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Strongly $g^{\#}$-Continuous and Perfectly $g^{\#}$-Continuous Maps in Ideal Topological Spaces

J. Antony Rex Rodrigo[1,] P.Mariappan[2.]

Associate Professor, PG and Research Department of Mathematics, V.O.Chidambaram College, Tuticorin, Tamilnadu, India.

Research Scholar, PG and Research Department of Mathematics, V.O.Chidambaram College, Tuticorin, Tamilnadu, India.

Abstract: *J.Antony Rex Rodrigo and P.Mariappan introduced the characterizations and properties of $g^{\#}$-closed sets in ideal topological space. In this paper, we introduced $T_{I_{g^{\#}}}$-space,$T^{*}_{I_{g^{\#}}}$ -space, strongly $I_{g^{\#}}$-continuous maps, perfectly $I_{g^{\#}}$-continuous and $I_{g^{\#}}$-compactness.*

Keywords: *$T_{I_{g^{\#}}}$-space,$T_{I_{g^{\#}}}$-space, $T^{*}_{I_{g^{\#}}}$ -space, Strongly $I_{g^{\#}}$-continuous maps, Perfectly $I_{g^{\#}}$-continuous , $I_{g^{\#}}$-compactness.*

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I. Introduction

Levine[8] introduced and investigated the concept of strong continuity in topological spaces. Sundaram [10] introduced strongly g-continuous maps and perfectly g-continuous maps in topological spaces.In [10], Sundaram introduced the concept of GO-compact space by using g-open covers.Antony Rex Rodrigo and Mariappan[3] introduced the characterizations and properties of $g^{\#}$-closed sets in ideal topological spaces.In this paper,we introduce the notion of $T_{I_{g^{\#}}}$-space,$T^{*}_{I_{g^{\#}}}$ -space, strongly$I_{g^{\#}}$-continuous maps,perfectly $I_{g^{\#}}$-continuous and $I_{g^{\#}}$-compactness in ideal topological spaces and obtain some of its properties.

An ideal I on a topological space (X,τ) is non-empty collection of subsets of X which satisfies (i)$A \in I$ and $B \subset A \Rightarrow B \in I$ and (ii) $A \in I$ and $B \in I \Rightarrow A \cup B \in I$.Given a topological space (X,τ) with an ideal I on X and if $\wp(X)$ is the set of all subsets of X, a set operator (.)* :$\wp(X) \rightarrow \wp(X)$,called a local function [4] of A with respect to τ and I is defined as follows: for $A \subseteq X$, $A^{*}(I,\tau) = \{x \in X: U \cap A \notin I \; for \; every \; U \in \tau(X)\}$ where $\tau(X) = \{U \in \tau: x \in U\}$.We will make use of the basic facts about the local functions[1,Theorem 2.3] without mentioning it explicitly. A Kuratowski closure operator cl*(.) for a topology $\tau^{*}(I,\tau)$, called the $*$-topology, finer than τ is defined by cl*$(A) = A \cup A^{*}(I,\tau)$[12].When there is no chance for confusion, we will simply write A* for $A^{*}(I,\tau)$ and τ^{*} for $\tau^{*}(I,\tau)$. If I is an ideal on X, then (X,τ,I) is called an ideal space.

II. Preliminaries

Definition 2.1: A subset A of a topological space (X,τ) is an α-open set [8]if$A \subseteq int(cl(int(A)))$.

Definition 2.2: A subset A of a topological space(X,τ) is called
(i)Generalized closed (briefly g-closed) [11] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
(ii)α-generalized closed (briefly αg-closed) [2] if $\alpha\text{-}cl(A) \subseteq$U whenever $A \subseteq U$ and U is open in X.
(iii)$g^{\#}$-closed [6] if$cl(A) \subseteq U$ whenever $A \subseteq U$ and U is αg-open in X.

Definition 2.3: A function f :$(X,\tau) \rightarrow (Y,\sigma)$ is called
(i)Strongly continuous [8] if $f^{-1}(V)$ is both open and closed in X for each subset Vin Y.
(ii)Perfectly continuous [13] if $f^{-1}(V)$ is both open and closed in X for each open set Vin Y.

Definition 2.4: A topological space X is called $T_{1/2}$-space [7] if every g-closed set of X is closed in X.

Definition 2.5: A subset A of an ideal space (X,τ,I) is said to be $I_{g^{\#}}$-closed [3] if $A^{*} \subseteq U$ whenever $A \subseteq U$ and U is αg-open in X.

Definition 2.6: A function $f:(X,\tau,I) \rightarrow (Y,\sigma)$ is called $I_{g^{\#}}$-continuous [3] if the inverse image of every closed set in $Y$is $I_{g^{\#}}$-closed in X.

Definition 2.7:A function $f:(X,\tau,I) \rightarrow (Y,\sigma,J)$ is called $I_{g^{\#}}$-irresolute [3] if the inverse image of every $I_{g^{\#}}$-closed set in Y is $I_{g^{\#}}$-closed in X.

III. Separation Axioms In Ideal Topological Space

Definition 3.1: An ideal topological space (X,τ,I) is called a $T_{I_{g^{\#}}}$-space if every $I_{g^{\#}}$-closed set of X is closed in X.

Definition 3.2: An ideal Topological space (X,τ,I) is called a T_{I_g}- space if every I_g-closed set of X is closed in X.

Definition 3.3: An ideal Topological space (X,τ,I) is called a $T^*_{I_{g^{\#}}}$ -space if every I_g-closed set of X is $I_{g^{\#}}$ - closed in X.

Theorem 3.4: If X is T_{I_g}then it is $T_{I_{g^{\#}}}$ but not conversely.

Proof Let Xbe aT_{I_g} – space and A be a $I_{g^{\#}}$ - closed set in X. Since every$I_{g^{\#}}$ - closed set is I_g- closed and X is T_{I_g}, A is closed in X. Hence X is $T_{I_{g^{\#}}}$.

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

Example 3.5: Let $X = \{a, b, c, d\}, \tau = \{\emptyset, X, \{b\}, \{c\}, \{b,c\}, \{b,c,d\}\}$and $I = \{\emptyset, \{a\}\}$.Then $(X,\tau,I)$is$T_{I_{g^{\#}}}$-space but not T_{I_g}-space.Since $I_{g^{\#}}$-closed sets of X are closed in X but the I_g-closed set {d} is not closed in X.

Theorem 3.6: If X is $T_{I_{g^{\#}}}$then it is $I^*_{g^{\#}}$ but not conversely.

Proof. Let Xbe a$T_{I_{g^{\#}}}$ - space and A be a I_g - closed set in X. Since X is $T_{I_{g^{\#}}}$ - space and every closed set is $I_{g^{\#}}$ - closed. Hence X is $T^*_{I_{g^{\#}}}$. The converse need not be true as seen from the following example.

Example 3.7: Let $X = \{a,b,c\}$, $\tau = \{\emptyset, X, \{a\}, \{b\}, \{a,b\}\}$ and $I = \{\emptyset, \{a\}\}$.Then (X,τ,I) is $T^*_{I_{g^{\#}}}$space but not $T_{I_{g^{\#}}}$-space. Since$I_{g^{\#}}$,I_g-closed sets of $X$are$\emptyset, X, \{a\}, \{c\}, \{b,c\}, \{a,c\}$andclosed sets of $X$are $\emptyset, X, \{c\}, \{b,c\}, \{a,c\}$.

Remark 3.8:$T_{1/2}$ and$T_{I_g^{\#}}$ spaces are independent from the following example.

Example 3.9:.This is obvious from remark 2.4[3].

Theorem 3.10: If a function f : $(X,\tau,I) \rightarrow (Y,\sigma,J)$ is continuous and Y is a $T_{I_{g^{\#}}}$ - space, then f is $I_{g^{\#}}$ - irresolute.

Proof. Assume that f is continuous.Let G be any $I_{g^{\#}}$ - closed set in Y. Since Y is a $T_{I_{g^{\#}}}$ - space, then G is closed in Y. Hence $f^{-1}(G)$ is closed in X. But every closed set is $I_{g^{\#}}$-closed. Therefore f is $I_{g^{\#}}$ - irresolute.

Theorem 3.11: If a function f : $(X,\tau,I) \rightarrow (Y,\sigma,J)$ is continuous and Y is a $T_{I_{g^{\#}}}$ - space, then f is strongly $I_{g^{\#}}$ -continuous.

Proof. Assume that f is continuous.Let G be any $I_{g^{\#}}$ - closed set in Y. Since Y is a $T_{I_{g^{\#}}}$ - space, then G is closed in Y. Hence $f^{-1}(G)$ is closed in X. Therefore f isstrongly $I_{g^{\#}}$ -continuous.

IV. Strongly $g^{\#}$-Continuous And Perfectly $g^{\#}$-Continuous Maps In Ideal Topological Spaces

Definition 4.1: A function $f : (X, \tau) \to (Y, \sigma, J)$ is said to be strongly $I_{g^{\#}}$-continuous if the inverse image of every $I_{g^{\#}}$ - closed set in Y is closed in X .

Remark 4.2: When Y is $T_{I_{g^{\#}}}$, strongly $I_{g^{\#}}$ - continuity coincides with continuity.

Theorem 4.3: If a map $f : (X, \tau) \to (Y, \sigma, J)$ from a topological space into an ideal topological space is strongly $I_{g^{\#}}$ - continuous then it is continuous but not conversely .

Proof. Assume that f is strongly $I_{g^{\#}}$ - continuous . Let G be any open set in Y . Since every open set is $I_{g^{\#}}$ - open , G is $I_{g^{\#}}$ - open in Y . Since f is strongly $I_{g^{\#}}$ - continuous , $f^{-1}(G)$ is open in X. Therefore f is continuous.

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

Example 4.4: Let $X = Y = \{a, b, c\}$ with the topologies $\tau = \{\emptyset, X, \{a\}, \{b\}, \{a, b\}\}$, $\sigma = \{\emptyset, X, \{a\}, \{a, b\}\}$ and $J = \{\emptyset, \{b\}\}$. Define a map $f : (X, \tau) \to (Y, \sigma, J)$ by f(a)=b, f(b)=a, f(c)=c then f is continuous. But f is not strongly $I_{g^{\#}}$ - continuous. Since $f^{-1}(\{b\})=\{a\}$ is not closed in X, where {b] is $I_{g^{\#}}$ - closed in Y.

Theorem 4.5: A function $f : (X, \tau) \to (Y, \sigma, J)$ from a topological space (X, τ) into an ideal topological space (Y, σ, J) *is strongly* $I_{g^{\#}}$ - continuous if and only if the inverse image of every $I_{g^{\#}}$ - closed set in Y is closed in X .

Proof. Assume that f is strongly $I_{g^{\#}}$ - continuous . Let F be any $I_{g^{\#}}$ - closed set in Y . Then F^C is $I_{g^{\#}}$ - open in Y . Since f is strongly $I_{g^{\#}}$ - continuous , $f^{-1}(F^C)$ is open in X . But $f^{-1}(F^C) = X - f^{-1}(F)$, $f^{-1}(F)$ is closed in X. Conversly assume that the inverse image of every $I_{g^{\#}}$ - closed set in Y is closed in X . Let G be any $I_{g^{\#}}$ *open in* Y. *Then* G^C *is* $I_{g^{\#}}$-closed in Y. By assumption , $f^{-1}(G^C)$ is closed set in X . But $f^{-1}(G^C) = X - f^{-1}(G)$ and so $f^{-1}(G)$ is open in X . Therefore f is strongly $I_{g^{\#}}$ - continuous .

Theorem 4.6: If a function $f : (X, \tau) \to (Y, \sigma, J)$ is strongly continuous , then it is strongly $I_{g^{\#}}$ - continuous but not conversely .

Proof. Let G be any $I_{g^{\#}}$ - open set in Y . Since f is strongly continuous , $f^{-1}(G)$ is open in X (by Definition) . Hence f is strongly $I_{g^{\#}}$ - continuous .

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

Example 4.7: Let $X = Y = \{a, b, c\}$ with the topologies $\tau = \{\emptyset, X, \{a\}, \{a, b\}, \{a, c\}\}$, $\sigma = \{\emptyset, X, \{a\}, \{a, b\}\}$ and $J = \{\emptyset, \{b\}\}$. Define a map $f : (X, \tau) \to (Y, \sigma, J)$ by f(a)=a, f(b)=c, f(c)=b, then f is strongly continuous. But f is not strongly continuous. Since for the set {a} in Y, $f^{-1}(\{a\})=\{a\}$ is open but not closed in X.

Theorem 4.8: If a map $f : (X, \tau) \to (Y, \sigma, J)$ is strongly $I_{g^{\#}}$- continuous and a map $g : (Y, \sigma, J) \to (Z, \gamma)$ is $I_{g^{\#}}$-continuous, then the composition $g \circ f : (X, \tau) \to (Z, \gamma)$ is continuous.

Proof . Let G be any open set in Z . Since g is $I_{g^{\#}}$-continuous , $g^{-1}(G)$ is $I_{g^{\#}}$ -open in Y. Since f is strongly $I_{g^{\#}}$-continuous $f^{-1}g^{-1}(G)$ is open in X . But $f^{-1}g^{-1}(G) = (g\, of)^{-1}(G)$. Therefore g of is continuous .

Theorem 4.9: If a map $f : (X, \tau) \to (Y, \sigma, J)$ is strongly $I_{g^{\#}}$- continuous and a map $g : (Y, \sigma, J) \to (Z, \gamma, K)$ is strongly $I_{g^{\#}}$-continuous, then the composition $g \circ f : (X, \tau) \to (Z, \gamma, K)$ is strongly $I_{g^{\#}}$-continuous.

(i.e) Composition of two strongly $I_{g^{\#}}$- continuous functions is strongly $I_{g^{\#}}$- continuous.

Proof. Let G be any $I_{g^{\#}}$-open set in Z . Since g is strongly $I_{g^{\#}}$-continuous ,$g^{-1}(G)$ is open in Y. Since f is strongly $I_{g^{\#}}$-continuous and every open set is $I_{g^{\#}}$-open, $f^{-1}g^{-1}(G)$ is open in X . But $f^{-1}g^{-1}(G) = (g\ of\ )^{-1}\ (G)$.Therefore g of is strongly $I_{g^{\#}}$- continuous .

Theorem 4.11: If a map f : $(X ,\tau, I) \rightarrow (Y ,\sigma ,J)$ is$I_{g^{\#}}$- continuous and a map g : $(Y ,\sigma ,J) \rightarrow (Z ,\gamma, K)$ is strongly $I_{g^{\#}}$-continuous, then the composition $g \circ f\ : (X ,\tau, I) \rightarrow (Z ,\gamma, K)$ is $I_{g^{\#}}$-irresolute.

Proof. Let G be any $I_{g^{\#}}$-open set in Z . Since g is strongly $I_{g^{\#}}$-continuous ,$g^{-1}(G)$ is open in Y. Since f is $I_{g^{\#}}$-continuous, $f^{-1}g^{-1}(G)$ is $I_{g^{\#}}$-open in X . But $f^{-1}g^{-1}(G) = (g\ of\ )^{-1}\ (G)$. Therefore g of is$I_{g^{\#}}$-irresolute.

Theorem 4.12: If a map f : $(X ,\tau) \rightarrow (Y ,\sigma ,J)$ is strongly$I_{g^{\#}}$- continuous and a map g : $(Y ,\sigma ,J) \rightarrow (Z ,\gamma, K)$ is $I_{g^{\#}}$-irresolute, then the composition $g \circ f\ : (X ,\tau, I) \rightarrow (Z ,\gamma, K)$ is continuous.

Proof. Let G be any open set in Z . Since g is $I_{g^{\#}}$-irresolute and every open set is $I_{g^{\#}}$-open , $g^{-1}(G)$ is $I_{g^{\#}}$-open in Y. Since f is strongly$I_{g^{\#}}$-continuous, $f^{-1}g^{-1}(G)$ is open in X . But $f^{-1}g^{-1}(G) = (g\ of\ )^{-1}\ (G)$.Therefore g of is continuous.

Definition 4.13:.A map $f: (X, \tau) \rightarrow (Y, \sigma, J)$ is said to be perfectly $I_{g^{\#}}$-continuous if the inverse image of every $I_{g^{\#}}$-open set in (Y, σ, J) is both open and closed in (X, τ).

Theorem 4.14:. A map $f: (X, \tau) \rightarrow (Y, \sigma, J)$ from a topological space (X, τ) into an ideal topological space (Y, σ, J) is perfectly $I_{g^{\#}}$-continuous then it is strongly $I_{g^{\#}}$-continuous but not conversely.

Proof. Assume that f is perfectly $I_{g^{\#}}$-continuous. Let G be any $I_{g^{\#}}$-open set in (Y, σ, J).Since f is perfectly $I_{g^{\#}}$-continuous , $f^{-1}(G)$ is open in (X, τ).Therefore f is strongly $I_{g^{\#}}$-continuous.

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

Example4.15: Let$X = Y = \{a, b, c\}$ with the topologies $\tau = \{\emptyset, X, \{a\}, \{a, b\}, \{a, c\}\}$ and $\sigma = \{\emptyset, X, \{a\}, \{a, b\}\}$ and $J = \{\emptyset, \{b\}\}$.Define a map $f: (X, \tau) \rightarrow (Y, \sigma, J)$ as the identity map. Then f is strongly $I_{g^{\#}}$-continuous but not perfectly $I_{g^{\#}}$-continuous.For the $I_{g^{\#}}$-open set {a} of Y,$f^{-1}(\{a\}) = \{a\}$ which is open but not closed in X.

Theorem 4.16: A map $f: (X, \tau) \rightarrow (Y, \sigma, J)$ from a topological space (X, τ) into an ideal topological space (Y, σ, J) is perfectly $I_{g^{\#}}$-continuous iff$f^{-1}(G)$ is both open and closed in (X, τ) for every $I_{g^{\#}}$-open set in (Y, σ, J).

Proof. Assume that f is perfectly $I_{g^{\#}}$-continuous. Let F be any $I_{g^{\#}}$-closed set in (Y, σ, J).Since f is perfectly $I_{g^{\#}}$-continuous , $f^{-1}(F^c)$ is both open and closed in (X, τ).But $f^{-1}(F^c) = X - f^{-1}(F)$ andso $f^{-1}(F)$ is both open and closed in (X, τ).Conversely assume that the inverse image of every $I_{g^{\#}}$-closed is both open and closed in (X, τ).Let G be any $I_{g^{\#}}$-open set in (Y, σ, J).Then G^c is $I_{g^{\#}}$-closed set in (Y, σ, J).By assumption $f^{-1}(G^c)$ is both open and closed in (X, τ). But $f^{-1}(G^c) = X - f^{-1}(G)$ andso $f^{-1}(G)$ is both open and closed in (X, τ).Therefore f is perfectly $I_{g^{\#}}$-continuous.

Remark 4.17: From the above observations we have the following implications.

V. $g^{\#}$-Compactness in Ideal Topological Space

Deinition 5.1:A collection $\{A_i; i \in I\}$ of $I_{g^{\#}}$-open sets in an ideal topological space (X, τ, I) is called a $I_{g^{\#}}$-open cover of a subset B in Xif $B \subseteq \cup_{i\in I} A_i$.

Definition 5.2: An ideal topological space (X, τ, I) is $I_{g^{\#}}$-compact if every $I_{g^{\#}}$-open cover of X has a finite subcoverof X.

Definition 5.3: A subset B of an ideal topological space $(X,\tau,I)$is called $I_{g^\#}$-compact relative to X ,if for every collection $\{A_i; i \in I\}$ of $I_{g^\#}$-open subsets of X such that $B \subseteq \bigcup_{i\in I} A_i$,there exist a finite subset I_0 of I such that $B \subseteq \bigcup_{i\in I_0} A_i$.

Definition 5.4:A subset B of an ideal topological space $(X,\tau,I)$is called $I_{g^\#}$-compact if B is $I_{g^\#}$-compact as the subspace of X.

Theorem 5.5: A $I_{g^\#}$-closed subset of $I_{g^\#}$-compact space is $I_{g^\#}$-compact relative to X.

Proof. Let A be a $I_{g^\#}$-closed subset of $I_{g^\#}$-compact space X.Then A^c is $I_{g^\#}$-open in X.Let S be a $I_{g^\#}$-open cover of A in X.Then ,S along with A^c form a $I_{g^\#}$-open cover of X.Since X is $I_{g^\#}$-compact ,it has a finite subcover, say $\{G_1, G_{2,} G_3 \ldots\ldots\ldots.. G_n\}$.If this subcover contains A^c,we discard it.Otherwise leave the subcover as it is.Thus we have obtained a finite subcover of A and so A is $I_{g^\#}$-compact relative to X.

Theorem 5.6:A $I_{g^\#}$-continuous image of a $I_{g^\#}$-compact space is compact.

Proof. Let $f: (X,\tau,I) \to (Y,\sigma)$ be a $I_{g^\#}$-continuous map from a $I_{g^\#}$-compact space X onto a topological space Y.Let $\{A_i; i \in I\}$ be an open cover of Y.Then $\{f^{-1}(A_i); i \in I\}$ is a $I_{g^\#}$-open cover of X.Since X is $I_{g^\#}$-compact, it has a finite subcover say $\{f^{-1}(A_1), f^{-1}(A_2) \ldots\ldots\ldots.. f^{-1}(A_n)\}$.Since f is onto, $\{A_1, A_{2,} A_3 \ldots\ldots\ldots.. A_n\}$ is an open cover of Y and so Y is compact..

Theorem 5.7: If $f: (X,\tau) \to (Y,\sigma,J)$ is strongly $I_{g^\#}$-continuous map from a compact space X onto an ideal topological space ,then$Y$ is $I_{g^\#}$-compact.

Proof. Let $\{A_i; i \in I\}$ be an $I_{g^\#}$-open cover of Y. Then $\{f^{-1}(A_i); i \in I\}$ is a open cover of X, Since f is strongly $I_{g^\#}$-continuous.Since$X$ is compact, it has a finite sub cover say $\{f^{-1}(A_1), f^{-1}(A_2) \ldots\ldots\ldots.. f^{-1}(A_n)\}$ and since f is onto ,$\{A_1, A_{2,} A_3 \ldots\ldots\ldots.. A_n\}$is a finite subcover of Y.Therefore Y is $I_{g^\#}$-compact..

Theorem 5.8: If $f: (X,\tau) \to (Y,\sigma,J)$ is perfectly $I_{g^\#}$-continuous map from a compact space X onto an ideal topological space Y,then$Y$ is $I_{g^\#}$-compact

Proof. It follows from theorem 5.7.

Theorem5.9: Let (X,τ,I) be an ideal space. If A is an I_g-closed subset of X,then A is I-compact.[5,Theorem 2.17]

Corollary 5.11: Let (X,τ,I) be an ideal space. If A is an $I_{g^\#}$-closed subset of X, then A is I-compact.

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