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Some Allied Semicontinuous Functions in Topology

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ABSTRACT : In this paper, we define and study the new concepts of allied semicontinuous functions, namely, semi-sg-continuous, semi-gs-continuous, semi-αgs-continuous functions in topology.**Mathematics Subject Classification(2010)**: 54A05, 54C08, 54D15

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I. INTRODUCTION

In 1963, Levine [16] introduced and studied semi-open sets and semi-continuous functions in topology. Later, in 1970 N. Biswas[5] , S.G. Crossley et. al [7] and P.Das[9] have studied the concepts of semi-closed sets, semi-closure operators and semi-interior operators, respectively. For the first time, the concept of generalized closed (in brief, g-closed) sets was considered by Levine in 1970[17]. Later, in 1987, 1990 and 1995 respectively, Bhattacharya et. al [4], Arya et.al.[3] and J. Dontchev [12] have defined and studied the concepts of sg-closed sets, gs-closed sets, gsp-closed sets. In [6 & 25], P. Sundaram et.al have defined and studied the concepts of sg-continuous functions.In [25] P.Sundaram had defined and studied the concept of gs-continuous functions in topology. In 1995, Dontchev[12] has defined and investigated the notions of gsp-continuity and gsp-irresoluteness. The aim of this paper is to define and study the new classes of allied semicontinuous functions , namely , semi-sg-continuous functions , semi-αgs-continuous functions and semi-gs-continuous functions in topology.Also, we study their basic characterizations and decomposition theorems of all these functions with the other type of semicontinuous functions .

II. PRELIMINARIES

Throughout this paper (X,τ) and (Y,σ) (or Simply X and Y) respectively, denote topological spaces on which no separation axioms are assumed unless otherwise explicitly stated.

For a subset A of (X,τ), the Closure of A, the Interior of A with respect to τ are denoted by $C\ell(A)$ and $Int(A)$ respectively.

The following definitions and results are useful in this sequel.

DEFINITION 2.1: A subset A of a space X is called

(i) semi-open-set [16] if $A \subset ClInt(A)$.

(ii) semipre-open set [1] if $A \subset ClIntCl(A)$.

(iii) α-open set [20] if $A \subset IntClInt(A)$.

The complement of semi-open (resp., semipre-open,α-open) set is called semi-closed [5] (resp. semipre-closed[1] , α-closed [18]) set. The family of all semi-open(resp.semipre-open) sets of a space X is denoted by $SO(X)$ (resp. $SPO(X)$).

DEFINITION 2.2: Let A be a subset of space X, then the semi-interior [9] (resp. the semi-pre-interior[1&19] , the α-interior [18]) of A is the union of all semi-open (resp. semi-pre-open ,α-open) sets contained in A and is denoted by $sInt(A)$ (resp. $spInt(A)$, $\alpha Int(A)$).

DEFINITION 2.3: Let A be a subset of a space X, then the intersection of all semi-closed(resp. semi-pre-closed , α-closed) sets containing A is called the semi-closure[7](resp. semi-pre-closure[1&19] , α-closure[18]) of A and is denoted by $sCl(A)$ (resp. $spCl(A)$,$\alpha Cl(A)$).

DEFINITION 2.4: A subset A of a space X is called :

(i) A generalised closed set (in brief , g-closed) [17] if $Cl(A) \subset U$ whenever $A \subset U$ and U is open.

(ii) semi-generalised closed (in brief , sg-closed) [4] if $sCl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi-open in X.

(iii) generalized semi-closed (in brief, gs-closed) [3] if $sCl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.

(iv) generalized semipre-closed (briefly,gsp-closed) [12] if $spcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.

(v) α-generalized semiclosed (in brief,αgs-closed) [22] if αCl(A) ⊂ U whenever $A \subseteq U$ and U is semiopen in X.

DEFINITION 2.5: A function $f : X \to Y$ is called :

(i) semi-continuous [16] if the inverse image of each open set Y is semi-open in X.

(ii) sg-continuous [6 & 25] if the inverse image of each open set of Y is sg-open in X.

(iii) gs-continuous [25] if the inverse image of each open set of Y is gs-open in X.

(iv) gsp-continuous [12] if the inverse image of each open set of Y is gsp-open in X.

(v) αgs-continuous [23] if the inverse image of each open set of Y is αgs-open in X.

DEFINITION 2.6: A function $f : X \to Y$ is called :

(i) sg-irresolute [6] if the inverse image of every sg-open set of Y sg-open in X.

(ii) gs-irresolute [25] if the inverse image of every gs-open set of Y is gs-open in X.

(iii) gsp-irresolute [12] if the inverse image of every gsp-open set of Y is gsp-open in X.

(iv) αgs-irresolute [23] if the inverse image of every αgs-open set of Y is αgs-open in X.

(v) Irresolute [8] if the inverse image of every semiopen set of Y is semiopen in X .

DEFINITION 2.7: A function $f : X \to Y$ is called :

(i) contra-semi-continuous [13] if the inverse image of each open set of Y is semiclosed in X.

(ii) strongly continuous [2] if the inverse image of each subset of Y is clopen in X.

DEFINITION 2.8: A space X is called :

(i) semi-g-regular [14] if for each sg-closed set A and each point x∉A, there exist disjoint semi-open sets U,V ⊆ X such that A ⊆ U and x∈ V.

(ii) αgs-regular [24] if for each αgs-closed set A and each point x∉A, there exist disjoint semi-open sets U,V ⊆ X such that A ⊆ U and x∈ V.

(iii) semi-connected [10] if X cannot be written as the disjoint union of two non-empty semiopen sets.

(iv) sg-connected [6] if X cannot be written as the disjoint union of two non-empty sg-open sets.

DEFINITION 2.9[15]: Let X be a topological space and $A \subset X$. Then the semi-generalized kernel of A is denoted by sg-ker(A) and is defined to be the set

$$sg-\ker(A) = \cap\{G \in SGO(X)/A \subset G\}$$

THEOREM 2.10[15]:Let X be a topological space and x in X then y ∈ sg-ker({x}) iff x ∈ sgCl({x}).

DEFINITION 2.11[8]: A function f: X → Y is called pre-semi-open if the image of each semi-open set of X is semi-open in Y.

III. PROPERTIES OF SEMI-SG-CONTINUOS FUNCTIONS

In section we define and study the following

DEFINITION 3.1: A function f: X → Y is said to be semi-sg-continuous if the inverse image of every sg-open set in Y is semi-open set in X.

Clearly, every semi-sg-continuous function is sg-irresolute.

DEFINITION 3.2: A function f: X → Y is called strongly sg-continuous if the inverse image of every sg-open set in Y is open in X.

THEOREM 3.3: Let f: X → Y be a single valued function, where X and Y are topological spaces, then the following statements are equivalent:

(i) The function f is semi-sg-continuous.

(ii) For each point p in X and each sg-open set V in Y with f(p) ∈ V, there is
a semi-open set U in X such that p ∈ U, f (U) ⊆ V.

PROOF: (i) → (ii). Let f (p) ∈ V and V ⊂ Y an sg-open set then p ∈ $f^{-1}(V)$ is semi-open set in X, since f is with semi-sg-continuous. Let U = $f^{-1}(V)$, then p ∈U and f (U) ⊆ V.

(ii) → (i). Let V be an sg-open set and p ∈ $f^{-1}(V)$ then f (p) ∈ V, there exists a semi-open set in U_p in X such that p ∈ U_p and f (U_p) ⊂ V. Then p ∈ U_p ⊂ f^{-1} (V) and $f^{-1}(V)$ = ∪ U_p ∈ SO(X). This implies that f is semi-sg-continuous

We define the following

DEFINITION 3.4: A function f: X → Y is called sg-gsp-continuous if the inverse image of every sg-open set in Y is gsp-open set in X.

Clearly , every sg-irresolute function is sg-gsp-continuous.

DEFINITION 3.5: A function f: X → Y is called semi-gsp-continuous if the inverse image of every gsp-open set of Y is semi-open in X.

DEFINITION 3.6: A function f: X → Y is called gsp-sg-continuous if the inverse image of every gsp-open set of Y is sg-open in X.

THEOREM 3.7: Let f: X → Y is semi-sg-continuous surjection and X is semi-connected then Y is sg-connected.

PROOF: Suppose Y is not sg-connected. Let $Y = A \cup B$ where A and B are disjoint non-empty sg-open sets in Y. Since f is semi-sg-continuous surjection $X = f^{-1}(A) \cup f^{-1}(B)$ where $f^{-1}(A)$ and $f^{-1}(B)$ are disjoint non-empty and semi-open sets in X. This contradicts the fact that X is semi-connected. Hence Y is sg-connected.

We, define the following.

DEFINITION 3.8 : A space X is called gsp-connected if X cannot be written as the disjoint union of two non-empty gsp-open sets.

THEOREM 3.9: Let f: X → Y is gsp-sg-continuous surjection and X is sg-connected then Y is gsp-connected.

PROOF: Obvious.

Easy proofs of the following are omitted.

THEOREM 3.10: Let f: X → Y is pre-sg-continuous, onto and X is sg-connected then Y is semi-connected.

THEOREM 3.11: Let f: X → Y is strongly-sg-continuous, onto and X is connected then Y is sg-connected.

THEOREM 3.12: Let f: X → Y is sg-gsp-continuous surjection and X is gsp-connected then Y is sg-connected.

We define the following

DEFINITION 3.13: A function f: X → Y is called contra-semi-sg-continuous if the inverse image of each sg-open of Y is semi-closed in X.

DEFINITION 3.14: A function f: X → Y is called contra-strongly-sg-continuous if the inverse image of each sg-open of Y is closed in X.

The routine proof of the following is omitted.

THEOREM 3.15 : The following are equivalent for a function f: X → Y

(i) f is contra-semi-sg-continuous..

(ii) For each sg-closed subset F of Y, $f^{-1}(F) \in SO(X)$

(iii) For each $p \in X$ and each sg-closed subset F of Y containing f(p), there exists semi-open set U in X containing point p such that $f(U) \subset F$

THEOREM 3.16 : If a function f: X→Y is contra-semi-sgs-continuous and Y is semi-g-regular, then f is semi-sg-continuous.

We define the following

DEFINITION 3.17: A function f: X → Y is said to be perfectly semi-sg-continuous if the inverse image of each sg-open set of Y is both semi-clopen in X.

REMARK 3.18 : Let f: X → Y be a function , then

(i) If f is perfectly semi-sg-continuous function is semi-sg-continuous function.

(ii) If f is perfectly semi-sg-continuous function is contra semi-sg-continuous function.

THEOREM 3.19 : The following are equivalent for a function f: X → Y is

(i) f is perfectly semi-sg-continuous.

(ii) The inverse image of every sg-open set in Y is both semi-open and semi-closed in X.

(iii) The inverse image of every sg-closed set in Y is both semi-open and semi-closed in X.

PROOF: Obvious.

THEOREM 3.20: The following are equivalent for a function f: X → Y

(i) f is contra-semi-sg-continuous..

(ii) The inverse image each sg-closed set in Y is semi-open.

PROOF: Easy.

We , state the following.

LEMMA 3.21 : Suppose that SF(X) is closed under arbitrary intersections then the following are equivalent for a function f: X → Y.

(i) f is contra-semi-sg-continuous.

(ii) the inverse image of each sg-closed set of Y is semi-open in X.

(iii) For each x in X and each sg-closed set B in Y with $f(x) \in B$, there exists a semi-open set A in X such that $x \in A$ and $f(A) \subset B$.

(iv) $f(sCl(A)) \subset$ sg-ker(f(A)) for every subset A of X.

(v) $sCl(f^{-1}(B)) \subset f^{-1}$(sg-ker(B)) for every subset B of Y.

Easy proofs of the followings are omitted

THEOREM 3.22 : If f: X→Y is a contra-semi-sg-continuous from a semi-connected space X onto any space Y, then Y is not a discrete space.

THEOREM 3.23 : If f: X→Y is a contra-semi-sg-continuous surjection and X is semi-connected space, then Y is connected.

Next, we state some decomposition on semi-sg-continuos functions :

THEOREM 3.24 : If f: X → Y and g: Y → Z be two functions then

(i) gof: X → Z is semi-sg-continuous function, if g is sg-irresolute and f is semi-sg-continuous.

(ii) gof: X → Z is semi-sg-continuous function, if g is sg-gsp-continuous and f is semi-sg-continuous.

(iii) gof: X → Z is semi-sg-continuous function, if g is strongly-gsp-continuous and f is semi-continuous.

THEOREM 3.25 : If f: X → Y and g: Y → Z be two functions then

(i) gof: X → Z is semi-continuous function, if f is semi-sg-continuous and g is sg-continuous.

(ii) gof: X → Z is semi-continuous function, if f is semi-strongly-sg-continuous and g is sg-continuous.
(iii) gof: X → Z is continuous function, if f is strongly-sg-continuous and g is sg-continuous.

We define the following.
DEFINITION 3.26 : A function f : X → Y is called strongly-semi-open if the image of each semi-open set of X is open in Y.
LEMMA 3.27: If f : X→Y and g : Y→Z be two functions such that gof : X→Z is semi-sg-continuous , then
(i)If f: X → Y is strongly-semi-open surjective , then g is strongly-sg-continuous.
(ii) If f: X → Y is surjective, pre-semi-open , then g is semi-sg-continuous.
Easy proof of the theorem is omitted.
LEMMA 3.28 : Let f: X → Y and g: Y → Z be two functions. Then,
(i) If f is irresolute and g is semi-sg-continuous then gof: X → Z semi-sg-continuous.
(ii) If f is irresolute and g is contra-semi-sg-continuous then gof: X → Z contra-semi-sg-continuous.
(iii) If f is contra-semi-continuous and g is sg-continuous then gof is contra-semi-continuous.
(iv) If f is strongly-semi-continuous and g is contra-semi-sg-continuous then gof is contra-strongly-sg-continuous.
PROOF: Obvious .

IV. PROPERTIES OF SEMI-GS-CONTINUOUS FUNCTIONS

DEFINITION 4.1 : A function f: X → Y is said to be semi-gs-continuous if the inverse image of every gs-open set in Y is semi-open set in X.
Clearly , every semi-gs-continuous function is gs-irresolute.
The routine proof of the following is omitted.

THEOREM 4.2: Let f: X → Y be a single valued function, where X and Y are topological spaces, then the following statements are equivalent:
(i) The function f is semi-gs-continuous.
(ii) For each point p in X and each gs-open set V in Y with f(p) ∈ V, there is
a semi-open set U in X such that p ∈ U, f (U) ⊆ V.
We define the following.
Definition 4.3: A function f: X → Y is said to be gs-gsp-continuous if the inverse image of every gs-open set in Y is gsp-open set in X.
Clearly , every gs-irresolute is gs-gsp-continuous.
Definition 4.4: A function f: X → Y is called strongly-gs-continuous if the inverse image of every gs-open set in Y is open in X.

We , prove the following.
THEOREM 4.5: Let f: X → Y is semi-gs-continuous surjection and X is semi-connected then Y is gs-connected.
PROOF: Suppose Y is not gs-connected. Let $Y = A \cup B$ where A and B are disjoint non-empty gs-open sets in Y. Since f is semi-gs-continuous surjection $X = f^{-1}(A) \cup f^{-1}(B)$ where $f^{-1}(A)$ and $f^{-1}(B)$ are disjoint non-empty and semi-open sets in X. This contradicts the fact that X is semi-connected. Hence Y is gs-connected.
We define the following.
Definition 4.6 : A function f: X → Y is called gsp-gs-continuous if the inverse image of every gsp-open set in Y is gs-open in X.
The routine proof of the following is omitted.
THEOREM 4.7 : Let f: X → Y is gsp-gs-continuous surjection and X is gs-connected then Y is gsp-connected.
We , define the following.
Definition 4.8 : A function f: X → Y is called pre-gs-continuous if the inverse image of every semi-open set of Y is gs-open in X.
Easy proofs are omitted of the following.
THEOREM 4.9: Let f: X → Y is pre-gs-continuous, onto and X is gs-connected then Y is semi-connected.
THEOREM 4.10: Let f: X → Y is strongly-gs-continuous, onto and X is connected then Y is gs-connected.
THEOREM 4.11: Let f: X → Y is gsp-gs-continuous surjection and X is gsp-connected then Y is gs-connected.
Next , we give some decompositions on semi-gs-continuity :
Theorem 4.12: If f: X → Y and g: Y → Z be two functions then
(i) gof: X → Z is semi-gs-continuous function, if g is gs-irresolute and f is semi-sg-continuous.
(ii) gof: X → Z is semi-gs-continuous function, if g is gs-gsp-continuous and f is semi-sg-continuous.
(iii) gof: X → Z is semi-gs-continuous function, if g is strongly-gs-continuous and f is semi-continuous.
(iv) gof: X → Z is gs-gsp-continuous function, if g is gs-gsp-continuous and f is gs-irresolute.
Theorem 4.13: If f: X → Y and g: Y → Z be two functions then
(i) gof is semi-continuous, if f is semi-sg-continuous and g is gs-continuous.
(ii) gof is irresolute, if f is semi-gs-continuous and if g pre-gs-continuous.

(iii) gof is semi-continuous, if f is irresolute and g is semi-continuous.

LEMMA 4.14: Let f: X → Y and g:Y→Z be two functions such that gof :X→Z is semi-gs-continuous . Then,

(i) If f is strongly-semi-open surjective , then g is strongly-gs-continuous.
(ii) If f is surjectiv pre-semi-open , then g is semi-gs-continuous.

Easy proof of the theorem is omitted.

We, state the following :

LEMMA 4.15: If f: X → Y and g: Y → Z be two functions. Then,

(i) If f is irresolute and g is semi-gs-continuous then gof: X → Z semi-gs-continuous.
(ii) If f is irresolute and g is contra-semi-gs-continuous then gof is contra-semi-gs-continuous.
(iii) If f is contra-semi-gs-continuous and g is gs-continuous then gof is contra-semi-continuous.
(iv) If f is strongly-semi-continuous and g is contra-semi-gs-continuous then gof: X → Z is contra-strongly-gs-continuous.

V. PROPERTIES OF SEMI-αGS-CONTINUOUS FUNCTIONS

DEFINITION 5.1 : A function f: X → Y is said to be semi-αgs-continuous if the inverse image of every αgs-open set in Y is semi-open in X.

Clearly , every semi-αgs-continuous function is αgs-irresolute.

Proof of the following is similar to Th.3.3.

THEOREM 5.2: Let f: X → Y be a single valued function, where X and Y are topological spaces, then the following statements are equivalent:

(i) The function f is semi-αgs -continuous.

(ii) For each point p in X and each αgs -open set V in Y with f(p) ∈ V, there is a semi-open set U in X such that p ∈ U, f (U) ⊆ V.

We , define the following.

DEFINITION 5.3: A function f: X → Y is said to be αgs-gsp-continuous if the inverse image of every αgs-open set of Y is gsp-open set in X.

THEOREM 5.4 Let f: X → Y is αgs-irresolute then f is αgs-gsp-continuous.

PROOF: Let V be a αgs-closed subset of Y. Then $f^{-1}(V)$ is αgs-closed set in X, as f is αgs-irresolute. We have, every αgs-closed set is gsp-closed set, then $f^{-1}(V)$ is gsp-closed set in X. Therefore, f is αgs-gsp-continuous.

DEFINITION 5.5: A function f: X → Y is called strongly-αgs-continuous if the inverse image of every αgs-open set in Y is open in X.

We recall the definition.

DEFINITION 5.6[23]: A topological space X is said to be αgs-connected if X cannot be written as the disjoint union of two non-empty αgs-open sets.

THEOREM 5.7: Let f: X → Y is semi-αgs-continuous surjection and X is semi-connected then Y is αgs-connected.

Proof is similar to Th.4.5.

DEFINITION 5.8 : A function f: X → Y is called gsp-αgs-continuous if the inverse image of every gsp-open set in Y is αgs-open in X.

DEFINITION 5.9 : A function f: X → Y is called pre-αgs-continuous if the inverse image of every semi-open set of Y is αgs-open in X.

The routine proofs of the followings are omitted.

THEOREM 5.10 : If f: X → Y is gsp-αgs-continuous, surjection and X is αgs-connected then Y is gsp-connected.

THEOREM 5.11: Let f: X → Y is pre-αgs-continuous, onto and X is αgs-connected then Y is semi-connected.

THEOREM 5.12: Let f: X → Y is strongly-αgs-continuous, onto and X is connected then Y is αgs-connected.

We define the following

DEFINITION 5.13 : A function f: X → Y is called contra-semi-αgs-continuous if the inverse image of each αgs-open of Y is semi-closed in X.

DEFINITION 5.14 : A function f: X → Y is called contra-strongly-αgs-continuous if the inverse image of each αgs-open of Y is closed in X.

REMARK 5.15 : Since every open set is αgs-open and every closed set is semi-closed set and hence we have the following

(i) Every contra-strongly-αgs-continuous function is contra-semi-αgs-continuous function.
(ii) Every contra-semi-αgs-continuous function is contra-semi-continuous function .

THEOREM 5.16: The following are equivalent for a function f: X → Y is

(i) f is contra-semi-αgs-continuous..
(ii)For each αgs-closed subset F of Y, $f^{-1}(F) \in SO(X)$
(iii) For each x∈ X and each αgs-closed subset F of Y containing f(x), there exists semi-open set U in X containing point x such that f(U) ⊂ F.

Easy proof of the theorem is omitted.

THEOREM 5.17 : If a function f: X→Y is contra-semi-αgs-continuous and Y is αgs-regular, then f is semi-αgs-continuous.

PROOF: Obvious.

DEFINITION 5.18: A space X is called locally αgs-indiscrete if every semi-open set is αgs-closed in X.

Easy proofs of the following are omitted.

THEOREM 5.19 : If a function f: X→Y is contra-semi-αgs-continuous and X is locally αgs-indiscrete space, then f is αgs-irresolute.

THEOREM 5.21: Let f: X→Y be a function and let g: X→X×Y be the graph function of f defined by g(x) =(x, f(x)) for every x∈X. If g is contra-semi-αgs-continuous, then f is contra-semi-αgs-continuous.

THEOREM 5.22: If f: X→Y is a contra-semi-αgs-continuous from a semi-connected space X onto any space Y, then Y is not a discrete space.

THEOREM 5.23: If f: X→Y is a contra-semi-αgs-continuous surjection and X is semi-connected space, then Y is αgs-connected.

We,define the following.

DEFINITION 5.24: A function f: X → Y is said to be perfectly semi-αgs-continuous if the inverse image of each αgs-open set of Y is both semi-clopen in X.

We , state the followings.

THEOREM 5.25: A function f: X → Y is perfectly semi-αgs-continuous if and only if the inverse image of every αgs-closed set in Y is both semi-open and semi-closed in X.

THEOREM 5.26: Every perfectly semi-αgs-continuous function is irresolute function.

REMARK 5.27: Let f: X → Y be a function, then

(i) If f is perfectly semi-αgs-continuous function is semi-αgs-continuous function.

(ii) If f is perfectly semi-αgs-continuous function is contra semi-αgs-continuous function.

THEOREM 5.28: The following are equivalent for a function f: X → Y is

(i) f is perfectly semi-αgs-continuous.

(ii)The inverse image of every αgs-open set in Y is both semi-open and semi-closed in X.

(iii)The inverse image of every αgs-closed set in Y is both semi-open and semi-closed in X.

PROOF: Obvious .

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