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New Forms of αg - continuous Maps in Topology

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Abstract: In this paper, we describe a novel class of continuous maps called as strongly alpha generalised continuous maps in topological spaces. Furthermore, we investigate their properties with existing continuous maps, and we also study their decomposition of continuous functions.
Keywords: Semi closed sets, M-αg-closed sets, continuous functions, strongly αg-continuous map, strongly gp-continuous map.
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I. INTRODUCTION

In mathematics and applied sciences, general topology is very significant. Many topologists use the generalised form of open and closed sets to generalize concept like the continuity and separation axioms, among others, in this approach.

N. Levine [16] established the concept of generalized closed sets in 1970, and it now plays an important role in general topology. Following the introduction of generalized closed sets, several scholars produced research publications that dealt with various types of sets and studied various features. H. Maki et al. [18] defined and established the idea of gp-closed sets in topology in 1993. Furthermore, H. Maki et al. [20] established the concept of α - generalized closed sets in topological spaces in 1994. This class of αg-closed sets is suitably lies between g-closedness and gs-closedness. Noiri [28] introduced and studied the strong forms of continuous functions in 1984. Following that, several mathematicians, including Levine.N [14], S. P. Arya and R. Gupta [5,] B.M.Munshi and D.S.Bassan [24], proposed and studied the idea of strongly continuous, perfectly continuous, and completely continuous functions, which are stronger than continuous functions. P. Sundaram [31] later defined and investigated the strongly g-continuous and perfectly g-continuous continuous functions in topological spaces.

II. PRELIMINARIES

Throughout this article, (X, τ), (Y, σ) and (Z, η) (or simply, X, Y, and Z) represent topological spaces for which no separation axioms are assumed unless explicitly stated.

The closure of A and the interior of A with respect to topology is denoted by Cl(A) and Int(A) for a subset A of X, respectively.

We recall the following known definitions and results which are very useful in the sequel.

1) *Definition 2.1:* A subset A of a topological space X is called a
   (i) semi-open [15] if $A \subseteq Cl(Int(A))$ and semi-closed [10] if $Int(Cl(A) \subseteq A$.
   (ii) pre-open [21] if $A \subseteq Int(Cl(A)$ and pre-closed [23] if $Cl(Int(A) \subseteq A$.
   (iii) α-open [27]if $A \subseteq Int(Cl(Int(A)))$ and α-closed [22] if $Cl(Int(Cl(A))) \subseteq A$.
   (iv)semipre-open[3](= β-open [1]) if $A \subseteq Cl(Int(Cl(A)))$ and semipre-closed[3](= β-closed [1]) if $Int(Cl(Int(A))) \subseteq A$.

The Pre-closure of a subset A of X, denoted by pcl(A) is the intersection of all pre-closed sets containing a subset A. The pre-interior of a subset A of X and is denoted by pInt(A), is the union of all pre-open sets of X contained in A.

2) *Definition 2.2:* A subset A of a topological space (X, τ) is called a
   (i) generalized closed (briefly, g-closed) [16] if $Cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
   (ii) α-generalised closed (briefly, αg-closed) [20] if $\alpha Cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
   (iii) generalised preclosed (briefly, gp-closed) [19] if $pCl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
   (iii) generalised semipre-closed (briefly, gsp-closed) [13] if $spCl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
   (iv)strongly generalised closed (briefly, g*-closed [32]) [29] if $Cl(A) \subseteq U$ whenever $A \subseteq U$ and U is g-open in X.

The compliment of the above mentioned closed sets are their respective open sets.

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3) *Definition 2.3:* A function f: (X, τ) → (Y, σ) is called a
   (i) semi-continuous[15] if $f^{-1}(V)$ semi-closed in X for every closed subset V of Y.
   (ii) α-continuous[22] if $f^{-1}(V)$ α-closed in X for every closed subset V of Y.
   (iii) pre-continuous[21] if $f^{-1}(V)$ pre-closed in X for every closed subset V of Y.
   (iv) g-continuous [6] if $f^{-1}(V)$ g-closed in X for every closed subset V of Y.
   (v) αg-continuous [20] if $f^{-1}(V)$ αg-closed in X for every closed subset V of Y.
   (vi) gp-continuous [4] if $f^{-1}(V)$ gp-closed in X for every closed subset V of Y.
   (vii) strongly continuous [14] if $f^{-1}(V)$ is both open and closed in X for every subset V of Y.
   (viii) strongly α-continuous [7] if $f^{-1}(V)$ is α-open in X for every semi-open set V of Y.
   (ix) strongly pre-continuous [9] if $f^{-1}(V)$ is preopen in X for every semi-open set V of Y.
   (x) strongly semi-continuous [2] if $f^{-1}(V)$ is open in X for every semi-open set V of Y.
   (xi) strongly g-continuous [31] if $f^{-1}(V)$ is open in X for every g-open set V of Y.
   (xii) βwg-continuous.[27],if g^{-1} (V) is βwg-open set in X, for every open set V of Y

4) *Definition 2.4:* A function f: (X, τ) → (Y, σ) is called a
   (i) irresolute[11] if $f^{-1}(V)$ semi-closed in X for every semi-closed subset V of Y.
   (ii) pre- irresolute[30] if $f^{-1}(V)$ pre-closed in X for every pre-closed set V of Y.
   (iii) α-irresolute[17] if $f^{-1}(V)$ α-closed in X for every α-closed subset V of Y.
   (iv) semi-α-irresolute[8] if $f^{-1}(V)$ is semi-open in X for every α-open set V of Y
   (v) gc-irresolute [31] if $f^{-1}(V)$ g-closed in X for every g-closed set V of Y.
   (vi) αg-irresolute [12] if $f^{-1}(V)$ αg-closed in X for every αg-closed subset V of Y.
   (vii) gp-irresolute [25] if $f^{-1}(V)$ gp-closed in X for every gp-closed subset V of Y.

5) *Definition 2.5:* A space (X, τ) is called
   (i) an ${}_{\alpha}T_b$ -space[20],[31] if every αg-closed set in it is closed.
   (ii) a T_g -space[4], if every gp-closed set is g-closed.

III. PROPERTIES OF STRONGLY AG-CONTINUOUS FUNCTIONS

In this section, we define and study a new type of continuous function using αg-open sets in the following.

1) *Definition 3.1:* A function f: X → Y is called strongly αg-continuous if f^{-1} (V) is αg-open in X for every semiopen set V of Y.
2) *Theorem 3.2:* Every strongly α-continuous function is strongly αg-continuous function.

Proof: Let V be a semiopen subset of Y and f be strongly α-continuous function, then f^{-1} (V) is α-open in X. Since f be strongly α -continuous function. But as every α-open set is αg-open set so, f^{-1} (V) is αg-open set in X. Therefore, f is strongly αg-continuous function.

The converse of the Theorem need not be true as seen from the following example.

3) *Example 3.3:* Let X = Y = {a, b, c} with topologies, τ = {φ, X, {a, b}} and σ = {φ, Y, {a}, {a, c}}; Here αO(Y) = { φ,Y, {a }, {a, c},{a, b}} and αGO(X) = {φ, X, {a}, {b}, {a, b}}. Define a function f: X → Y by f(a)= a, f(b) = c , f(c) = b. Then f is α-continuous function. But not αg - continuous, since f^{-1} ({a,b}) = (a,c} is not αg-open set in X for the α-open set {a,b} of Y.

4) *Theorem 3.4:* A function f: X → Y is a strongly αg - continuous if and only if for each x in X and each semi-open set V of Y with f(x) ∈ V, there exists an αg - open set U of X such that x ∈ U, f (U) ⊆ V.

Proof: Let f (x) ∈ V. Since f is a strongly αg-continuous, we have x ∈ $f^{-1}(V)$ ∈ αg-open of X. Let U = $f^{-1}(V)$. Then x ∈ V and f (U) ⊆ V.

Conversely, let V be an semi- open set in Y and let x ∈ $f^{-1}(V)$. Then f(x) ∈ V and thus there exists an αg-open set U_x such that x ∈ U_x and f $(U_{x)}$ ⊆ V. Now x ∈ U_x ⊆ $f^{-1}(V)$ and $f^{-1}(V) = U_{x \in f-1(v)} U_x$. Therefore, $f^{-1}(V)$ is αg-open in X and consequently, f is a strongly αg-continuous function.

5) *Theorem 3.5:* Every strongly αg-continuous function is continuous and thus strongly pre-continuous, αg-continuous and strongly semi-continuous.

Proof: Follows from the definitions.

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

6) *Example 3.6:* Let X = Y = {a, b, c} with topologies, τ = {φ, X, {a}, {a, c}} and σ = {φ, Y, {a}, {b}, {a, b}};
Define a function f: X → Y by f(a) = a, f(b) = c, f(c) = b. Then f is strongly pre-continuous (resp. αg-continuous function, strongly semi-continuous) function but not strongly αg-continuous, since for the semiopen set {a,b} of Y, f^{-1} ({a,b}) = (a,c} is not αg-open set in X.

7) *Theorem 3.7:* Every strongly continuous function is strongly αg-continuous but not conversely.

Proof: Follows from the definitions.

8) *Example 3.8:* Let X = Y = {a, b, c} with topologies, τ = {φ, X, {a}, {a, c}} and σ = {φ, Y, {a}}. Define a function f: X → Y be an Identity function. Then f is strongly αg-continuous function but not strongly continuous, since for the subset {b,c} in Y, f^{-1} ({b,c}) = (b,c} is closed but not open in X.

9) *Theorem 3.9:* Every strongly α-continuous function is an irresolute but not conversely.

Proof: Let f: X → Y be a strongly α - continuous function and let V be a semiopen set in Y. Then f^{-1} (V) is α-open and hence semiopen in X. Hence f is an irresolute.

10) *Example 3.10:* Let X = Y = {a, b, c} with topologies, τ = {φ, X, {a}, {b}, {a, b}} and σ = {φ, Y, {a}}.
Define a function f: X → Y by f(a) = a, f(b) = c and f(c) = b. Then f is an irresolute function but not strongly α - continuous, since for the subset {a,b} of Y, f^{-1} ({a,b}) = (a,c} is open in X.

11) *Theorem 3.11:* Let (Y, σ) be any topological spaces, (X, τ) is a $_{\alpha}T_b$ - space and
f: X → Y be any function. Then the following are equivalent:

(i) f is strongly αg-continuous

(ii) f is strongly semi-continuous

Proof: (i) ⇒ (ii): Follows from the Theorem 3.5.4.

(ii) ⇒ (i): Let U be any semiopen set in Y. Since f is strongly αg - continuous. Then f^{-1}(U) is αg - open in X.

But X is a $_{\alpha}T_b$ - space, then f^{-1} (U) is open in X, which implies that f is strongly semi - continuous function.

12) *Remark 3.12:* Strongly αg - continuity and strongly g-continuity are independent of each other as shown in the following examples.

13) *Example 3.13:* Let X = Y = {a, b, c} with topologies, τ = {φ, X, {a, b}} and σ = {φ, Y, {a}}.
Define a function f: X → Y by f(a) = a, f(b) = b and f(c) = c. Then f is strongly g-continuous but not strongly αg - continuous, since for the semiopen subset {a, c} of Y, f^{-1} ({a,c}) = (a,c} is not αg-open in X.

14) *Example 3.14:* Let X = Y = {a, b, c} with topologies, τ = {φ, X, {a}, {a, c}} and σ = {φ, Y, {a}, {a,b}}.
Define a function f: X → Y by f (a) = a, f (b) = c and f (c) = b. Then f is strongly αg - continuous but not strongly g - continuous, since for the subset {a,c} of Y, f^{-1} ({a,c}) = (a,b} is not g-open in X.

Now, we derive decomposition of strongly αg-continuous functions in the following

15) *Theorem 3.15:* If f: X → Y is strongly αg-continuous and g: Y → Z is strongly semi-continuous. Then their composition gof: X → Z is strongly αg-continuous function.

Proof: Let U be any open set in Z. Since g is strongly semi - continuous, g^{-1} (U) is open set in Y. Since every open set is semiopen set and hence g^{-1} (U) is semiopen in Y. Again, f is strongly αg - continuous, and f^{-1} (g^{-1} (U)) = $(gof)^{-1}$ (U) is αg- open in X. Thus, gof is strongly αg - continuous function.

16) *Theorem 3.16:* If f: X → Y is strongly αg-continuous and g: Y → Z is strongly α-continuous. Then the composition gof: X → Z is strongly αg-continuous function.

Proof: Let V be any semiopen set in Z. Since g is strongly α-continuous, g^{-1} (V) is α-open set of Y. Since every α-open set is semiopen set and hence g^{-1} (V) is α-open in Y. Again, f is strongly αg-continuous, f^{-1} (g^{-1} (V)) = $(g \circ f)^{-1}$ (V) is αg-open in X. Thus, the composition gof is strongly αg-continuous function.

17) *Theorem 3.17:* If the function f: X → Y is αg-continuous and the function g:Y → Z is strongly semi-continuous. Then the composition gof:X → Z is strongly αg-continuous function.

Proof: Let U be any semiopen set in Z. Since g is strongly semi - continuous, g^{-1} (U) is an open set of Y. Again, f is strongly αg-continuous, f^{-1} (g^{-1} (U)) = $(g \circ f)^{-1}$ (U) is αg-open in X. Thus, the composition g o f is strongly αg-continuous function.

We define the following

18) *Definition 3.18:* A function f: X→Y is said to be M-αg-continuous if the inverse image of each αg-open set of Y, is αg-open in X.

19) *Theorem 3.19:* If the function f: X → Y is M-αg-continuous and the function, g:Y → Z is strongly αg-continuous. Then the composition gof: X → Z is strongly αg-continuous.

Proof: Let V be an arbitrary semi - open set in Z. Since g is strongly αg - continuous, g^{-1} (V) is αg-open set in Y. Again, f is M-αg-continuous, f^{-1} (g^{-1} (V)) = $(gof)^{-1}$ (V) is αg-open in X. Thus, the composition gof: X → Z is strongly αg-continuous.

20) *Theorem 3.20:* Let X and Z be any two topological spaces, and let Y be an ${}_{\alpha}T_b$ - space. Then the composition gof: X → Z is strongly αg - continuous if the function f: X → Y is M-αg-continuous and the function g: Y → Z is strongly αg-continuous.

Proof: Let F be any semiopen set in Z. Since g is strongly αg-continuous, g^{-1} (F) is αg-open in Y. But Y is ${}_{\alpha}T_b$ - space and so g^{-1}(F) is open set in Y. Since f is M-αg-continuous, f^{-1}(g^{-1}(F)) = $(gof)^{-1}$ (F) is αg-open in X. Hence, gof is strongly αg- continuous.

Also, further we define and studied the followings

21) *Definition 3.21:* A function f: X → Y is called strongly gp-continuous if f^{-1} (V) is gp-open in X for every semiopen set V of Y.

22) *Lemma 3. 22:* Every strongly pre-continuous function is strongly gp-continuous function.

Proof: Let V be a semiopen subset of Y and f be strongly pre-continuous function, then f^{-1} (V) is preopen in X. Since f be strongly pre - continuous function. But as every preopen set is gp-open set and so, f^{-1} (V) is gp-open set in X. Therefore, f is strongly gp-continuous function.

23) *Theorem 3.23:* A function f: X → Y is a strongly gp-continuous if and only if for each x in X and each semi-open set V of Y with f (x) ∈ V, there exists an gp-open set U of X such that x ∈ U, f(U) ⊆ V.

Proof: Let f(x) ∈ V. Since f is a strongly gp-continuous, we have x ∈ f^{-1} (V) ∈ gp-open of X. Let U = f^{-1} (V). Then x ∈ V and f(U) ⊆ V. Conversely, let V be a semi - open set in Y and let x ∈ f^{-1}(V). Then f (x) ∈ V and thus there exists a gp-open set U_x such that x ∈ U_x and f (U_x) ⊆ V. Now x ∈ U_x ⊆ f^{-1} (V) and $f^{-1}(V) = U_{x \in f^{-1}(v)} U_x$. Therefore, f^{-1}(V) is gp-open in X and consequently, f is a strongly gp-continuous.

24) *Theorem 3.24:* Every strongly αg-continuous function is strongly gp-continuous but not conversely.

Proof: Let V be a semiopen subset of Y and f be strongly strongly αg-continuous function, then f^{-1}(V) is αg-open in X since f is strongly αg-continuous function. But as every αg-open set is gp-open set and so, f^{-1} (V) is gp-open set in X. Therefore, f is strongly gp-continuous function.

25) *Example 3.25:* Let X = Y = {a, b, c}, τ = {Ø, X, {a,b}} and σ = {φ, Y, {a}, {a,b}}. Define a function f: X → Y be an Identity function, f (a) = a, f (b) = b and f (c) = c. Then f is strongly gp-continuous but not strongly αg-continuous, since for the semiopen subset {a,c} of Y, f^{-1}({a,c}) = (a,c} is not αg-open in X.

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26) *Remark 3.26:* Strongly gp-continuity and strongly g-continuity are independent of each other as shown in the following examples.

27) *Example 3.27:* Let (X, τ) be as in the Example 3.5.14. Define a function f: X → Y be an Identity function, f (a) = a, f (b) = b and f (c) = c. Then f is strongly gp - continuous but not strongly g - continuous, since for the subset {a, b} of Y, f^{-1} ({a, b}) = (a, b} is not g - open in X.

28) *Example 3.28:* Let X= Y = {a, b, c}, τ = {φ, X, {a}, {b}, {a, b}} and σ = {φ, Y, {a}, {a, b}}. Define a function f: X → Y be an Identity function. Then f is strongly g - continuous but not strongly gp-continuous, since for the semiopen subset {a,c} of Y, f^{-1} ({a,c}) = (a,c} is not gp - open in X.

Now, we give decomposition of strongly gp-continuous functions in the following

29) *Theorem 3.29:* If f: X → Y is strongly gp - continuous and g: Y → Z is strongly pre-continuous. Then the composition gof: X → Z is strongly gp-continuous.

Proof: Let U be any open set in Z. Since g is strongly pre-continuous, g^{-1} (U) is preopen set in Y. Since every preopen set is gp-open set, and hence g^{-1} (U) is gp-open in Y. Again, f is strongly gp-continuous, and f^{-1} (g^{-1} (U)) = $(gof)^{-1}$ (U) is gp-open in X. Thus, gof is strongly gp - continuous function.

30) *Theorem 3.30:* If f: X → Y is strongly gp - continuous and g: Y → Z is βwg-continuous. Then the composition gof: X → Z is gp-continuous.

Proof: Let U be any open set in Z. Since g is βwg -continuous, g^{-1} (U) is βwg-open set in Y. Since every βwg- open set is gp-open set, and hence g^{-1} (U) is gp-open in Y. Again, f is strongly gp-continuous, and f^{-1} (g^{-1} (U)) = $(gof)^{-1}$ (U) is gp-open in X. Thus, gof is gp - continuous function.

31) *Theorem 3.31:* If f: X → Y is gp-irresolute and g: Y → Z is strongly αg-continuous. Then the composition gof: X → Z is strongly gp-continuous.

Proof: Let V be any semiopen set in Z. Since g is strongly αg-continuous, g^{-1} (V) is αg-open set of Y. Since every αg-open set is gp-open set and hence g^{-1} (V) is gp-open in Y. Again, f is gp-irresolute, f^{-1} (g^{-1} (V)) = $(gof)^{-1}$ (V) is gp-open in X. Thus, the composition gof is strongly gp-continuous.

32) *Theorem 3.32:* Let f: X → Y and g: Y → Z be any two functions such that gof: X → Z . Then

(i) gof is strongly gp-continuous if f is strongly gp-irresolute and g is strongly gp-continuous
(ii) gof is strongly gp-continuous if f is strongly gp-continuous and g is strongly α-continuous
(iii) gof is strongly gp-continuous if f is gp-continuous and g is strongly semi-continuous.

Proof: The proof follows from the definitions.

33) *Theorem 3.33:* Let X and Z be any two topological spaces, and let Y be an T_g - space. Then the composition g o f: X → Z is strongly gp - continuous if the function f: X → Y is (αg,g) continuous and the function g: Y → Z is strongly gp-continuous.

Proof: Let F be any semiopen set in Z. Since g is strongly gp-continuous, g^{-1} (F) is gp-open in Y. But Y is T_g - space and so g^{-1} (F) is g-open set in Y. Since f is (αg,g) -continuous, $f^{-1}(g^{-1}(F)) = (gof)^{-1}(F)$ is αg-open in X. Hence, gof is strongly αg-continuous.

IV. NEW FORMS OF CLOSED AND OPEN FUNCTIONS

In this present section we also define and studied the followings

1) *Definition 4.1:* A function f: X → Y said to be Strongly α - generalized-closed function (resp. Strongly αg-open), if the image of every semi closed (resp. semi open) subset in X is αg-closed (resp. is αg -closed) set in Y.
2) *Definition 4.2:* A function f: X → Y said to be Strongly generalized pre-closed function (resp. Strongly gp-open), if the image of every semi closed (resp. semi open) subset in X is gp-closed (resp. is gp -closed) set in Y.
3) *Theorem 4.3:* Every strongly αg-open function is strongly pre open function, not conversely.
   Proof: Let f: X → Y be strongly αg-open function. Let G be semi open set in X. Then f(G) is an αg-open set in Y. Therefore f(G) is gp-open In Y. Hence f is strongly gp-open in Y.

4) *Example 4.4:* Let X={p, q, r}=Y, $\tau = \{X, \phi, \{p\}, \{q\}, \{p,q\}\}$, and $\sigma = \{Y, \phi, \{p\}\}$. Let f: $X \rightarrow Y$ be the identity function. Then f is gp-open, since for the semopen sets {p, r},{q, r}in X, then f({p,r}) = {p, r} and f({q, r}) = {q, r} are not strongly αg-open in Y but it is strongly gp-open in Y.

V. CONCLUSIONS

Every year many topologists introduced different types of sets and maps in topological spaces. In this paper, we studied a new forms of continuous functions in topological spaces, namely is strongly αg-continuous, gp-continuous functions introduced. Then some new examples and theorems in separation axioms on topological spaces are developed.

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