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TOTALLY α * CONTINUOUS FUNCTIONS IN TOPOLOGICAL SPACES

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ABSTRACT
The aim of this paper is to define a new class of functions namely totally α * continuous functions and slightly α * continuous functions and study their properties . Additionally, we relate and compare these functions with some other functions in topological spaces.

Keywords and phrases: totally α * continuous and slightly α * continuous.

I. INTRODUCTION

Continuity is an important concept in mathematics and many forms of continuous functions have been introduced over the years. In 1980 S.N Maheswari and S.S.Thakur [4] defined α continuous functions. RC Jain [2] introduced the concept of totally continuous functions and slightly continuous for topological spaces. In this paper, we define totally α * continuous functions and slightly α * continuous functions and basic properties of these functions are investigated and obtained.

II. PRELIMINARIES

Throughout this paper (X, τ), (Y, σ) and (Z, η) or X , Y , Z represent non-empty topological spaces on which no separation axioms are assumed unless otherwise mentioned. For a subset A of a space (X, τ), cl(A) and int(A) denote the closure and the interior of A respectively. The power set of X is denoted by P(X). If A is α *open and α * closed , then it is said to be α * clopen.

Definition 2.1: A subset A of a topological space X is said to be a α ***open** [5] if A $\subseteq$ int* (cl (int* (A))).
Definition 2.2: A function f : (X, τ) ⟶(Y, σ) is called ***totally continuous*** [2] if f^{-1}(V) is clopen set in X for each open set V of Y .
Definition 2.3: A function f: (X, τ) ⟶ (Y, σ) is called a α **** continuous*** [8]if f^{-1}(O) is a α *open set of (X, τ) for every open set O of (Y, σ).
Definition 2.4: A map f: (X, τ) ⟶ (Y, σ) is said to be ***perfectly*** α **** continuous*** [6]if the inverse image of every α *open set in (Y, σ) is both open and closed in (X, τ) .
Definition 2.5: A function f: (X, τ) ⟶ (Y, σ) is called a ***slightly continuous***[2] if the inverse image of every clopen set in Y is open in X.
Definition 2.6: A function f: (X, τ) ⟶ (Y, σ) is called a ***contra continuous*** [1] if f^{-1} (O) is closed in (X, τ) for every open set O in (Y, σ).
Definition 2.7: A function f: (X, τ) ⟶ (Y, σ) is called ***Contra*** α **** continuous functions*** **[7]** if f^{-1} (O) is α * closed in (X, τ) for every open set O in (Y, σ).
Definition 2.8: A topological space X is called a α * ***connected*** [9] if X cannot be expressed as a disjoint union of two non-empty α *open sets.
Definition 2.9: A map f : (X, τ) ⟶(Y, σ) is said to be ***pre*** α ****open*** [7] if the image of every α *****open set of X is α *****open in Y.
Definition 2.10: A topological space X is said to be **connected** [10] if X cannot be expressed as the union of two disjoint nonempty open sets in X.
Definition 2.11: A function f: (X, τ) ⟶ (Y, σ) is called a ***strongly*** α **** continuous*** [6] if the inverse image of every α *open set in (Y, σ) is open in (X, τ).

Definition 2.12: A Topological space X is said to be α ***$T_{1/2}$ space** *or* α ***space** [8] if every α * open set of X is open in X.
Definition 2.13: A space (X, τ) is called a ***locally indiscrete space*** [3] if every open set of X is closed in X.
Theorem 2.14[5]**:**
(i) Every open set is α *- open and every closed set is α *-closed set

III. Totally α * continuous functions

Definition 3.1: A function (X, τ) ⟶(Y, σ) is called **totally α * continuous functions** if the inverse image of every open set of (Y, σ) is both α * open and α * closed subset of (X, τ).
Example 3.2: Let X = Y ={a, b, c, d}, τ = {ϕ,{a},{abc}, X}, σ = {ϕ, {a},{b},{ab},Y} , α *O(X, τ) = {ϕ {a},{b},{c},{ab},{ac},{bc}, {ad},{abd},{acd},{abc},X} and α *C(X,τ) = {ϕ , {b} , {c} , {d} ,{ad} ,{bc} ,{bd} ,{cd} ,{abd},{acd},{bcd},X}. Let *g:* (X, τ) ⟶(Y, σ) be defined by g (a) = c , g(b) = b, g(c) = a , g(d) = d. since , g^{-1}({a}) = {c} , g^{-1}({b}) = {b} and g^{-1}({ab}) = {bc} is both α * open and α * closed in X. Therefore, g is totally α * continuous.
Theorem 3.2: Every totally α * continuous functions is α * continuous.
Proof: Let O be an open set of (Y, σ). Since, f is totally α * continuous functions, f^{-1}(O) is both α * open and α * closed in (X, τ). Therefore, f is α * continuous.
Remark 3.3: The converse of above theorem need not be true.
Example 3.4: Let X = Y = {a, b, c,d}, τ = {ϕ, {a},{b},{ab},{bc},{abc}, X}, σ = {ϕ, {a},{b},{ab},Y}. Let *g:* (X, τ) ⟶(Y, σ) be defined by g (a) = a , g(b) = c, g(c) = b , g(d) = d. α * O(X, τ) = { ϕ, {a},{b},{c},{ab},{ac}{bc},{abc},{abd},X} and α * C(X, τ) = { ϕ, {c},{d},{ad},{bd},{cd},abd},{acd},{bcd},X} . Clearly, g is not totally α *continuous since g^{-1}({a}) = {a} is α * open in X but not α * closed. However, g is α * continuous.
Theorem3.5: Every totally continuous function is totally α * continuous.
Proof: Let O be an open set of (Y, σ). Since, f is totally continuous functions, f^{-1}(O) is both open and closed in (X, τ). Since every open set is α * open and every closed set is α * closed. f^{-1}(O) is both α * open and α * closed in (X, τ). Therefore, f is totally α * continuous.
Remark 3.6: The converse of above theorem need not be true.
Example 3.7: Let X = Y = {a, b, c,d}, τ = {ϕ, {ab}, X}, τ^c = {ϕ, {cd}, X} , σ = {ϕ, {a},{b},{ab},{bc},{abc},Y}. Let *g:* (X, τ) ⟶(Y, σ) be defined by g (a) = a , g(b) = b, g(c) = c , g(d) = d. α * O(X, τ) = P(X) = α * C(X, τ) . Clearly, g is totally α *continuous but g^{-1}({a,b}) = {a,b} is open in X but not closed in X. Therefore, g is not totally continuous.
Theorem 3.8: Every perfectly α * continuous map is totally α * continuous.
Proof: Let f : (X, τ) ⟶(Y, σ) be a perfectly α * continuous map. Let O be an open set of (Y, σ). Then O is α * open in (Y, σ). Since f is perfectly α * continuous, f^{-1}(O) is both open and closed in (X, τ), implies f^{-1}(O) is both α * open and α * closed in (X, τ). Therefore, f is totally α * continuous.
Remark 3.9: The converse of above theorem need not be true.
Example3.10: Let X = Y = {a, b, c,d}, τ = {ϕ, {ab}, X}, τ^c = {ϕ, {cd}, X} , σ = {ϕ, {a},{b},{ab},{bc},{abc},Y}. Let *g:* (X, τ) ⟶(Y, σ) be defined by g (a) = a , g(b) = b, g(c) = c , g(d) = d. α * O(X, τ) = P(X) = α * C(X, τ) . α * O(Y, σ) = {ϕ, {a},{b},{c},{ab},{ac},{bc},{abc},{abd},Y}.Clearly, g is totally α *continuous but g^{-1}({a,b}) = {a,b} is open in X but not closed in X. Therefore, g is not perfectly α *continuous.
Remark 3.11: The concept of totally α * continuous and strongly α * continuous are independent of each other.
Example 3.12: Let X = Y = {a, b, c,d}, τ = {ϕ, {ab}, X}, τ^c = {ϕ, {cd}, X} , σ = {ϕ, {a},{b},{ab},{bc},{abc},Y}. Let *g:* (X, τ) ⟶(Y, σ) be defined by g (a) = a , g(b) = b, g(c) = c , g(d) = d. α * O(X, τ) = P(X) = α * C(X, τ) . and α * O(Y, σ) = {ϕ, {a},{b},{c},{ab},{ac},{bc},{abc},{abd},Y}. Clearly, g is totally α *continuous but g^{-1}({b}) = {b} is not open in X .Therefore, g is not strongly α * continuous.
Example 3.13: Let X = Y = {a, b, c}, τ = {ϕ, {a},{ab},{ac}, X}, σ = {ϕ, {a},{b},{ab },Y}. Let *g:* (X, τ) ⟶(Y, σ) be defined by g (a) = a = g(b) , g(c) = c . α * O(X, τ) = {ϕ, {a},{ab},{ac}, X}, α * C(X, τ) = {ϕ, {bc},{b},{c}, X} and α * O(Y, σ) = {ϕ, {a},{b},{ab }, {ac},Y} . Clearly, g is strongly α *continuous but g^{-1}({a}) = {ab} is α * open in X but not α * closed .Therefore, g is not totally α * continuous.

Theorem 3.14: If f: X $\to$ Y is a totally α * continuous map, and X is α * connected, then Y is an indiscrete space.

Proof: Suppose that Y is not an indiscrete space. Let A be a non-empty open subset of Y. Since, f is totally α * continuous map, then $f^{-1}(A)$ is a non-empty α * clopen subset of X. Then X = $f^{-1}(A) \cup (f^{-1}(A))^c$. Thus, X is a union of two non-empty disjoint α * open sets which is contradiction to the fact that X is α * connected. Therefore, Y must be an indiscrete space

Theorem 3.15: Let f: X $\to$ Y and g: Y $\to$ Z be functions. Then $g \circ f$: X $\to$ Z

(i) If f is α * irresolute and g is totally α * continuous then $g \circ f$ is totally α * continuous

(ii) If f is totally α * continuous and g is continuous then $g \circ f$ is totally α * continuous.

Proof:

(i) Let O be an open set in Z. Since g is totally α * continuous, $g^{-1}(O)$ is α * clopen in Y. Since f is α * irresolute, $f^{-1}(g^{-1}(O))$ is α * open and α * closed in X. Since, $(g \circ f)^{-1}(O) = f^{-1}(g^{-1}(O))$. Therefore, $g \circ f$ is totally α * continuous.

(ii) Let O be an open set in Z. Since g is continuous, $g^{-1}(O)$ is open in Y. Since, f is totally α * continuous, $f^{-1}(g^{-1}(O))$ is α * clopen in X. Hence, $g \circ f$ is totally α * continuous.

IV. Slightly α * continuous functions.

Definition 4.1: A function (X, τ) ⟶(Y, σ) is called **slightly α * continuous** at a point $x \in X$ if for each clopen subset V of Y containing f(x), there exists a α * open subset U in X containing x such that $f(U) \subseteq V$. The function f is said to be slightly α * continuous if f is slightly α * continuous at each of its points.

Definition 4.2: A function (X, τ) ⟶(Y, σ) is said to be **slightly α * continuous** if the inverse image of every clopen set in Y is α * open in X.

Example 4.3: Let X = Y = {a, b, c,d}, τ = {ϕ, {ab}, {abc}, X} , σ = {ϕ, {a},{bcd},Y} and α * O(X, τ) = {ϕ, {a},{b},{c},{ab},{ac},{ad},{bc},{bd},{abc},{abd},{acd},{bcd},X}.Let *g:* (X, τ) ⟶(Y, σ) be defined by g (a) = b , g(b) = a, g(c) = d , g(d) = c. Clearly, g is slightly α *continuous .

Proposition 4.4: The definition 4.1 and 4.2 are equivalent.

Proof: Suppose the definition 4.1 holds. Let O be a clopen set in Y and $x \in f^{-1}(O)$. Then $f(x) \in O$ and thus there exists a α * open set U_x such that $x \in U_x \subseteq f^{-1}(O)$ and $f^{-1}(O) = \cup_{x \in f^{-1}(O)} U_x$. Since, arbitrary union of α * open set is α * open. $f^{-1}(O)$ is α * open in X and therefore, f is slightly α *continuous .

Suppose, the definition 4.2 holds. Let $f(x) \in O$ where, O is a clopen set in Y. Since, f is slightly α *continuous, $x \in f^{-1}(O)$ where $f^{-1}(O)$ is α * open in X. Let U = $f^{-1}(O)$. Then U is α * open in X, $x \in X$ and $f(U) \subseteq O$.

Theorem 4.5: For a function f: (X, τ) ⟶(Y, σ) , the following statements are equivalent.

(i) f is slightly α *continuous.

(ii) The inverse image of every clopen set O of Y is α * open in X.

(iii) The inverse image of every clopen set O of Y is α * closed in X.

(iv) The inverse image of every clopen set O of Y is α * clopen in X.

Proof:

(i) $\Rightarrow$ (ii): Follows from the proposition 4.4

(ii) $\Rightarrow$ (iii): Let O be a clopen set in Y which implies O^c is clopen in Y. By (ii), $f^{-1}(O^c) = (f^{-1}(O))^c$ is α * open in X. Therefore, $f^{-1}(O)$ is α * closed in X.

(iii) $\Rightarrow$ (iv): By (ii) and (iii), $f^{-1}(O)$ is α * clopen in X.

(iv) $\Rightarrow$ (i): Let O be a clopen set in Y containing f(x), by (iv) $f^{-1}(O)$ is α * clopen in X. Take U = $f^{-1}(O)$, then $f(U) \subseteq O$. Hence, f is slightly α *continuous .

Theorem 4.6: Every slightly continuous function is slightly α *continuous.

Proof: Let f: (X, τ) ⟶(Y, σ) be a slightly continuous function. Let O be a clopen set in Y. Then, $f^{-1}(O)$ is open in X. Since, every open set is α * open. Hence, f is slightly α *continuous .

Remark 4.7: The converse of the above theorem need not be true as can be seen from the following example.

Example 4.8: Let X = Y = {a, b, c,d}, τ = {ϕ, {ab}, {abc}, X} , σ = {ϕ, {a},{bcd},Y} and α * O(X, τ) = {ϕ, {a},{b},{c},{ab},{ac},{ad},{bc},{bd},{abc},{abd},{acd},{bcd},X}.Let *g:* (X, τ) ⟶(Y, σ) be defined by g (a)

= b , g(b) = a, g(c) = d , g(d) = c. Clearly, g is slightly α *continuous but not slightly continuous. Since, g^{-1}(a) = b where a is clopen in Y but b is not open in X.

Theorem 4.9: Every α *continuous function is slightly α *continuous.

Proof: Let f: (X, τ) ⟶(Y, σ) be a α *continuous function. Let O be a clopen set in Y. Then, f^{-1} (O) is α * open in X and α * closed in X. Hence, f is slightly α *continuous.

Remark 4.10: The converse of the above theorem need not be true as can be seen from the following example.

Example 4.11: Let X = { a,b,c} and Y= {a,b}, τ = {ϕ, {a},{b},{ab},X} , σ = {ϕ, {a},Y} and α * O(X, τ) = {ϕ, {a},{b}{ab},{ac},X}. Let *g:* (X, τ) ⟶(Y, σ) be defined by g(a)=b , g(b)=g(c)=a, The function f is slightly α *continuous but not α *continuous, since, g^{-1} (a) = (bc) is not α * open in X.

Theorem 4.12: Every contra α *continuous function is slightly α *continuous.

Proof: Let f: (X, τ) ⟶(Y, σ) be a contra α *continuous function. Let O be a clopen set in Y. Then, f^{-1} (O) is α * open in X. Hence, f is slightly α *continuous.

Remark 4.13: The converse of the above theorem need not be true as can be seen from the following example.

Example 4.14: Let X = Y ={ a,b,c}, τ = {ϕ, {a},{b},{ab},X} , σ = {ϕ, {a}, {c},{ab},{ac},Y}and σ^c = {ϕ, {b}, {c},{ab},{bc},Y} and α * O(X, τ) = {ϕ, {a},{b}{ab},{ac},X}. Let *g:* (X, τ) ⟶(Y, σ) be defined by g(a)=a , g(b)= c ,g(c)=b. The function f is slightly α *continuous but not contra α *continuous, since, g^{-1} (b) = (c) is not α * open in X.

Remark 4.15: Composition of two slightly α *continuous need not be slightly α *continuous as it can be seen from the following example.

Example 4.16: Let X=Y={a,b,c,d} , Z = {a,b,c} and the topologies are τ = { ϕ ,{a} ,{ab}, {abc } ,X} and σ = { ϕ , {a} , {bcd} ,Y } and η = {ϕ ,{b},{ac},Z}. Define f*:* (X, τ) ⟶(Y, σ) by f(a) = b ,f(b) = a, f(c) = c, f(d)=d, α *O (X,τ)={ ϕ , {a} , {b} , {c} , {ab} , {ac} , {ad},{bc} , {abc},{abd},{acd} , X } . Clearly, f is slightly α *continuous. Define g: (Y, σ) ⟶ (Z , η) by g(a) = a, g(b) = b = g (c) , g(d) = c, α *O (Y, σ)= P(Y). Clearly, g is slightly α *continuous. But (g ∘ f): (X, τ) ⟶ (Z , η) is not slightly α *continuous, since $(g \circ f)^{-1}$ ({ac}) = f^{-1}(g^{-1}{ac}) = f^{-1}({ ad}) = {bd} is not a α *open in (X, τ).

Theorem 4.17: Let f: X → Y and g: Y → Z be functions. Then the following properties hold:

(i) If f is α * irresolute and g is slightly α *continuous then (g ∘ f) is slightly α *continuous.
(ii) If f is α * irresolute and g is α *continuous then (g ∘ f) is slightly α *continuous.
(iii) If f is α * irresolute and g is slightly continuous then (g ∘ f) is slightly α *continuous.
(iv) If f is α *continuous and g is slightly continuous then (g ∘ f) is slightly α *continuous.
(v) If f is strongly α *continuous and g is slightly α * continuous then (g ∘ f) is slightly continuous.
(vi) If f is slightly α *continuous and g is perfectly α * continuous then (g ∘ f) is α * irresolute.
(vii) If f is slightly α *continuous and g is contra continuous then (g ∘ f) is slightly α *continuous.
(viii) If f is α * irresolute and g is contra α *continuous then (g ∘ f) is slightly α *continuous.

Proof:

(i) Let O be a clopen set in Z. Since, g is slightly α *continuous, g^{-1}(O) is α *open in Y. Since, f is α * irresolute, f^{-1}(g^{-1}(O)) is α *open in X. Since, $(g \circ f)^{-1}$ (O) = f^{-1}(g^{-1} (O)), g ∘ f is slightly α *continuous .
(ii) Let O be a clopen set in Z. Since, g is α *continuous, g^{-1}(O) is α *open in Y. Since, f is α * irresolute, f^{-1}(g^{-1}(O)) is α *open in X. Hence, g ∘ f is slightly α *continuous.
(iii) Let O be a clopen set in Z. Since, g is slightly continuous, g^{-1}(O) is open in Y . Since, f is α * irresolute, f^{-1}(g^{-1}(O)) is α *open in X. Hence, g ∘ f is slightly α *continuous.
(iv) Let O be a clopen set in Z. Since, g is slightly continuous, g^{-1}(O) is open in Y . Since, f is α * continuous, f^{-1}(g^{-1}(O)) is α *open in X. Hence, g ∘ f is slightly α *continuous.
(v) Let O be a clopen set in Z. Since, g is slightly α *continuous, g^{-1}(O) is α *open in Y. Since, f is strongly α * continuous, f^{-1}(g^{-1}(O)) is open in X. Therefore, g ∘ f is slightly continuous.
(vi) Let O be a α *open in Z. Since, g is perfectly α *continuous, g^{-1}(O) is open and closed in Y. Since, f is slightly α *continuous, f^{-1}(g^{-1}(O)) is α *open in X. Hence, g ∘ f is α * irresolute.
(vii) Let O be a clopen set in Z. Since, g is contra continuous, g^{-1}(O) is open and closed in Y. Since, f is slightly α *continuous, f^{-1}(g^{-1}(O)) is α *open in X. Hence, g ∘ f is slightly α *continuous.
(viii) Let O be a clopen set in Z. Since, g is contra α *continuous, g^{-1}(O) is α *open and α *closed in Y.Since, f is α *irresolute, f^{-1}(g^{-1}(O)) is α *open and α *closed in X. Hence, g ∘ f is slightly α *continuous.

Theorem 4.18: If the function f: (X, τ) ⟶(Y, σ) is slightly α *continuous and (X, τ) is α * $T_{1/2}$ space, then f is slightly continuous.
Proof: Let O be a clopen set in Y. Since, g is slightly α *continuous, $f^{-1}(O)$ is α *open in X. Since, X is α * $T_{1/2}$ space, $f^{-1}(O)$ is open in X. Hence, f is slightly continuous.
Theorem 4.19: Let f: (X, τ) ⟶(Y, σ) and g: (Y, σ) ⟶ (Z , η) be functions. If f is surjective and pre α *open and (g ∘ f): (X, τ) ⟶ (Z , η) is slightly α *continuous, then g is slightly α *continuous.
Proof: Let O be a clopen set in (Z , η). Since, (g ∘ f): (X, τ) ⟶ (Z , η) is slightly α *continuous, $f^{-1}(g^{-1}(O))$ is α *open in X. Since, f is surjective and pre α *open $f(f^{-1}(g^{-1}(O))) = g^{-1}(O)$ is α *open in Y. Hence, g is slightly α *continuous.
Theorem 4.20: Let f: (X, τ) ⟶(Y, σ) and g: (Y, σ) ⟶ (Z , η) be functions. If f is surjective , pre α *open and α * irresolute, then (g ∘ f): (X, τ) ⟶ (Z , η) is slightly α *continuous if and only if g is slightly α *continuous.
Proof: Let O be a clopen set in (Z , η). Since, (g ∘ f): (X, τ) ⟶ (Z , η) is slightly α *continuous, $f^{-1}(g^{-1}(O))$ is α *open in X. Since, f is surjective and pre α *open $f(f^{-1}(g^{-1}(O))) = g^{-1}(O)$ is α *open in Y. Hence, g is slightly α *continuous.
Conversely, let g is slightly α *continuous. Let O be a clopen set in (Z , η), then $g^{-1}(O)$ is α *open in Y. Since, f is α * irresolute, $f^{-1}(g^{-1}(O))$ is α *open in X. Hence, (g ∘ f): (X, τ) ⟶ (Z , η) is slightly α *continuous.
Theorem 4.21: If f is a slightly α *continuous from a α *connected space (X, τ) onto a space (Y, σ) then Y is not a discrete space.
Proof: Suppose that Y is a discrete space. Let O be a proper non-empty open subset of Y. Since, f is slightly α *continuous, $f^{-1}(O)$ is a proper non-empty α *clopen subset of X which is contradiction to the fact that X is α *connected.
Theorem 4.22: If f: (X, τ) ⟶(Y, σ) is a slightly α *continuous surjection and X is α *connected, then Y is connected.
Proof: Suppose Y is not connected, then there exists non-empty disjoint open sets U and V such that Y = U ∪ V. Therefore, U and V are clopen sets in Y. Since, f is slightly α *continuous, $f^{-1}(U)$ and $f^{-1}(V)$ are non-empty disjoint α *open in X and X= $f^{-1}(U) \cup f^{-1}(V)$. This shows that X is not α *connected. This is a contradiction and hence, Y is connected.
Theorem 4.23: If f: (X, τ) ⟶(Y, σ) is a slightly α *continuous and (Y, σ) is a locally indiscrete space then f is α *continuous.
Proof: Let O be an open subset of Y. Since, (Y, σ) is a locally indiscrete space, O is closed in Y. Since, f is slightly α *continuous, $f^{-1}(O)$ is α *open in X. Hence, f is α *continuous.
Theorem 4.24: If f: (X, τ) ⟶(Y, σ) is a slightly α *continuous and A is an open subset of X then the restriction $f|_A$: (A, τ_A) ⟶(Y, σ) is slightly α *continuous.
Proof: Let V be a clopen subset of Y. Then $(f|_A)^{-1}(V) = f^{-1}(V) \cap A$. Since $f^{-1}(V)$ is α *open and A is open, $(f|_A)^{-1}(V)$ is α *open in the relative topology of A. Hence, $f|_A$: (A, τ_A) ⟶(Y, σ) is slightly α *continuous.

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