Functions on α * g –Open Set in Topological Spaces

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Abstract
*The purpose of this paper is to introduce α *g –open maps and α *g –closed mapsin topological spaces and discussits properties. Additionally, we relate and compare these functions with some other functions in topological spaces.*

Keywords - *α *g –open maps andα *g–closed maps.*

I. INTRODUCTION

Generalized closed mappings were introduce and studied by Malghan. In 1983,A.SMashour et al and I.A. Hasanein introducedα–open maps and α –closed maps, recentlyP. Anbarasi Rodrigo and S.Pious Missier introduced α*–open maps and α*–closed maps in Topology. In this paper, we introduce α*g –open maps and α*g–closed maps also we relate and compare these functions with some other functions in topological spaces.

II. PRELIMINARIES

Throughout this paper (X, τ), (Y, σ) and (Z, η) or X , Y , Z represent non-empty topological spaceson 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 isdenoted by P(X).

Definition 2.1
A map $f:(X,\tau)\rightarrow(Y,\sigma)$ is called a**open map** if image of each open set in X is open in Y.

Definition 2.2
A map $f:(X,\tau)\rightarrow(Y,\sigma)$ is called a **closed map** if image of each closed set in X is closed in Y.

Definition 2.3
A map $f:(X,\tau)\rightarrow(Y,\sigma)$ is called a$\boldsymbol{\alpha}$ **−open map**[6] if image of each open set in X is $\alpha-$ open in Y.

Definition 2.4
A subset A of a topological space X is said to be ***α*-open**[7]if A⊆ int*(cl(int*(A))).

Definition 2.5
A map $f:(X,\tau)\rightarrow(Y,\sigma)$ is called a$\boldsymbol{g}$ **−open map**[6] if image of each open set in X is $g-$ open in Y.

Definition 2.6
A map $f:(X,\tau)\rightarrow(Y,\sigma)$ is called a$\boldsymbol{g\alpha}$ **−open map**[6] if image of each open set in X is $g\alpha-$ open in Y.

Definition 2.7
A map $f:(X,\tau)\rightarrow(Y,\sigma)$ is called a$\boldsymbol{\alpha g}$ **−open map**[6] if image of each open set in X is $\alpha g-$ open in Y.

Definition 2.8

A subset A of a topological space X is said to be **generalized closed**(briefly g-closed) [3] if cl (A) ⊆ U whenever A ⊆ U and U is open in X.

Definition 2.9

A subset A of a topological space X is said to be **generalizedα −closedset**[5](briefly g α-closed) αcl (A) ⊆ U whenever A ⊆ U and U is $\alpha -$ open in (X,τ).

Definition 2.10

A subset A of a topological space X is said to be **αgeneralized–closed set**[4] ifαcl (A) ⊆ U whenever A ⊆ U and U is open in (X,τ).

III.α*g –OPEN MAPSAND α *g–CLOSED MAPS

Definition 3.1:

A map $f : (X,\tau) \rightarrow (Y,\sigma)$ is called a**$\alpha * g$ −open map**if image of each open set in X is $\alpha * g$ −open in Y.

Theorem 3.2:

Every open map is $\alpha * g$ −open map

Proof:

Let $f : (X,\tau) \rightarrow (Y,\sigma)$ be an open map. Since f is an open map, the image of each open set in X is open in Y. Since every open set is $\alpha * g$ −open. Hence, f is$\alpha * g$ −open map.

Remark 3.3:

The following example supports that the converse of the above theorem is not true in general.

Example 3.4:

Let X = Y= {a, b, c}, τ = {ϕ, {a}, {a, b}, {a, c}, X} and σ = {ϕ, {a},{a ,b}, Y},
α * g O(X,τ) = {ϕ, {a}, {a, b}, {a, c}, X} and α * gO(Y, σ) = {ϕ, {a}, {b}, {a, b}, {a, c}, Y}.
Let f: (X, τ) ⟶ (Y, σ) be a map defined by f(a) = a, f(b) = b, f(c) = c. Clearly, f is α * g –open map. But f({a, c}) ={a,c}is not open in Y. Therefore, f is not an open map.

Theorem 3.5:

Every α –open map is $\alpha * g$ −open map.

Proof:

Let $f : (X,\tau) \rightarrow (Y,\sigma)$ be a α –open map. Since f is a α -open map, the image of each open set in X is α –open in Y. Since every α –open set is $\alpha * g$ −open. Hence, f is $\alpha * g$ −open map.

Remark 3.6:

The converse of above theorem need not be true.

Example 3.7:

Let X = Y= {a, b, c}, τ = {ϕ, {a}, {b}, {a ,b}, X} and σ = { ϕ, {a},{a ,b},Y},α*gO(X,τ)= {ϕ, {a}, {b}, {a ,b}, X}, α O(X,τ)= { ϕ, {a}, {b}, {a ,b}, X} and α*gO(Y, σ) = {ϕ, {a},{b},{a ,b}, {a ,c}, Y},αO(Y, σ) = { ϕ, {a}, {a ,b},
{a ,c}, Y}.Let f: (X, τ) ⟶ (Y, σ) be an identity map. Clearly, f is α * g –open map. But f({b}) = {b}is not α -open in Y. Therefore, f is not α -open map.

Theorem 3.8:

Every g –open map is $\alpha * g$ −open map

Proof:

Let $f : (X,\tau) \rightarrow (Y,\sigma)$ be a g –open map. Since f is a g -open map, the image of each open set in X is g –open in Y. Since every g –open set is $\alpha * g$ −open. Hence, f is $\alpha * g$ −open map.

Remark 3.9:

The converse of above theorem need not be true.

Example 3.10:
Let X = Y= {a, b, c, d}, τ = {ϕ, {a},{b ,c ,d}, X} andσ = {ϕ, {a},{b},{a ,b},{b ,c},{a ,b ,c}, Y}, α * gO(X,τ) = {ϕ, {a}, {b ,c ,d}, X}, g O(X,τ) = P(X) and α*gO(Y, σ) = {ϕ,{a}, {b}, {a ,b}, {b ,c}, {a ,b ,c}, {a ,b ,d}, Y}, gO(Y, σ) = {ϕ,{a}, {b}, {c}, {a ,b}, {b ,c}, {a ,c}, {a ,b ,c}, Y}. Let f: (X, τ) ⟶ (Y, σ) be a map defined by f(a) = f(b) = a, f(c) = d, f(d)=b. Clearly, f is α*g –open map. But f({b, c ,d})={a ,b ,d} is not g -open in Y. Therefore, f is notg–open map.

Theorem 3.11:
Everyα *g –open map is gα −open map
Proof:
Let $f : (X, \tau) \rightarrow (Y, \sigma)$be a α *g –open map. Since f is α *g -open map, the image of each open set in X is α *g –open in Y. Since every α *g –open set is gα −open. Hence, f is g$\boldsymbol{\alpha}$ −open map.

Remark 3.12:
The converse of above theorem need not be true.

Example 3.13:
Let X = Y= {a, b, c}, τ = { ϕ, {a},{b},{a ,b}, X} and σ = { ϕ, {a ,b},Y},α*gO(X,τ)= { ϕ, {a},{b},{a ,b}, X}, gα O(X,τ) = {ϕ, {a}, {b}, {a ,b},X}, and α*gO(Y, σ) = { ϕ, {a ,b},Y}, gα O(Y, σ) = { ϕ, {a},{b},{a ,b},Y}.
Let f: (X, τ) ⟶ (Y, σ) be a mapdefined by f(a) = a, f(b) = b, f(c) = c. Clearly, f is gα –open map.Butf({a}) = {a} is not α * g–open in Y. Therefore, f is not α * g–open map.
Theorem 3.14:
Everyα *g –open map isαg−open map.
Proof:
Let $f : (X, \tau) \rightarrow (Y, \sigma)$ be a α *g –open map. Since f is α *g -open map, the image of each open set in X is α *g –open in Y. Since every α *g –open set isαg−open. Hence, f isαg−open map.

Remark 3.15:
The converse of above theorem need not be true.

Example 3.16:
Let X = Y= {a, b, c}, τ = {ϕ, {a},{a ,b}, X} and σ = { ϕ, {a},Y},
α*gO(X,τ)= { ϕ, {a},{b},{a ,b},{a ,c}, X }, αg O(X,τ) = {ϕ, {a}, {b}, {a ,b},{a ,c},X}, and α*gO(Y, σ) = { ϕ,{a},{a ,b},{a ,c},Y}, αg O(Y, σ) = { ϕ, {a},{b},{c},{a ,b},{a ,c},Y}.
Let f: (X, τ) ⟶ (Y, σ) be a mapdefined by f(a) = c, f(b) = a, f(c) = b. Clearly, f is αg –open map.But f({a}) = {c} is not α * g–open in Y. Therefore, f is not α * g–open map.

Theorem 3.17:
A map f: (X, τ) ⟶ (Y, σ) is α * g-open if and only if f(int(A)) ⊆ α *g int (f(A)) for each set Ain X.
Proof:
Suppose that f is a α * g-open map. Since int (A) ⊆A, then f(int (A)) ⊆ f(A). By hypothesis,
f(int (A))is a α * g-open and α *g int (f(A)) is the largest α * g-open set contained in f(A).Hence f(int(A)) ⊆ α *g int (f(A)). Conversely, suppose A is an open set in X. Then
f(int(A)) ⊆ α * gint (f(A)) . Since int (A) = A, then f(A)⊆ α *g int (f(A)). Therefore, f(A) is a α *g- open set in (Y, σ) and f is α * g-open map.

Theorem 3.18:
Let (X, τ) , (Y, σ) and (Z , η) be three topologies spaces f: (X, τ) ⟶ (Y, σ) and
g: (Y, σ) ⟶(Z , η) be two maps. Then
1. If (g ∘ f) is α *g- open and f is continuous, then g is α *g- open.
2. If (g ∘ f) is open and g is α *g-continuous, then f is α *g- open map.
Proof:
1. Let A be an open set in Y .Then, $f^{-1}(A)$ is an open set in X. Since (g ∘ f) is α *g- open map, then (g ∘ f) $(f^{-1}(A))$ = g(f(($f^{-1}(A)$) = g(A) is α *g- open set in Z. Therefore, g is a α *g- open map.

2. Let A be an open set in X. Then, g(f(A)) is an open set in Z. Therefore, $g^{-1}(g(f(A))) = f(A)$ is a α *g-open set in Y . Hence, f is a α *g- open map.

Remark 3.19:
The concept ofα * g–open map and semi –open map are independent as can be seen from the following examples.

Example 3.20:
Let X = Y= {a, b, c}, τ = {ϕ, {a},{b}, {a ,b}, X} and σ = {ϕ, {a},{a ,b}, Y},
α * gO(X,τ) = {ϕ, {a}, {b}, {a, b}, X}, SO(X,τ) = {ϕ, {a}, {b}, {a, b}, {a ,c}, {b ,c}, X} and α * gO(Y, σ) = {ϕ, {a},{b}, {a ,b}, {a ,c}, Y},SO(Y, σ) = {{ϕ,{a}, {a ,b}, {a ,c}, Y}.
Let f: (X, τ) ⟶ (Y, σ) be a mapdefined by f(a) = a, f(b) = b, f(c) = c.Clearly, f is α * g–open map.But, f({b}) ={b} is not semi–open in Y. Hence, f is not semi -open map.

Example 3.21:
Let X = Y= {a, b, c,d}, τ = {ϕ, {a},{b}, {a,b}, {b,c},{a,b,c},X} and σ = {ϕ, {a}, {b},{a,b},{a,b,c}, Y},
α * gO(X,τ) = {ϕ, {a}, {b}, {a,b},{b,c},{a,b,c},{a,b,d}, X}, SO(X,τ) = {ϕ, {a}, {b}, {a,b}, {b,c}, {a,d},{b,d}, {a,b ,c},{a, b ,d},{b ,c ,d}, X} and α * gO(Y, σ) = {ϕ, {a},{b},{a,b},{a,b,c},{a, b, d},Y},
SO(Y,σ) = {{ϕ,{a}, {b},{a, b}, {a ,c},{a, d},{b, c},{b, d},{c, d},{a, b, c},{a, b, d},{a ,c, d},{b, c, d}, Y}.
Let f: (X, τ) ⟶ (Y, σ) be a mapdefined by f(a) = a, f(b) = b, f(c) = c. f(d)=d. Clearly, f is semi–open map.But, f({b, c}) ={b, c} is not α * g–open in Y. Hence, f is not α * g-open map.

Remark 3.22:
The concept ofα * g–open map and semi* –open map are independent as can be seen from the following examples.

Example 3.23:
Let X = Y= {a, b, c, d}, τ = {ϕ, {a,b}, X} and σ = {ϕ, {a}, {a,b,c}, Y},α∗ g O(X,τ) = {ϕ, {a,b}, {a,b,c}, {a,b,d}, X},S*O(X,τ) = {ϕ, {a,b}, X} and α∗gO(Y, σ) = {ϕ, {a}, {a,b}, {a,c}, {a,d}, {a,b,c}, {a,b,d}, {a,c,d}, Y},
S*O(Y, σ) = {ϕ, {a},{a,d},{a,b,c},Y}.Let f: (X, τ) ⟶ (Y, σ) be an identity map. Clearly, f isα∗ g –open map. But f({a, b})= {a, b} is not semi*-open in Y. Hence, f is not semi* –open map.

***Example 3.24*:**
Let X = Y= {a, b, c, d}, τ = {ϕ, {a},{b},{a, b},{b, c},{a, b, c}, X} andσ = {ϕ, {a},Y},α∗ g O(X,τ) = {ϕ, {a},{b},
{a, b},{b, c},{a, b, c},{a, b,d}, X},S*O(X,τ) = {ϕ, {a},{b},{a,b},{a,d},{b,c},{b,d},{a,b,c},{a,b,d},{b,c,d}, X} and
α∗gO(Y, σ) = {ϕ, {a}, {a,c}, {a,d}, {a,b,c}, {a,b,d}, {a,c,d}, Y},S*O(Y, σ) = P(X)
Let f: (X, τ) ⟶ (Y, σ) be an identity map. Clearly, f is semi∗–open map. But(f{b}) = {b} is not α∗ g-open in Y. Hence, f is notα∗ g–open map.

Remark 3.25:
The concept ofα * g–open map and g* –open map are independent as can be seen from the following examples.

Example 3.26:
Let X = Y= {a, b, c}, τ = {ϕ, {a},{a, b},{a, c},X} and σ = {ϕ, {a},{a, b},Y},α∗ g O(X,τ) = {ϕ,{a},{a, b},{a, c}, X}, g*O(X,τ) = {ϕ,{a}, {b}, {c}, {a, b}, {a, c},{b, c}, X} and α∗gO(Y, σ) = {ϕ, {a},{b},{a, b}, {a, c},Y},
g*O(Y, σ) = {ϕ, {a},{b},{c},{a, b},Y}. Let f: (X, τ) ⟶ (Y, σ) be an identity map. Clearly, f is α∗ g –open map. But f({a, c})= {a, c} is not g*-open in Y. Hence, f is notg* –open map.

Example 3.27:
Let X = Y= {a, b, c}, τ = {ϕ, {a}, X} and σ = {ϕ, {b},{a, b},{b, c}, Y},α∗g O(X,τ) = {ϕ,{a},{a, b}, {a, c}, X},g*O(X,τ) = {ϕ, {a},{b},{c}, X} and α∗gO(Y, σ) = {ϕ,{b}, Y},g*O(Y, σ) = {ϕ, {a},{b},{c},Y}.
Let f: (X, τ) ⟶ (Y, σ) be a mapdefined by f(a)=a, f(b)=b , f(c)=c. Clearly, f is g* –open map. But f({a}) = {a} is not
α*g-open in Y. Hence, f is notα*g–open map.

Theorem 3.28:

If a map $f : (X,\tau) \to (Y,\sigma)$ is open and $g : (Y,\sigma) \to (Z,\eta)$ isα*g-open, then $(g \circ f)$ is α*g- open map.
Proof:
Let O be an open set in X. Since f is an open map,f(O) is open in Y and we know that g is α*g- open map then$(g \circ f)$(O) =g(f(O)) is α*g- open in Z. Therefore , $(g \circ f)$ is α*g- open map.

Remark 3.29:
The composition of twoα * g–open maps need not be α * g –open maps as it can beseen from the following examples.

Example 3.30:
Let X = Y= Z={a, b, c}, τ = {ϕ, {a},{a, b},{a, c}, X} and σ = {ϕ, {a},{a, b}, Y} andη = {ϕ, {a},{b},{a, b}, Z},α∗ g O(X,τ) = {ϕ,{a},{a, b}, {a, c}, X},α∗gO(Y, σ) = {ϕ, {a},{b},{a, b},{a, c},Y} and α∗gO(Z,η) = {ϕ,{a},{b},{a,b},Z}.Let f: (X, τ) ⟶ (Y, σ) be an identity map.Clearly, f is α*g –open map. Consider the map $g : (Y,\sigma) \to (Z,\eta)$defined by g(a)= a, g(b)=b, g(c)=c. Clearly, g is α*g –open map. Here, f and g are α*g –open maps. But $(g \circ f)(\{a,c\}) = g\big(f(\{a,c\})\big) = g(\{a,c\})$ ={a, c} is not α*g -open in Z. Therefore, $(g \circ f)$ is not α*g-open open map.

IV. α * g –CLOSED MAPS

Definition 4.1:
A map $f : (X,\tau) \to (Y,\sigma)$ is called a $\boldsymbol{\alpha * g - closed}$ **map**if image of each closed set in X is $\alpha * g -$ closed in Y.

Theorem 4.2:
A map f: (X, τ) ⟶ (Y, σ) is α * g-closed if and only if α*g cl (f(A)) ⊆ f(cl(A)) for each set A in X.
Proof:
Suppose that f is a α *g-closed map. Since for each set A in X, cl(A) is closed set in X, then f(cl(A)) is aα * g-closed set in Y. Since, f(A) ⊆ f(cl(A)), then α *g cl (f(A)) ⊆ f(cl(A))
Conversely, suppose A is a closed set in X. Since α *g cl (f(A)) is the smallest α * g-closed set containing f(A),then f(A) ⊆α * g cl (f(A)) ⊆ f(cl(A)) = f(A). Thus, f(A) = α *g cl (f(A)). Hence, f (A) is a α *g-closed set inY. Therefore, f is a α *g-closed map.

Theorem 4.3:
If f: (X, τ) ⟶ (Y, σ) is g - closed map and g: (Y, σ) ⟶ (Z, η) is α *g -closed and (Y, σ) is $T_{1/2}$spaces . Then the composition g ◦f : (X, τ) ⟶ (Z, η) is α *g -closed map.
Proof:
Let O be a closed set in (X, τ). Since f is g – closed , f(O) is g – closed in (Y, σ) and g is α *g –closedwhich implies g(f(O)) is α *g -closed in Z and g(f(O)) = g ◦f (O). Therefore, g◦f isα *g -closed.

Theorem 4.4:
Let f: (X, τ) ⟶ (Y, σ) and g: (Y, σ) ⟶ (Z, η) be two mappings such that their composition g ◦f : (X, τ) ⟶ (Z, η) be α *g -closed mapping. Then the following statements are true.
1. If f is continuous and surjective, then g is α *g-closed.
2. If g is α * g -irresolute and injective, then f is α *g -closed.
3. If f is g – continuous ,surjective and (X, τ) is a $T_{1/2}$ spaces, then g is α *g -closed.
4. If g is strongly α * g-continuous and injective, then f is α *g-closed.
Proof:
1. Let O be a closed set in (Y, σ) . Since, f is continuous, f^{-1}(O) is closed in (X, τ) . Since, g ◦f isα *g-closed which implies g ◦f (f^{-1}(O)) is α *g-closed in (Z, η). That is g(O) is α *g-closed in (Z, η), since f issurjective. Therefore, g is α *g-closed.
2. Let O be a closed set in (X, τ). Since g ◦f is α *g-closed, g ◦f (O) is α *g-closed in (Z, η), Since g is α * g-irresolute, g^{-1}(g ◦f (O)) is α *g-closed in (Y, σ). That is f(O) is α *g-closed in (Y, σ). Since f is injective.Therefore, f is α *g-closed.

3. Let O be a closed set of (Y, σ). Since, f is g- continuous , f^{-1}(O) is g – closed in (X, τ) and (X, τ) is a $T_{1/2}$ spaces, f^{-1}(O) is closed in (X, τ) . Since, g ◦f is α *g-closed which implies, g ◦f (f^{1} (O)) is α *g-closed in (Z,η). That is g(O) is α *g-closed in (Z, η) , since f is surjective. Therefore, g is α *g-closed.

4. Let O be a closed set of (X, τ).Since, g ∘ f is α *g-closed which implies , g ∘f (O) is α *g-closed in (Z, η).Since,
g is strongly α *g- continuous, g^{-1}(g ∘f (O)) is closed in (Y, σ).That is f(O) is closed in (Y, σ). Since g isinjective, f is α *g-closed.

Theorem 4.5:
Let f: (X, τ) ⟶ (Y, σ) be a bijective map. Then the following are equivalent:
(1) f is a α *g- open map.
(2) f is a α *g- closed map.
(3) f^{-1} is a α *g- continuous map.
Proof:
(1)⟹ (2) Suppose O is a closed set in X. Then X\O is an open set in X and by (1) f(X\O) is aα * g- openin Y. Since, f is bijective, then f(X\O) = Y\ f(O). Hence, f(O) is a α * g- closedin Y. Therefore, f is a α * g- closed map.
(2) ⇒ (3) Let f be a α * g-closed map and O be closed set in X. Since, f is bijectivethen $(f^{-1})^{-1}$(O) = f(O) which is a α *g- closed set in Y. Therefore, f is a α *g- continuous map.
(3) ⇒ (1) Let O be an open set in X. Since, f^{-1} is a α *g- continuous map then $(f^{-1})^{-1}$(O) = f(O) is a α *g-open set in Y. Hence, f is α *g- open map.

Theorem 4.6:
A map f: (X, τ) ⟶ (Y, σ) is α * g-open if and only if for any subset O of (Y, σ) and any closed set of (X, τ) containing f^{-1}(O), there exists a α *g-closed set A of (Y, σ) containing O such that f^{-1}(A) ⊂ F.
Proof:
Suppose f is α *g- open. Let O ⊂ Y and F be a closed set of (X, τ) such that f^{-1}(O) ⊂ F. Now X- F is an open set in (X, τ). Since f is α *g- open map, f (X – F) is α *g- open set in (Y, σ). Then, A = Y - f (X – F) is aα *g-closed set in (Y, σ). Note that f^{-1}(O) ⊂ F implies O ⊂ A and f^{-1}(A) = X – f^{-1}(X – F) ⊂ X - (X – F) = F. That is ,f^{-1}(A) ⊂ F.Conversely, let B be an open set of (X, τ) . Then, $f^{-1}((f(B))^c) \subset B^c$ and B^c is a closed set in (X, τ). Byhypothesis, there exists a α *g- closed set A of (Y, σ) such that $(f(B))^c$⊂A and $f^{-1}(A) \subset B^c$ and so B $\subset (f^{-1}(A))^c$. Hence, A^c⊂ f(B) ⊂ f $((f^{-1}(A)))^c$which implies f(B) =A^c . Since, A^c is a α *g- open. f (B) is α *g- open in (Y, σ) and therefore f is α *g- open map.

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