

ON $I_{s\hat{g}}$ -CONTINUITY IN IDEAL TOPOLOGICAL SPACES

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ABSTRACT

In this paper we introduce and study the notions of $I_{s\hat{g}}$ -closed sets, $I_{s\hat{g}}$ -continuity, $I_{s\hat{g}}$ -irresolute, $I_{s\hat{g}}$ -connected, $I_{s\hat{g}}$ -normal in ideal topological spaces.

Keywords: $I_{s\hat{g}}$ -closed, $I_{s\hat{g}}$ -continuity, $I_{s\hat{g}}$ -irresolute, $I_{s\hat{g}}$ -connected and $I_{s\hat{g}}$ -normal.

1. INTRODUCTION AND PRELIMINARIES

An ideal I on a topological space (X, τ) is a non-empty collection of subsets of X which satisfies the following properties. (1) $A \in I$ and $B \subseteq A$ implies $B \in I$, (2) $A \in I$ and $B \in I$ implies $A \cup B \in I$. An ideal topological space is a topological space (X, τ) with an ideal I on X and is denoted by (X, τ, I) . For a subset $A \subseteq X$, $A^*(I, \tau) = \{x \in X: A \cap U \notin I \text{ for every } U \in \tau(X, x)\}$ is called the local function of A with respect to I and τ [8]. We simply write A^* in case there is no chance for confusion. A kuratowski closure operator $cl^*(\cdot)$ for a topology $\tau^*(I, \tau)$ called the $*$ - topology, finer than τ is defined by $cl^*(A) = A \cup A^*$ [13]. If $A \subseteq X$, $cl(A)$ and $int(A)$ will respectively, denote the closure and interior of A in (X, τ) .

Definition 1.1: A subset A of a topological space (X, τ) is called

1. g -closed [9], if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X, τ) .
 2. g^* -closed [14], if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is g -open in (X, τ) .
 3. \hat{g} -closed [15], if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi open in (X, τ) .
 4. gs -closed [2], if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X, τ) .
 5. sg -closed [5], if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi open in (X, τ) .
 6. $s\hat{g}$ -closed [11], if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is \hat{g} -open in (X, τ) .
- Complements of the above mentioned closed sets are called their respective open sets.

Definition 1.2: A subset A of an ideal topological spaces (X, τ, I) is said to be

1. semi- I -closed [7], if $int(cl^*(A)) \subseteq A$
 2. I_{gs} -closed [10], if $sIcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X .
 3. I_{sg} -closed [10], if $sIcl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi-open in X .
- The complements of the above mentioned closed sets are called their respective open sets.

Definition 1.3: A function $f: (X, \tau, I) \rightarrow (Y, \sigma)$ is said to be

1. g -continuous [3], if for every open set $v \in \sigma$, $f^{-1}(v)$ is g -open in (X, τ) .
2. gs -continuous [5], if for every open set $v \in \sigma$, $f^{-1}(v)$ is gs -open in (X, τ) .
3. sg -continuous [12], if for every open set $v \in \sigma$, $f^{-1}(v)$ is sg -open in (X, τ) .
4. gp -continuous [1], if for every open set $v \in \sigma$, $f^{-1}(v)$ is gp -open in (X, τ) .
5. gsp -continuous [6], if for every open set $v \in \sigma$, $f^{-1}(v)$ is gsp -open in (X, τ) .

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2. $I_{s\hat{g}}$ -CLOSED SETS

Definition 2.1: A subset A of a space (X, τ, I) is called $I_{s\hat{g}}$ -closed, if $sIcl(A) \subseteq U$ whenever $A \subseteq U$ and U is \hat{g} -open.

Theorem 2.2: Every closed set is $I_{s\hat{g}}$ -closed but not conversely.

Proof: Let A be a closed set. Let U be \hat{g} -open such that $A \subseteq U$. Since A is closed, $sIcl(A) \subseteq cl(A) = A \subseteq U$. Hence A is $I_{s\hat{g}}$ -closed.

Example 2.3: Let $X = \{a, b, c\}, \tau = \{\Phi, \{a\}, \{a,b\}, X\}$ and $I = \{\Phi, \{a\}\}$. Here $\{a, c\}$ is $I_{s\hat{g}}$ -closed but not closed.

Theorem 2.4: Every $I_{s\hat{g}}$ -closed is $s\hat{g}$ -closed but not conversely.

Proof: Let A be $I_{s\hat{g}}$ -closed set of (X, τ, I) . Let U be \hat{g} -open such that $U \supseteq sIcl(A) = A \cup \text{int}^*(cl(A)) \subseteq A \cup \text{int}(cl(A)) = scl(A)$. This shows that A is $s\hat{g}$ -closed.

Example 2.5: Let $X = \{a, b, c\}, \tau = \{\Phi, \{a\}, \{b,c\}, X\}$ and $I = \{\Phi, \{a\}, \{b\}, \{a,b\}\}$. Here $\{b\}$ and $\{c\}$ are $s\hat{g}$ -closed but not $I_{s\hat{g}}$ -closed.

Theorem 2.6: Every $I_{s\hat{g}}$ -closed is gs -closed but not conversely.

Proof: Let A be $I_{s\hat{g}}$ -closed set of (X, τ, I) . Let U be any open set such that $A \subseteq U$. Since every open set is \hat{g} -open. $scl(A) \subseteq U$. Hence A is gs -closed set.

Example 2.7: Let $X = \{a, b, c\}, \tau = \{\Phi, \{a\}, \{b,c\}, X\}$ and $I = \{\Phi, \{a\}, \{b\}, \{a,b\}\}$. Here $\{a, b\}$ is gs -closed but not $I_{s\hat{g}}$ -closed.

Theorem 2.8: The union of two $I_{s\hat{g}}$ -closed set is $I_{s\hat{g}}$ -closed set.

Proof: Assume that A and B are $I_{s\hat{g}}$ -closed in (X, τ, I) . Let U be \hat{g} -open such that $A \cup B \subseteq U$. Then $A \subseteq U$ and $B \subseteq U$. Since A and B are $I_{s\hat{g}}$ -closed, $sIcl(A) \subseteq U$, $sIcl(B) \subseteq U$. $sIcl(A \cup B) = sIcl(A) \cup sIcl(B) \subseteq U$. That is $sIcl(A \cup B) \subseteq U$. Hence $A \cup B$ is $I_{s\hat{g}}$ -closed in (X, τ, I) .

Theorem 2.9: Let A be $I_{s\hat{g}}$ -closed set of (X, τ, I) . Then $sIcl(A) - A$ does not contain a nonempty set.

Proof: Let A be $I_{s\hat{g}}$ -closed set and F be a \hat{g} -closed set contained in $sIcl(A)$. Then F^c is \hat{g} -open set, such that $A \subseteq F^c$. Since A is $I_{s\hat{g}}$ -closed set. $sIcl(A) \subseteq F^c$. Thus $F \subseteq (sIcl(A))^c$. Also $F \subseteq sIcl(A) - A$.

Therefore $F \subseteq (scl(A))^c \cap sIcl(A) = \Phi$. Hence $F = \Phi$.

Remark 2.10: Suppose $I = \{\Phi\}$, then $I_{s\hat{g}}$ -closed sets coincides with $s\hat{g}$ -closed set.

Theorem 2.11: Let (X, τ, I) be an ideal space. Then either $\{x\}$ is \hat{g} -closed or $\{x\}^c$ is $I_{s\hat{g}}$ -closed for every $x \in X$.

Proof: Suppose that $\{x\}$ is not \hat{g} -closed in X , then $\{x\}^c$ is not \hat{g} -open and that only \hat{g} -open set containing $\{x\}^c$ is the space X itself. That is $\{x\}^c \subseteq X$. Therefore $sIcl(A) \subseteq X$ and so $\{x\}^c$ is a $I_{s\hat{g}}$ -closed.

Theorem 2.12: Let A be a $I_{s\hat{g}}$ -closed in (X, τ, I) . Then A is semi-I-closed iff $sIcl(A) - A$ is closed.

Proof:

Necessity: Let A be an $I_{s\hat{g}}$ -closed and semi-I-closed. Then $sIcl(A) = A$ and so $sIcl(A) - A = \Phi$ which is closed.

Sufficiency: Since A is $I_{s\hat{g}}$ -closed set by Theorem 2.9, $sIcl(A) - A$ contains no nonempty closed set. But $sIcl(A) - A$ is closed. This implies that $sIcl(A) - A = \Phi$. That is $sIcl(A) = A$. Hence A is semi-I-closed.

Theorem 2.13: Every $I_{s\hat{g}}$ -closed is g -closed, g^* -closed, sg -closed, gp -closed and gsp -closed but not conversely.

Example 2.14: Let $X = \{a, b, c\}, \tau = \{\Phi, \{a\}, \{b,c\}, X\}$ and $I = \{\Phi, \{a\}, \{b\}, \{a,b\}\}$. Here $\{a,b\}$ is g -closed, g^* -closed, sg -closed, gp -closed and gsp -closed but not $I_{s\hat{g}}$ -closed.

3. $I_{s\hat{g}}$ – Continuity

Definition 3.1: A function $f: (X, \tau, I) \rightarrow (Y, \sigma)$ is said to be $I_{s\hat{g}}$ continuous, if $f^{-1}(v)$ is $I_{s\hat{g}}$ -closed in (X, τ, I) for every closed set v in (Y, σ) .

Theorem 3.2: For a function $f: (X, \tau, I) \rightarrow (Y, \sigma)$, the following hold.

1. Every continuous function is $I_{s\hat{g}}$ -continuous.
2. Every $I_{s\hat{g}}$ -continuous function is $s\hat{g}$ -continuous.
3. Every $I_{s\hat{g}}$ -continuous function is gs -continuous.

Proof

- (i) Let f be a continuous function and v be a closed set in (Y, σ) . Then $f^{-1}(v)$ is closed in (X, τ, I) . Since every closed set is $I_{s\hat{g}}$ -closed, $f^{-1}(v)$ is $I_{s\hat{g}}$ -closed in (X, τ, I) . Hence f is $I_{s\hat{g}}$ -continuous.
- (ii) Let f be a $I_{s\hat{g}}$ -continuous function and v be a closed set in (Y, σ) . Then $f^{-1}(v)$ is $I_{s\hat{g}}$ -closed in (X, τ, I) . Since every $I_{s\hat{g}}$ -closed set is $s\hat{g}$ -closed set, $f^{-1}(v)$ is $s\hat{g}$ -closed in (X, τ, I) . Hence f is $s\hat{g}$ -continuous.
- (iii) Let f be a $I_{s\hat{g}}$ -continuous function and v be a closed set in (Y, σ) . Then $f^{-1}(v)$ is $I_{s\hat{g}}$ -closed in (X, τ, I) . Since every $I_{s\hat{g}}$ -closed set is gs -closed set, $f^{-1}(v)$ is gs -closed in (X, τ, I) . Hence f is gs -continuous.

The above theorem need not be true as seen from the following examples.

Examples 3.3:

- (i) Let $X = Y = \{a, b, c\}$, $\tau = \{\Phi, \{a\}, X\}$, $\sigma = \{\Phi, \{b\}, \{a, b\}, Y\}$ and $I = \{\Phi, \{a\}, \{c\}, \{a, c\}\}$. Let the function $f: (X, \tau, I) \rightarrow (Y, \sigma)$ is defined by $f(a) = a$, $f(b) = b$, $f(c) = c$. Then the function f is $I_{s\hat{g}}$ -continuous but not continuous.
- (ii) Let $X = Y = \{a, b, c\}$, $\tau = \{\Phi, \{a\}, \{a, b\}, X\}$, $\sigma = \{\Phi, \{b\}, Y\}$ and $I = \{\Phi, \{a\}\}$. Let the function $f: (X, \tau, I) \rightarrow (Y, \sigma)$ is defined by $f(a) = b$, $f(b) = c$, $f(c) = a$. Then the function f is $s\hat{g}$ -continuous but not $I_{s\hat{g}}$ -continuous.
- (iii) Let $X = Y = \{a, b, c\}$, $\tau = \{\Phi, \{a\}, \{b, c\}, X\}$, $\sigma = \{\Phi, \{c\}, \{a, c\}, Y\}$ and $I = \{\Phi, \{a\}, \{b\}, \{a, b\}\}$. Let the function $f: (X, \tau, I) \rightarrow (Y, \sigma)$ be the identity function. Then the function f is sg -continuous but not $I_{s\hat{g}}$ -continuous.

Theorem 3.4: For a function $f: (X, \tau, I) \rightarrow (Y, \sigma)$, the following hold.

- (i) Every $I_{s\hat{g}}$ -continuous function is g -continuous.
- (ii) Every $I_{s\hat{g}}$ -continuous function is g^* -continuous.
- (iii) Every $I_{s\hat{g}}$ -continuous function is sg -continuous.
- (iv) Every $I_{s\hat{g}}$ -continuous function is gp -continuous.
- (v) Every $I_{s\hat{g}}$ -continuous function is gsp -continuous.

Proof: It is obvious.

The above theorem need not be true as seen from the following examples.

Examples 3.5:

- (i) Let $X = Y = \{a, b, c\}$, $\tau = \{\Phi, \{a\}, \{b, c\}, X\}$, $\sigma = \{\Phi, \{a\}, \{a, b\}, Y\}$ and $I = \{\Phi, \{a\}, \{c\}, \{a, c\}\}$. Let the function $f: (X, \tau, I) \rightarrow (Y, \sigma)$ is defined by $f(a) = b$, $f(b) = c$, $f(c) = a$. Then the function f is g -continuous but not $I_{s\hat{g}}$ -continuous.
- (ii) Let $X = Y = \{a, b, c\}$, $\tau = \{\Phi, \{a\}, \{a, b\}, \{a, c\}, X\}$, $\sigma = \{\Phi, \{a\}, Y\}$ and $I = \{\Phi, \{a\}, \{b\}, \{a, b\}\}$. Let the function $f: (X, \tau, I) \rightarrow (Y, \sigma)$ be the identity function. Then f is g^* -continuous but not $I_{s\hat{g}}$ -continuous.
- (iii) Let $X = Y = \{a, b, c\}$, $\tau = \{\Phi, \{b\}, \{a, b\}, X\}$, $\sigma = \{\Phi, \{c\}, Y\}$ and $I = \{\Phi, \{b\}\}$. Let the function $f: (X, \tau, I) \rightarrow (Y, \sigma)$ be the identity function. Then f is sg -continuous but not $I_{s\hat{g}}$ -continuous.
- (iv) Let $X = Y = \{a, b, c\}$, $\tau = \{\Phi, \{a\}, \{a, c\}, X\}$, $\sigma = \{\Phi, \{c\}, Y\}$ and $I = \{\Phi, \{a\}\}$. Let the function $f: (X, \tau, I) \rightarrow (Y, \sigma)$ be the identity function. Then the function f is gp and gsp -continuous but not $I_{s\hat{g}}$ -continuous.

Theorem 3.6: A map $f: (X, \tau, I) \rightarrow (Y, \sigma)$ is $I_{s\hat{g}}$ -continuous iff the inverse image of every closed set in (Y, σ) is $I_{s\hat{g}}$ -closed in (X, τ, I) .

Proof:

Necessary: Let v be an open set in (Y, σ) . Since f is $I_{s\hat{g}}$ -continuous, $f^{-1}(v^c)$ is $I_{s\hat{g}}$ -closed in (X, τ, I) . But $f^{-1}(v^c) = X - f^{-1}(v)$. Hence $f^{-1}(v)$ is $I_{s\hat{g}}$ -closed in (X, τ, I) .

Sufficiency: Assume that the inverse image of every closed set in (Y, σ) is $I_{s\hat{g}}$ -closed in (X, τ, I) . Let v be a closed set in (Y, σ) . By our assumption $f^{-1}(v^c) = X - f^{-1}(v)$ is $I_{s\hat{g}}$ -closed in (X, τ, I) , which implies that $f^{-1}(v)$ is $I_{s\hat{g}}$ -closed in (X, τ, I) . Hence f is $I_{s\hat{g}}$ -continuous.

Remark 3.7:

- (i) The union of any two $I_{s\hat{g}}$ -continuous function is $I_{s\hat{g}}$ -continuous.
- (ii) The intersection of any two $I_{s\hat{g}}$ -continuous function is need not be $I_{s\hat{g}}$ -continuous.
- (iii) Suppose $I = \{\Phi\}$, then the notion of $I_{s\hat{g}}$ -continuous coincides with $s\hat{g}$ -continuous.

Definition 3.8: A function $f: (X, \tau, I_1) \rightarrow (Y, \sigma, I_2)$ is said to be $I_{s\hat{g}}$ -irresolute, if $f^{-1}(v)$ is $I_{s\hat{g}}$ -closed in (X, τ, I_1) for every $I_{s\hat{g}}$ -closed set v in (Y, σ, I_2) .

Example 3.9: Let $X = Y = \{a, b, c\}$, $\tau = \{\Phi, X, \{a\}, \{a, b\}\}$, $I_1 = \{\Phi, \{a\}\}$ and $\sigma = \{\Phi, Y, \{b\}\}$, $I_2 = \{\Phi, \{a\}, \{b\}, \{a, b\}\}$. Then the function $f: (X, \tau, I_1) \rightarrow (Y, \sigma, I_2)$ defined by $f(a) = c$, $f(b) = a$ and $f(c) = b$ is $I_{s\hat{g}}$ -irresolute.

Theorem 3.14: Let $f: (X, \tau, I_1) \rightarrow (Y, \sigma, I_2)$ and $g: (Y, \sigma, I_2) \rightarrow (Z, \eta, I_3)$ be any two functions. Then the following hold.

- (i) $g \circ f$ is $I_{s\hat{g}}$ -continuous if f is $I_{s\hat{g}}$ -continuous and g is continuous.
- (ii) $g \circ f$ is $I_{s\hat{g}}$ -continuous if f is $I_{s\hat{g}}$ -irresolute and g is $I_{s\hat{g}}$ -continuous.
- (iii) $g \circ f$ is $I_{s\hat{g}}$ -irresolute if f is $I_{s\hat{g}}$ -irresolute and g is irresolute.

Proof:

- (i) Let v be a closed set in Z . Since g is continuous, $g^{-1}(v)$ is closed in Y . $I_{s\hat{g}}$ -continuous of f implies, $f^{-1}(g^{-1}(v))$ is $I_{s\hat{g}}$ -closed in X and hence $g \circ f$ is $I_{s\hat{g}}$ -continuous.
- (ii) Let v be a closed set in Z . Since g is $I_{s\hat{g}}$ -continuous, $g^{-1}(v)$ is $I_{s\hat{g}}$ -closed in Y . Since f is $I_{s\hat{g}}$ -irresolute, $f^{-1}(g^{-1}(v))$ is $I_{s\hat{g}}$ -closed in X . Hence $g \circ f$ is $I_{s\hat{g}}$ -continuous.
- (iii) Let v be a $I_{s\hat{g}}$ -closed set in Z . Since g is $I_{s\hat{g}}$ -irresolute, $g^{-1}(v)$ is $I_{s\hat{g}}$ -closed in Y . Since f is $I_{s\hat{g}}$ -irresolute, $f^{-1}(g^{-1}(v))$ is $I_{s\hat{g}}$ -closed in X . Hence $g \circ f$ is $I_{s\hat{g}}$ -irresolute.

Theorem 3.15: Let $X = A \cup B$ be a topological space with topology τ and Y be a topological space with topology σ . Let $f: (A, \tau/A) \rightarrow (Y, \sigma)$ and $g: (B, \tau/B) \rightarrow (Y, \sigma)$ be $I_{s\hat{g}}$ -continuous maps such that $f(x) = g(x)$ for every $x \in A \cap B$. Suppose that A and B are $I_{s\hat{g}}$ -closed sets in X . Then the combination $\alpha: (X, \tau, I) \rightarrow (Y, \sigma)$ is $I_{s\hat{g}}$ -continuous.

Proof: Let F be any closed set in Y . Clearly $\alpha^{-1}(F) = f^{-1}(F) \cup g^{-1}(F) = C \cup D$ where $C = f^{-1}(F)$ and $D = g^{-1}(F)$. But C is $I_{s\hat{g}}$ -closed in A and A is $I_{s\hat{g}}$ -closed in X and so C is $I_{s\hat{g}}$ -closed in X . Since we have proved that if $B \subseteq A \subseteq X$, B is $I_{s\hat{g}}$ -closed in A and A is $I_{s\hat{g}}$ -closed in X , then B is $I_{s\hat{g}}$ -closed in X . Also $C \cup D$ is $I_{s\hat{g}}$ -closed in X . Therefore $\alpha^{-1}(F)$ is $I_{s\hat{g}}$ -closed in X . Hence α is $I_{s\hat{g}}$ -continuous.

Definition 3.16: A topological space (X, τ, I) is said to be $I_{s\hat{g}}$ -connected if X cannot be written as a disjoint union of two non-empty $I_{s\hat{g}}$ -open subsets. A subset A of X is $I_{s\hat{g}}$ -connected if it is $I_{s\hat{g}}$ -connected as a subspace.

Theorem 3.17: If $f: (X, \tau, I) \rightarrow (Y, \sigma)$ is $I_{s\hat{g}}$ -continuous surjection and X is $I_{s\hat{g}}$ -connected, then Y is connected.

Proof: Suppose $Y = A \cup B$ where A and B are disjoint open sets in Y . Since f is $I_{s\hat{g}}$ -continuous and onto, $X = f^{-1}(A) \cup f^{-1}(B)$ where $f^{-1}(A)$ and $f^{-1}(B)$ are disjoint non-empty $I_{s\hat{g}}$ -open sets in X , a contradiction since X is $I_{s\hat{g}}$ -connected. Hence Y is connected.

Definition 3.18: An ideal space (X, τ, I) is said to be $I_{s\hat{g}}$ -normal if for each pair of non-empty disjoint closed sets A and B of X , there exists disjoint $I_{s\hat{g}}$ -open subsets U and V of X such that $A \subseteq U$ and $B \subseteq V$.

Theorem 3.19: If $f: (X, \tau, I) \rightarrow (Y, \sigma)$ is $I_{s\hat{g}}$ -continuous, closed injection and Y is normal, then X is $I_{s\hat{g}}$ -normal.

Proof: Let A and B be disjoint closed subsets of X . Since f is closed and injective, $f(A)$ and $f(B)$ are disjoint, closed subsets of Y . Since Y is normal, there exists disjoint open subsets U and V of Y such that $f(A) \subseteq U$ and $f(B) \subseteq V$.

Hence $A \subseteq f^{-1}(U)$ and $B \subseteq f^{-1}(V)$ and $f^{-1}(U) \cap f^{-1}(V) = \Phi$. Since f is $I_{s\hat{g}}$ -continuous, $f^{-1}(U)$ and $f^{-1}(V)$ are $I_{s\hat{g}}$ -open in X which implies X is $I_{s\hat{g}}$ -normal.

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