bT^μ T_0, there exist a bT^μ clopen set containing say f(a) but not f(b). Then we have a $\in$ f^{-1} (U) and b $\notin$ f^{-1}(U). Since f is perfectly bT^μ-continuous, f^{-1}(U) is supra clopen in (X,τ). Also a $\in$ f^{-1}(U) and b $\in$ X-f^{-1}(U). This implies every pair of distinct points of X can be separated by disjoint supra clopen sets in (X,τ). Therefore (X,τ) is supra ultra Hausdorff. □

Theorem 4.10. *If f:(X,τ) $\rightarrow$(Y, σ) is bT^μ-set connected injection on (Y,σ) is supra ultra Hausdroff space, then X is co bT^μ T_2 space.*

Proof. Let c and d be any pair of distinct points of (X,τ) and f be injective. Then f(c) $\neq$ f(d) in (Y,σ). Since (Y,σ) is supra ultra Hausdorff space, there exist supra clopen sets U and V in (Y,σ) such that f(c) $\in$ U and f(d) $\in$V and U$\cap$V = ϕ. This implies c $\in$ f^{-1} (U) and d $\in$ f^{-1}(V). Since f is bT^μ-set connected, f^{-1}(U) and f^{-1}(V) is bT^μ clopen in (X,τ). Also f^{-1}(U)$\cap f^{-1}$(V) = f^{-1}(U$\cap$V) = ϕ. Thus every two distinct points of (X,τ) can be separated by disjoint bT^μ clopen sets. Therefore (X,τ) is co bT^μ T_2 space. □

Theorem 4.11. *If f:(X,τ) $\rightarrow$(Y, σ) is perfectly bT^μ-continuous injection on (Y,σ) is co bT^μ T_2 space, then X is supra ultra Hausdorff space.*

Proof. Let a and b be any pair of distinct points of (X,τ) and f be injective. Then f(a) $\neq$ f(b) in (Y,σ). Since (Y,σ) is co bT^μ T_2 space, there exist bT^μ clopen sets U and V in (Y,σ) such that f(a) $\in$ U and f(b) $\in$V and U$\cap$V = ϕ. This implies a$\in$ f^{-1} (U) and b$\in$ f^{-1}(V). Since f is perfectly bT^μ-continuous, f^{-1}(U) and f^{-1}(V) is bT^μ clopen in (X,τ). Also f^{-1}(U)$\cap f^{-1}$(V) = f^{-1}(U$\cap$V) = ϕ. Thus every two distinct points of (X,τ) can be separated by disjoint supra clopen sets . Therefore (X,τ) is supra ultra Hausdorff. □

Theorem 4.12. *Let (X,τ) be a space and (Y,σ) be co bT^μ T_2 space. If f:(X,τ) $\rightarrow$(Y, σ) is co bT^μ-irresolute injective, then (X,τ) is co bT^μ T_2.*

Proof. Let x and y be any two distinct points of (X,τ). Then, f(x) and f(y) are distinct points of (Y,σ), because f is injective. Since (Y,σ) is co bT^μ T_2 space, there are disjoint bT^μ clopen sets U and V in (Y,σ) containing f(x)and f(y) respectively. Since, f is co bT^μ-irresolute and U$\cap$V = ϕ, we have f^{-1}(U) and f^{-1}(V) are disjoint bT^μ clopen sets in (X,τ) such that x$\in$ f^{-1}(U) and y $\in$ f^{-1}(V). Hence (X,τ) is co bT^μ T_2 space. □

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