SLIGHTLY GENERALIED STAR ωα-CONTINUOUS FUNCTIONS IN TOPOLOGICAL SPACES

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Abstract: The purpose of this paper is to introduce the concept of slightly generalized star ωα-continuous (briefly slightly g*ωα-continuous) functions in topological spaces. Further, the basic properties and preservation theorems of slightly g*ωα-continuous functions are studied.

Keywords: g*ωα-closed sets, g*ωα-continuous functions, g*ωα-irresolute maps.

1. Introduction: The concept of slightly continuous functions and their properties were first studied by Jain [5] in 1980. Later Nour [7], Baker [1] and Ekiri and Caldas [4] introduced and studied slightly semi continuity, slightly pre continuity and slightly γ-continuity in topological spaces.

The object of this paper is to introduce a new generalization of slightly continuity, which we call slightly g*ωα-continuity using g*ωα-closed sets in topological spaces.

2. Preliminary: Throughout this paper, the spaces (X, τ) and (Y, σ) (or simply X and Y) always denote topological spaces on which no separation axioms are assumed unless explicitly stated.

Definition 2.1 [8]: A subset A of a topological space X is called a generalized star ωα-closed (briefly g*ωα-closed) if cl(A) ⊆ U whenever A ⊆U and U is ωα-open in X.

The family of all g*ωα-closed subsets of X is denoted by G*ωαC(X).

Definition 2.2: A subset A of a topological space X is called

(i) $T_{g^*\omega\alpha}$-space [9] if every g*ωα-closed set is closed.

Definition 2.3: A topological space X is said to be a

(i) Mildly compact [11] if every clopen cover of X has a finite subcover.

(ii) Clopen T_1 [11] if for each pair of distinct points x and y in X, there exist a disjoint clopen sets U containing x but not y and V containing y but not x.

(iii) Clopen T_2 [11] if for each pair of distinct points x and y in X, there exist disjoint clopen sets U and V such that x ∈ U and y ∈ V.

(iv) Ultra Hausdroff [11] if every distinct points of X can be separated by disjoint clopen sets.

Definition 2.4: A function f: X → Y is called

(i) slightly continuous [5] if for each x ∈ X and every clopen subset V of Y containing f(x) there exists an open set U of X with x ∈ U and f(U) ⊆ V.

(ii) g*ωα-continuous [10] if $f^{-1}(V)$ is g*ωα-closed in X for every closed set V of Y.

(iii) g*ωα-irresolute [10] if $f^{-1}(V)$ is g*ωα-closed in X for every g*ωα-closed set V of Y.

(iv) g*ωα-open [10] if f(V) is g*ωα-open in Y for every open set V of X.

3. Slightly Generalized Star ωα-Continuous Functions in Topological Spaces:

Definition 3.1: A function f: X → Y is said to be slightly g*ωα-continuous at a point x ∈ X if for each clopen subset V of Y containing f(x), there exists a g*ωα-open subset U of X containing x such that f(U) ⊆ V.

Remark 3.2: If the above property holds for each point x ∈ X, then f is said to be slightly g*ωα-continuous functions.

Lemma 3.3: The following statements are equivalent for a function f: X → Y:

(i) f is slightly g*ωα-continuous.

(ii) for every x∈X and each clopen set V⊆Y containing f(x), there exists U ∈ G*ωαO(X, x) such that f(U)⊆V.

Proof: Suppose (i) holds. Let x∈X and let V be a clopen set in Y containing f(x). By hypothesis, f is slightly g*ωα-continuous, then $f^{-1}(V)$ is g*ωα-open in X and x∈$f^{-1}(V)$. Let U= $f^{-1}(V)$. Then U is g*ωα-open set in X, such that x∈U and f(U)⊆V. Hence (ii) holds.

Suppose (ii) holds. Let x∈X and V be a clopen in Y such that x ∈ $f^{-1}(V)$. Then f(x) ∈V, from the hypothesis, there exist g*ωα-open set U_x in X such that x ∈ U_x and f(U_x) ⊆V. Now x∈ U_x ⊆ $f^{-1}(V)$ and $f^{-1}(V)$ = ∪ {U_x: x ∈ $f^{-1}(V)$}. Since arbitrary union of g*ωα-open set is g*ωα-open, thus $f^{-1}(V)$ is g*ωα-open in X. Therefore f is slightly g*ωα-continuous. Hence (i) hold.

Theorem 3.4: The following statements are equivalent for a function f: X → Y:

(i) f is slightly g*ωα-continuous.

(ii) for every clopen set V⊆Y, $f^{-1}(V)$ is g*ωα-open.

(iii) for every clopen set V⊆Y, $f^{-1}(V)$ is g*ωα-closed.

(iv) for every clopen set V⊆Y, $f^{-1}(V)$ is g*ωα-clopen.

Proof: (i) → (ii) Let V be a clopen set in Y. Let x∈X and x∈$f^{-1}(V)$. Since f is slightly g*ωα-continuous and by the lemma 3.3, there exist g*ωα-open set U_x in X containing x such that f(U_x)⊆V, this implies U_x⊆$f^{-1}(V)$. Therefore $f^{-1}(V)$ = ∪{U_x : x∈$f^{-1}(V)$}. Since arbitrary union of g*ωα-open set is g*ωα-open. Thus $f^{-1}(V)$ is g*ωα-open set in X.

(ii) → (iii) Let V be a clopen set in Y, then Y-V is clopen in Y. From (ii), $f^{-1}(Y-V)$ is g*ωα-open. That is

f^{-1}(Y-V) = X-f^{-1}(V) is g*ωα-open, implies f^{-1}(V) is g*ωα-closed.
(iii) → (iv) It follows from (ii) and (iii).
(iv) → (i) Let V be a clopen set in Y containing f(x). Then by hypothesis, f^{-1}(V) is g*ωα-clopen in X. Put U= f^{-1}(V), implies f(U)⊆V. Therefore for each x∈X and each clopen set V⊆Y, there exist g*ωα-open set U in X such that f(U)⊆V. Thus f is slightly g*ωα-continuous.

Theorem 3.5: Every slightly continuous function is slightly g*ωα-continuous.

Proof: Let f: X →Y be a slightly g*ωα-continuous. Let U be a clopen set in Y, then f^{-1}(U) is g*ωα-open in X. Since every open set is g*ωα-open [8], f^{-1}(U) is g*ωα-open. Hence f is slightly continuous.

The converse of the above theorem need not be true in general as seen from the following example.

Example 3.6: LetX= Y = {a, b, c}, τ = {X, ϕ, {a, b} } and σ = {Y, ϕ, {a}, {b}, {a, b}, {a, c} }. Then the identity function f: X →Y is slightly g*ωα-continuous but not slightly continuous, since for the set A = {b} is clopen in Y, f^{-1}({b}) = {b} is g*ωα-open but not an open set in X.

Remark 3.7: The converse of the theorem 3.5 holds, if X is $T_{g^*\omega\alpha}$ space.

Definition 3.8[6]: A space X is called Locally Indiscrete space if every open set is closed in X.

Theorem 3.9: If a function f: X → Y is slightly g*ωα-continuous and Y is locally indiscrete space, then f is g*ωα-continuous.

Proof: Let U be an open set in Y. Since Y is locally indiscrete, U is closed in Y, implies U is clopen in Y. Since f is slightly g*ωα-continuous, f^{-1}(U) is g*ωα-open in X. Hence f is g*ωα-continuous.

Theorem 3.10: Let f: X → Y and g: Y → Z are any two functions. Then, the following properties hold:

(i) If f is g*ωα-irresolute and g is slightly g*ωα-continuous, then gof is slightly g*ωα-continuous.

(ii) If f is g*ωα-continuous and g is slightly continuous, then gof is slightly g*ωα-continuous.

Proof: (i) Let V be a clopen set in Z. Since g is slightly g*ωα-continuous, g^{-1}(V) is g*ωα-open in Y. Since f is g*ωα-irresolute, f^{-1}(g^{-1}(V)) = $(gof)^{-1}$(V) is g*ωα-open in X. Therefore gof is slightly g*ωα-continuous.

Let V be clopen set in Z. Then g^{-1}(V) is open in Y as g is slightly continuous function. Since f is g*ωα-continuous, f^{-1}(g^{-1}(V)) = $(gof)^{-1}$(V) is g*ωα-open in X. Therefore, gof is slightly g*ωα continuous.

Corollary 3.11: Let f: X → Y and g: Y → Z are any two functions. Then, the following properties hold:

(i) If f is g*ωα-irresolute and g is slightly continuous, then gof is slightly g*ωα-continuous.

(ii) If f is g*ωα-continuous and g is slightly continuous, then gof is slightly g*ωα-continuous.

Definition 3.12: A topological space X is said to be g*ωα-compact if every g*ωα-open cover of X has a finite subcover.

Theorem 3.13: If f: X → Y is slightly g*ωα-continuous surjection and X is g*ωα-compact then Y is mildly compact.

Proof: Let {V_α : V_α∈ CO(Y), α∈I } be an cover of Y. Since f is slightly g*ωα-continuous, then {$f^{-1}(V_\alpha)$: α∈I } is g*ωα-open cover of X. Since X is g*ωα-compact, there exist a finite subset I_o of I such that
X = ∪ {$f^{-1}(V_\alpha)$: α∈I_o}. Therefore Y = ∪{V_α : α∈I_o}, since f is surjective. Thus, every clopen cover of Y has finite subcover. Hence Y is mildly compact.

Definition 3.14: A space X is called g*ωα-connected provided that X is not the union of two disjoint non empty g*ωα-open sets.

Theorem 3.15: If f: X → Y is slightly g*ωα-continuous surjection and X is g*ωα-connected then Y is connected.

Proof: Suppose, on the contrary Y is disconnected space. Then, there exist two 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 g*ωα-continuous, f^{-1}(U) and f^{-1}(V) are g*ωα-open sets in X. Moreover f^{-1}(U) and f^{-1}(V) are disjoint non empty and X= f^{-1}(U) ∪ f^{-1}(V) as X is g*ωα-compact and f is surjective. Therefore X is not g*ωα-connected, which is a contradiction. Hence Y is connected.

Recall that, a space X is said to be (1)extremely disconnected [2] if the closure of every open set of X is open. (2) 0-dimensional space if its topology has a base consisting of clopen sets.

Theorem 3.16: If f: X → Y is slightly g*ωα-continuous and Y is extremally disconnected space then f is g*ωα-continuous.

Proof: Let x∈X and V be a clopen set in Y containing f(x). Since f is extremally disconnected, cl(V) is open and hence clopen. Since f is slightly g*ωα-continuous, there exist g*ωα-open set U in X with x∈ U and f(U)⊆ cl(V). Thus, f is g*ωα-continuous.

Theorem 3.17: If f: X → Y is slightly g*ωα-continuous and Y is locally indiscrete space then f is g*ωα-continuous.

Proof: Let V be an open set in Y. Since f is locally indiscrete space, V is closed in Y and hence clopen in Y. Since f is slightly g*ωα-continuous, f^{-1}(V) is g*ωα-open in X. Therefore f is g*ωα-continuous.

Theorem 3.18: If f: X → Y is slightly g*ωα-continuous and Y is 0-dimensional space then f is g*ωα-continuous.

Proof: Let x∈X and V be an open set in Y containing f(x). Since Y is 0-domensional space, there exist clopen set U in Y containing f(x) such that U⊆V. Since f is slightly g*ωα-continuous, there exist g*ωα-open set G in X such that f(G)⊆U, that is f(x)∈f(G)⊆U⊆V. Therefore f is g*ωα-continuous.

4. Separation Axioms Related to Generalized Star ωα-Open Sets:

Theorem 4.1: Let f: X → Y be a function and g: X → XxY be the graph of f, defined by g(x) = (x, f(x)) for every x∈X. Then g is slightly g*ωα-continuous if and only if f is slightly g*ωα-continuous.

Proof: Let V be a clopen set in Y, then XxV is clopen in XxY. Since g is slightly g*ωα-continuous, then $f^{-1}(V) = g^{-1}(XxV) \in G^*\omega\alpha O(X)$. Thus f is slightly g*ωα-continuous.

Conversely, let x∈X and F be a clopen set in XxY containing g(x). Then F∩({x}xY) is clopen in {x}xY containing g(x). Also {x}xY is homeomorphic to Y. Hence {y∈Y: (x, y)∈F} is a clopen set in Y. Since f is slightly g*ωα-continuous, $\cup\{f^{-1}(y): (x, y) \in F\}$ is a g*ωα-open set in X. Further $x \in\cup\{f^{-1}(y): (x, y) \in F\} \subseteq g^{-1}(F)$. Hence $g^{-1}(F)$ is g*ωα-open. Then g is slightly g*ωα-continuous.

Definition 4.2 [10]: A topological space X is said to be

(i) g*ωα-T_1 space if for each pair of distinct points x and y of X, there exist disjoint g*ωα-open sets U containing x but not y and V containing y but not x.

(ii) g*ωα-T_2 space if for each pair of distinct points x and y of X, there exist disjoint g*ωα-open sets U and V such that x ∈ U and y∈ V.

Theorem 4.3: If f: X → Y is slightly g*ωα-continuous injection and Y is ultra Hausdroff space then X is g*ωα-T_2 space.

Proof: Let x_1 and x_2 be any two distinct points in X. Then $f(x_1) \neq f(x_2)$ as f is injective. Since Y is ultra Hausdroff, there exist clopen sets V_1 and V_2 in Y such that $f(x_1) \in V_1$ and $f(x_2) \in V_2$ and $V_1 \cap V_2 = \phi$. Since f is slightly g*ωα-continuous, $x_i \in f^{-1}(V_i) \in G^*\omega\alpha O(X)$ for i=1, 2 and $f^{-1}(V_1) \cap f^{-1}(V_2)=\phi$. Thus, X is g*ωα-$T_2$ space.

Theorem 4.4: If f: X → Y is slightly g*ωα-continuous injective and Y is clopen T_1 then X is g*ωα-T_1 space.

Proof: Let x and y be any two distinct points in X. Since f is injective, f(x)≠f(y). Since Y is clopen T_1, then there exist disjoint clopen sets V and W in Y such that f(x)∈V, f(y)∉V and f(x)∉W, f(y)∈W. Since f is slightly g*ωα-continuous, $f^{-1}(V)$ and $f^{-1}(W)$ are disjoint g*ωα-open sets in X such that $x \in f^{-1}(V)$, $y \notin f^{-1}(V)$ and $x \notin f^{-1}(W)$, $y \in {}^{-1}(W)$. This shows that X is g*ωα-T_1.

Theorem 4.5: If f: X → Y is slightly g*ωα-continuous injective and Y is clopen T_2 then X is g*ωα-T_2 space.

Proof: Let x and y be any two distinct points in X, f(x)≠f(y) as f is injective. Since Y is clopen T_2, then there exist disjoint clopen sets V and W in Y such that f(x)∈V and f(y)∈W. Since f is slightly g*ωα-continuous, $f^{-1}(V) \in G^*\omega\alpha O(X, x)$ and $f^{-1}(W) \in G^*\omega\alpha O(X, y)$ and $f^{-1}(V) \cap f^{-1}(W) = \phi$. Therefore for each distinct points x, y in X, there exist two disjoint g*ωα-open sets $f^{-1}(V)$ and $f^{-1}(W)$ such that $f^{-1}(V) \cap f^{-1}(W) = \phi$. Hence X is g*ωα-$T_2$.

Definition 4.6: A topological space X is said to be

(i) g*ωα normal if for any pair of disjoint g*ωα-closed sets A and B in X, there exist disjoint open sets U and V in X such that A ⊆U, B ⊆V.

(ii) g*ωα-regular if for each x ∈ X and for each g*ωα-closed set F not containing x there exist disjoint open sets U and V such that x ∈ U and F ⊆ V.

Theorem 4.7: Let Y be a 0-dimensional space and f: X → Y be a slightly g*ωα-continuous injection. Then the following properties hold:

(i) If Y is T_1 (respectively T_2) then X is g*ωα-T_1 (respectively g*ωα-T_2).

(ii) If f is either open or closed then X is g*ωα-regular.

(iii) If f is closed and Y is normal then X is g*ωα-regular.

Proof: (i) The first part is obvious, we prove the second part. Let Y be T_2 space. Since f is injective, for any pair of distinct points x, y ∈ X, f(x) ≠ f(y). Since Y is T_2, then there exist disjoint open sets V_1 and V_2 in Y such that $f(x) \in V_1$, $f(y) \in V_2$ and $V_1 \cap V_2 = \phi$. From hypothesis Y is 0-dimensional, then there exists U_1 and $U_2 \in CO(Y)$ such that $f(x) \in U_1 \subseteq V_1$, $f(y) \in U_2 \subseteq V_2$. Consequently $x \in f^{-1}(U_1) \subseteq f^{-1}(V_1)$ and $y \in f^{-1}(U_2) \subseteq f^{-1}(V_2)$ and $f^{-1}(U_1) \cap f^{-1}(U_2) = \phi$. Since f is slightly g*ωα-continuous, $f^{-1}(U_1)$ and $f^{-1}(U_2)$ are g*ωα-open sets and so X is g*ωα-T_2 space.

(ii)Suppose f is open. Let x ∈ X and U be an open set containing x. Then f(x) ∈ f(U) as f is open. On the other hand, 0-dimensional of Y gives the existence of V ∈ CO(Y) such that f(x) ∈ V ⊆ f(U). So, $x \in f^{-1}(V) \subseteq U$ as f is injective. Again, f is slightly g*ωα-continuous and $f^{-1}(V)$ is g*ωα-clopen set in X from theorem 3.4, hence $x \in f^{-1}(V) = cl(f^{-1}(V)) \subseteq U$. This implies X is g*ωα-regular.

Suppose f is closed. Let x ∈X and F be a closed set in X such that x ∉ F. Then f(x) ∉ f(F) and f(x) ∈ X-f(F), which is open in Y. But Y is 0-dimensional, then there exist clopen set V in Y such that f(x) ∈V ⊆ Y-f(F). Since f is slightly g*ωα-continuous, we have $x \in f^{-1}(V) \in G^*\omega\alpha CO(X)$, $F \subseteq X-f^{-1}(V) \in G^*\omega\alpha CO(X)$. Therefore X is g*ωα-regular.

(iii)Let F_1 and F_2 be any two closed sets in X such that $F_1 \cap F_2 = \phi$. Since f is closed and injective, we have f(F1) and f(F2) are closed sets in Y with $f(F_1) \cap f(F_2) = \phi$. By normality of Y, there exist two open set U and V in Y such that f(F1) ⊆ U, f(F2) ⊆V and U ∩ V = ϕ. Let y ∈ f(F1), then y ∈ U. Since Y is 0-dimensional and U is open in Y, there exists a clopen set U_y such that $y \in U_y \subseteq U$. Then $f(F_1) \subseteq\cup \{ U_y : U_y \in CO(Y), y \in f(F1) \} \subseteq U$ and thus $F_1 \subseteq\cup \{f^{-1}(U_y) : U_y \in CO(Y), y \in f(F_1) \} \subseteq f^{-1}(U)$. Since f is slightly g*ωα-continuous, $f^{-1}(U_y)$ is g*ωα-open for each U_y : CO(Y), so that $G = \cup\{ f^{-1}(U_y) : y \in f(F_1) \}$ is g*ωα-open in X and $F_1 \subseteq G \subseteq f^{-1}(U)$. Similarly, there exist g*ωα-open set H in X such that

$F_2 \subseteq H \subseteq f^{-1}(V)$ and $G \cap H \subseteq f^{-1}(U \cap V) = \phi$. This shows that X is g*ωα-normal.

Definition 4.8: A space X is said to be g*ωα-connected between subsets A and B provided there is no g*ωα-clopen set F for which $A \subseteq F$ and $F \cap B = \phi$.

Definition 4.9: A function $f : X \to Y$ is said to be set g*ωα-connected if whenever X is g*ωα-connected between f(A) and f(B) with respect to the relative topology on f(X).

Theorem 4.10: A function $f : X \to Y$ is set g*ωα-connected if and only if $f^{-1}(F)$ is g*ωα-clopen for every clopen subsets F of f(X) (w.r.t. the relative topology on f(X)).

Proof: Necessity: Assume the F is clopen subsets of f(X) w.r.t the relative topology on f(X). Suppose that $f^{-1}(F)$ is not g*ωα-closed in X. Then there exist $x \in X\text{-}f^{-1}(F)$ such that for every g*ωα-open set U with $x \in U$ and $U \cap f^{-1}(F) \neq \phi$. We claim that the space X is set g*ωα-connected between x and $f^{-1}(F)$. Suppose, there exist g*ωα-clopen set A such that $f^{-1}(F) \subseteq A$ and $x \notin A$. Then $x \in X\text{-}A \subseteq X - f^{-1}(F)$ and equivalently X-A is g*ωα-open set containing x and disjoint from $f^{-1}(F)$, this contradiction implies that X is set g*ωα-connected between x and $f^{-1}(F)$. Since f is set g*ωα-connected, f(X) is connected between f(x) and $f(f^{-1}(F))$. But $f(f^{-1}(F)) \subseteq F$, which is a contradiction. Therefore $f^{-1}(F)$ is g*ωα-closed in X and from the argument will show that $f^{-1}(F)$ is also g*ωα-open.

Sufficiency: Suppose X is g*ωα-connected between A and B and also f(X) is not connected between f(A) and f(B) (in relative topology on f(X)). Thus, there is a set $F \subseteq f(X)$ that is clopen in the relative topology on f(X) such that $f(A) \subseteq F$ and $F \cap f(B) = \phi$. Then $A \subseteq f^{-1}(F)$, $B \cap f^{-1}(F) = \phi$ and $f^{-1}(F)$ is g*ωα-clopen, which shows that X is not g*ωα-connected between A and B. It follows that f is set g*ωα-connected.

Corollary 4.11: Every slightly g*ωα-continuous surjection is set g*ωα-connected.

Theorem 4.12: Every set g*ωα-connected function is slightly g*ωα-continuous.

Proof: Assume that $f : X \to Y$ is set g*ωα-connected. Let F be a clopen subset of Y. Then $F \cap f(X)$ is clopen in the relative topology on f(X). Since f is set g*ωα-connected, by theorem 4.10, $f^{-1}(F) = f^{-1}(F \cap f(X))$ is g*ωα-clopen in X.

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