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On I_g-Continuous Functions

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Abstract

In this paper, we introduced some notions related g-closed set and we investigated some of properties of I_g-continuous and $r_I g$-continuous functions which is derived in terms of I_g-closed set, $r_I g$-closed set in ideal topological spaces. Also, we examined relationship with other types of functions.

Keywords: *I_g-Closed set, $r_I g$-Closed set, I_g-Continuous, $r_I g$-Continuous, Ideal topological spaces.*

1 Introduction

One of basic topics the continuity of functions in general topology which was researched by many authors. In 1990, Jankovic and Hamlett [4], were initiated the application ideal topological spaces. Khan and Noiri [4] were introduced semi-local functions in ideal topological spaces. Firstly, the notion of I_g-closed set was given by Dontchev et. al [2]. In 2007, Navaneethakrishnan and Joseph [13] was investigated some of properties of I_g-closed sets and I_g-open sets by using local function. Although Karabiyik [5], by defining $r_I g$-closed set a weaker I_g-closed set was examined some properties, of these sets give some characterization.

In this paper, we define and characterize I_g-continuous and $r_I g$-continuous functions in ideal topological spaces by the use of the I_g-closed set and $r_I g$-closed set. We have investigate some of their properties. With the help of other existing sets obtain decompositions of continuity.

2 Preliminaries

In this section, we give some known basic concepts in ideal topological spaces. An ideal I on a nonempty set X is a collection of subsets of X which satisfies the following properties (i) $A \in I$ and $B \subseteq A$ implies $B \in I$ and (ii) $A \in I$ and $B \in I$ implies $A \cup B \in I$.
A topological space (X, τ) with an ideal I on X is called an ideal topological space and is denoted by (X, τ, I). If Y is a subset of X then $I_Y = \{V \cap Y : V \in I\}$ is an ideal on Y and $(Y, \tau_{/Y}, I_{/Y})$ denote the ideal topological sub space. Let $P(X)$ is the set of all subset of X, a set operator $()^* : P(X) \longrightarrow P(X)$, called a local function of A with respect to τ and I is defined as follows: for $A \subset X$, $A^*(I, \tau) = \{x \in X : U \cap A \notin I$ for every $U \in \tau(X, x)\}$[7]. We simply write A^* instead of $A^*(I, \tau)$ in case there is no concision. For every ideal topological space (X, τ, I) there exists a topology τ^* finer than τ defined as $\tau^* = \{U \subseteq X : cl^*(X - A) = X - A\}$ generated by the base $\beta(I, \tau) = \{U \subseteq J : U \in \tau$ and $J \in I\}$. A kuratowski closure operator $cl^*(.)$ for a topology $\tau^*(I, \tau)$ called the $*$-topology, finer than τ is defined by $cl^*(A) = A \cup A^*$ [16].

For a subset A of X, $cl^*(A)$ and $int^*(A)$ represent the closure of A and the interior of A in (X, τ^*). A subset A of an ideal topological space (X, τ, I) is said to be τ^*-closed [4](resp.$*$-dense-in-itself, $*$-perfect [3]) if $A^* \subset A$ (resp.$A \subset A^*$, $A = A^*$). From [17], it follows that every $*$-perfect set is τ^*-closed and every $*$-perfect set is $*$-dense-in-itself set. A subset A of space (X, τ) said to be regular open [8](resp.regular closed) if $A = int(cl(A))$(resp.$A = cl(int(A))$) and A is said to be generalized closed [9] if $cl(A) \subset U$ whenever $A \subset U$ and is open. A subset A of a space (X, τ) is said to be rg-closed [14] if $cl(A) \subset U$ whenever $A \subset U$ and U regular open and rg-open(resp.g-open) if $(X - A)$ is rg-closed(resp.g-closed). A subset A of space (X, τ, I) said to be regular-I-open [17] if $A = (int(A))^*$ and every regular-I- closed set is $*$-perfect.

3 I_g-Closed Set, $r_I g$-Closed Set

Definition 3.1 (i) *A subset A of an (X, τ, I) be a ideal topological space is said to be I_g-closed [2] $A^* \subset U$ whenever $A \subseteq U$ and is open in X. The complement of I_g-closed set is said to be I_g-open.*
(ii) *A subset A of an (X, τ, I) be a ideal topological space is said to be I_{rg}-closed [12] $A^* \subset U$ whenever $A \subseteq U$ and is regular open in X.*

Definition 3.2 *A subset A of an (X, τ, I) be a ideal topological space is said to be regularI-generalized set (briefly r_Ig-closed) [5] if $cl^*(A) \subset U$ whenever $A \subseteq U$ and is regular open in X. A is r_Ig-open if $(X - A)$ is an r_Ig-closed set.*

Lemma 3.3 *[11] Let (X, τ, I) be a ideal topological space and $A \subset X$. If $A \subset A^*$, then $A^* = cl(A^*) = cl(A) = cl^*(A)$.*

Proposition 3.4 *(i) Every g-closed set is I_g-closed [2] set.*
(ii) Every I_g-closed set is r_Ig-closed set.
(iii)Every rg-closed set is r_Ig-closed set.
(iv)Every g-closed set is rg-closed [14] set.

Proof: The proof follows from the Definitions 3.1, 3.2.

Remark 3.5 *By Proposition 3.4, converse is not true in general as the following example show.*

Example 3.6 *(i) $X = \{a, b, c, d\}$, $\tau = \{X, \emptyset, \{a\}, \{b, d\}, \{a, b, d\}\}$ and $I = \{\emptyset, \{a\}, \{c\}, \{a, c\}\}$. Then $A = \{a, b\} \subset X$ is I_g-closed but is not g-closed set.*
(ii) $X = \{a, b, c, d\}$, $\tau = \{X, \emptyset, \{a\}, \{b, d\}, \{a, b, d\}\}$ and $I = \{\emptyset, \{c\}\}$. Then $A = \{a\} \subset X$ is r_Ig-closed but is not I_g-closed, since $A^* = \{a\}^* = \{a, c\}$ where A^* is contained in the regular open set U but $A^* \subset A$.
(iii) Let $X = \{a, b, c, d\}$, $\tau = \{X, \emptyset, \{c\}, \{a, c\}, \{b, c\}, \{a, b, c\}, \{a, c, d\}\}$ and $I = \{\emptyset, \{c\}, \{d\}, \{c, d\}\}$. Then $A = \{c, d\}$ is r_Ig-closed set but is not rg-closed set. Since $A = \{c, d\} \subset \{a, c, d\}$ regular open set in X. $A^* = \{c, d\}^* = \emptyset \subset \{a, c, d\}$, A is not an rg-closed set.
(iv) [14], Example 3.9.

Every r_Ig-closed set in an I_{rg}-closed but not vice versa. The following Theorem shows that for $*$-dense-in-itself sets, the concepts r_Ig-closeness and I_{rg}-closeness are equivalent.

Theorem 3.7 *Let (X, τ, I) be a ideal topological space. If A is a $*$-dense-in-itself and I_{rg}-closed subset of X, then A is r_Ig-closed.*

Proof: According to Lemma 3.3, the proof of Theorem obvious.

Corollary 3.8 *Let (X, τ, I) be a ideal topological space and $I = \{\emptyset\}$. Then, A is I_{rg}-closed if and only if A is r_Ig-closed.*

Proof: A is I_{rg}-closed then $A^* \subset U$, $A \subset U$ and U regular open. If $I = \{\emptyset\}$ then $A^* = cl(A) = cl^*(A)$ for every subset A of X and so I_{rg}-closed sets coincide with r_Ig-closed sets.

Definition 3.9 *Let (X,τ,I) be a ideal topological space and $A\subset X$. A is open and $*$-perfect then A is O^*-set.*

It is well known that in both open and closed set is define *clopen* set. Clearly every O^*-set is *clopen* set.

Proposition 3.10 *For a subset A of an ideal topological space (X,τ,I) the following properties hold:*
(i) Every O^*-set is regular-I-closed,
(ii) Every τ^*-closed is I_g-closed.

Proof: (i) Let A be a O^*-set then we have $A\in\tau$ and A is $*$-perfect set. Since A is open set we have $A^*=(int(A))^*$. On the other hand A is $*$-perfect that $A=A^*=(int(A))^*$. Therefore we obtain $A=(int(A))^*$. This shows that A is regular-I-closed.
(ii) Let A be a τ^*-closed set and $A\subset U$. Then we have $A^*\subset A\subset U$. Thus $A^*\subset U$ and this shows that A is I_g-closed.

Remark 3.11 *The converses of Proposition 3.10 need not be true as shown the following example.*

Example 3.12 (i) *Let $X=\{a,b,c,d\}$, $\tau=\{X,\emptyset,\{a\},\{b,d\},\{a,b,d\}\}$ and $I=\{\emptyset,\{a\},\{c\},\{a,c\}\}$. Then $A=\{a,c\}$ is regular-I-closed set which is not O^*-set. For $A=\{a,c\}\subset X$ since $int(A)=\{a\}$, $(int(A))^*=\{a,c\}=A$, A is regular-I-closed set. On the other hand, since $A^*=\{a,c\}=A$, A is not O^*-set.*
(ii) Let $X=\{a,b,c,d\}$, $\tau=\{X,\emptyset,\{b\},\{a,c\},\{a,b,c\}\}$ and $I=\{\emptyset,\{b\}\}$. Then $A=\{c,d\}$ is I_g-closed set which is not τ^*-closed set. Let $A=\{c,d\}$ open set. Since $A^*=\{a,c\}\subset U$, A is I_g-closed set. On the other hand, since $A^*=\{a,c\}\nsubseteq\{c,d\}=A$ we have A is not τ^*-closed set.

4 On Decompositions of I_g-Continuity and r_Ig-Continuity

In this section, with the help of the concepts introduced in Section 3, it is possible to define several forms of g-continuity.

Definition 4.1 *A function $f:(X,\tau)\rightarrow(Y,\varphi)$ is called g-continuous [1](resp.rg-continuous [14]) if for every closed set V in Y, $f^{-1}(V)$ is g-closed(resp.rg-closed) in (X,τ).*

Theorem 4.2 *[15] For a function $f : (X, \tau) \to (Y, \varphi)$ the following properties are equivalent:*
(a) f is rg-continuous,
(b) For every open set V of Y, $f^{-1}(V)$ is rg-open in X,
(c) For every closed set V of Y, $f^{-1}(V)$ is rg-closed in X.

Proof: $(a) \Rightarrow (b)$ Let $V \subset Y$ open set, such that $(Y - V)$ is closed set. Therefore $f^{-1}(Y - V) = X - f^{-1}(V)$ is rg-closed set. Since, $X - f^{-1}(V)$ is rg-closed, $f^{-1}(V)$ is rg-open.
$(b) \Rightarrow (c)$ and $(c) \Rightarrow (a)$ are proved in a similar way.

Definition 4.3 *A function $f : (X, \tau, I) \to (Y, \varphi)$ is called I_g-continuous(resp.$r_I g$-continuous) if for every closed set F in Y, $f^{-1}(F)$ is I_g-closed(resp.$r_I g$-closed) in (X, τ, I).*

Theorem 4.4 *For a function $f : (X, \tau, I) \to (Y, \varphi)$, the following properties are equivalent:*
(a) f is $r_I g$-continuous,
(b) For every open set F of Y, $f^{-1}(F)$ is $r_I g$-open in X,
(c) For every closed set F of Y, $f^{-1}(F)$ is $r_I g$-closed in X.

Proof: $(a) \Rightarrow (b)$ Let $F \subset Y$ open set, such that $(Y - F)$ is closed set. Since, f is $r_I g$-continuous we have $f^{-1}(Y - F) = X - f^{-1}(F)$ is $r_I g$-closed set. Hence, $f^{-1}(F)$ is $r_I g$-open in X.
$(b) \Rightarrow (c)$ and $(c) \Rightarrow (a)$ are proved in a similar way.

Remark 4.5 *By Definition 4.1, 4.3, we have the following diagram in which none of the implications is reversible as shown by four examples stated as below.*

$$\begin{array}{ccccc} continuous & \longrightarrow & g - continuous & \longrightarrow & rg - continuous \\ & & \downarrow & & \downarrow \\ & & Ig - continuous & \longrightarrow & r_I g - continuous \end{array}$$

Example 4.6 *Let $X = \{a, b, c, d\}$, $\tau = \{X, \emptyset, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}, \{a, b, d\}\}$ and $Y = \{p, q\}$, $\varphi = \{Y, \emptyset, \{p\}\}$. $f : (X, \tau) \to (Y, \varphi)$ be a function defined as: $f(b) = f(d) = p$, $f(a) = f(c) = q$. Then, f is rg-continuous but not g-continuous. Since $V = \{q\}$ is closed in Y, $f^{-1}(V) = \{a, c\}$ and V is a rg-closed set of (X, τ). Thus f is rg-continuous. On the other hand, since $cl(V) = \{a, c, d\} \nsubseteq \{a, b, c\}$, V is not g-closed. Hence f is not g-continuous.*

Example 4.7 *Let* $X = \{a, b, c\}$, $\tau = \{X, \emptyset, \{a\}, \{b\}, \{a, b\}\}$ *and* $I = \{\emptyset, \{c\}\}$, $Y = \{p, q\}$, $\varphi = \{Y, \emptyset, \{q\}\}$ *and* $f : (X, \tau, I) \to (Y, \varphi)$ *be a function defined as:* $f(a) = p$, $f(b) = f(c) = q$. *Then,* f *is* $r_I g$*-continuous but not* I_g*-continuous.*

Example 4.8 *Let* $X = \{a, b, c, d\}$, $\tau = \{X, \emptyset, \{a\}, \{b, d\}, \{a, b, d\}\}$ *and* $I = \{\emptyset, \{a\}, \{c\}, \{a, c\}\}$, $Y = \{p, q\}$ $\varphi = \{Y, \emptyset, \{q\}\}$. $f : (X, \tau, I) \to (Y, \varphi)$ *be a function defined as:* $f(a) = f(b) = p$, $f(c) = f(d) = q$. *Then,* f *is* I_g*-continuous but not g-continuous.* $V = \{p\}$ *is closed in* Y. *Since* $f^{-1}(V) = \{a, b\}$ *and* $U = \{a, b, d\} \in \tau$ *we have* $\{a, b\}^* = \{b, d\} \subset U$. *Thus,* f *is* I_g*-continuous. On the other hand, since* $cl(\{a, b\}) = X \nsubseteq U$, f *is not g-continuous.*

Example 4.9 *Example 4.8 in a given spaces,* $f : (X, \tau, I) \to (Y, \varphi)$ *be a function defined as:* $f(a) = f(b) = p$, $f(c) = f(d) = q$. *Then* f *is* $r_I g$*-continuous but not rg-continuous.* $V = \{q\}$ *is closed in* Y. *Since* $f^{-1}(V) = \{c, d\} \nsubseteq U = \{a, b, d\}$, f *is not rg-continuous. On the other hand, since* $cl^*(\{c, d\}) = cl(\emptyset) = \emptyset \subset \{a, c\}$, f *is* $r_I g$*-continuous.*

Definition 4.10 *A function* $f : (X, \tau, I) \to (Y, \varphi)$ *is said to be Ic-continuous if for every closed set* F *in* Y, $f^{-1}(F) \in \tau^*(X, \tau, I)$.

Remark 4.11 *Every Ic-continuous is* I_g*-continuous. The converse of this remark need not be true as the following example shows.*

Example 4.12 *Let* $X = \{a, b, c\}$, $\tau = \{X, \emptyset, \{b\}, \{a, c\}\}$ *and* $I = \{\emptyset, \{b\}\}$, $Y = \{p, q\}$ $\varphi = \{Y, \emptyset, \{p\}\}$. $f : (X, \tau, I) \to (Y, \varphi)$ *be a function defined as follows:* $f(c) = f(b) = q$, $f(a) = p$. $V = \{q\}$ *is closed in* Y. *Since* $f^{-1}(V) = \{b, c\}$ *and* $U = \{a, b, c\} \in \tau$, *we have* $\{b, c\}^* = \{a, c\} \subset U$. *Thus* f *is* I_g*-continuous. On the other hand, since* $(\{b, c\})^* = \{a, c\} \nsubseteq \{b, c\}$, f *is not Ic-continuous.*

Definition 4.13 *A function* $f : (X, \tau) \to (Y, \varphi)$ *is said to be strongly continuous [10](resp.strongly rg-continuous [15]) if for every* $V \in \varphi$, $f^{-1}(V)$ *is a clopen set(reps.*V *is rg-open in* Y, $f^{-1}(V) \in \tau$*).*

Definition 4.14 *A function* $f : (X, \tau, I) \to (Y, \varphi, J)$ *is said to be strongly I-continuous(resp.strongly* $r_I g$*-continuous) if for every* $V \in \varphi$, $f^{-1}(V) \in O^*(X, \tau, I)$*(reps.every* V *is* $r_I g$*-open set in* Y, $f^{-1}(V) \in (X, \tau, I)$*).*

Proposition 4.15 *For a function* $f : (X, \tau, I) \to (Y, \varphi, J)$ *the following properties holds:*
a) If f *is strongly continuous then* f *is strongly-I-continuous,*
b) If f *is strongly-I-continuous then* f *is strongly-*$r_I g$*-continuous.*

Proof: The proof is obvious.

Remark 4.16 *The converse of the Proposition 4.15 is not true.*

Example 4.17 *(i) Let* $X = \{a, b, c\}$, $\tau = \{X, \emptyset, \{a\}, \{b, c\}\}$ *and* $I = \{\emptyset, \{c\}\}$, $Y = \{p, q\}$ $\varphi = \{Y, \emptyset, \{p\}\}$ *and* $J = \{\emptyset, \{p\}\}$. *Define a function* $f : (X, \tau, I) \to (Y, \varphi, J)$ *as follows:* $f(c) = f(b) = p$, $f(a) = q$. *Then* f *is strongly-*I*-continuous but it is not strongly continuous.*
(ii) Let $X = \{a, b, c, d\}$, $\tau = \{X, \emptyset, \{d\}, \{a, c\}, \{a, c, d\}, \{a, b, c\}\}$ *and* $I = \{\emptyset, \{a\}, \{c\}\}$, $Y = \{p, q\}$ $\varphi = \{Y, \emptyset, \{p\}\}$ *and* $J = \{\emptyset, \{p\}\}$. *Define a function* $f : (X, \tau, I) \to (Y, \varphi, J)$ *as follows:* $f(b) = f(c) = f(a) = p$, $f(d) = q$. *Then* f *is strongly-*$r_I g$*-continuous but it is not strongly-*I*-continuous.*

Theorem 4.18 *Let* $f : (X, \tau, I) \to (Y, \varphi, J)$ *strongly-*$r_I g$*-continuous and* $g : (Y, \varphi, J) \to (Z, \sigma)$ $r_I g$*-continuous so is* $gof : (X, \tau, I) \to (Z, \sigma)$ *is continuous function.*

Proof: Let V be a closed set in Z. Since g is $r_I g$-continuous, $g^{-1}(V)$ is $r_J g$-continuous in Y. Because of f is $r_I g$-continuous, we can write $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V) \in \tau$. Therefore gof is continuous.

Remark 4.19 *Composition of two* $r_I g$*-continuous functions need not to be* $r_I g$*-continuous.*

Example 4.20 *Let* $X = Y = Z = \{a, b, c, d\}$, $\tau = \{X, \emptyset, \{a\}, \{b, c\}, \{a, b, c\}\}$, $I = \{\emptyset, \{b\}\}$, $\varphi = \{Y, \emptyset, \{a\}, \{b, d\}, \{a, b, d\}\}$, $J = \{\emptyset, \{a\}, \{c\}, \{a, c\}\}$, $\sigma = \{Z, \emptyset, \{d\}, \{a, c\}, \{a, c, d\}, \{a, b, c\}\}$. f *is defined as* $f(a) = b, f(b) = c, f(c) = d, f(d) = a$ *and* g *is the identity map. The functions* f *and* g *are* $r_I g$*-continuous functions but their composition is not* $r_I g$*-continuous. For the closed set* $\{d\}$ *in* Z, $(gof)^{-1}(\{d\}) = f^{-1}(\{d\}) = \{c\}$ *is not* $r_I g$*-closed in* X.

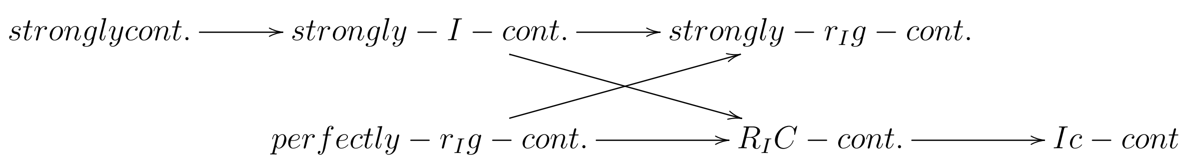
Definition 4.21 *A function* $f : (X, \tau, I) \to (Y, \varphi)$ *is called* $R_I C$*-continuous [6] if for every closed set* F *in* Y, $f^{-1}(F)$ *is regular-*I*-closed in* (X, τ, I).

Definition 4.22 *A function* $f : (X, \tau, I) \to (Y, \varphi)$ *is called perfectly* $r_I g$*-continuous if* $f^{-1}(F)$ *is clopen in* (X, τ, I) *for every* $r_I g$*-open set* F *in* Y.

Theorem 4.23 *For a function* $f : (X, \tau, I) \to (Y, \varphi, J)$*, the following properties are equivalent:*
(a) f *is perfectly* $r_I g$*-continuous,*
(b) For every $r_I g$*-open set* V *of* Y, $f^{-1}(V)$ *is clopen in* X,
(c) For every $r_I g$*-closed set* V *of* Y, $f^{-1}(V)$ *is clopen in* X.

Proof: $(a) \Rightarrow (b)$ This proof is obvious by Definition 4.22.
$(b) \Rightarrow (c)$ Let $V \subset Y$ $r_I g$-open set, such that $(Y - V)$ is $r_I g$-closed set. Since, f is $r_I g$-continuous $f^{-1}(Y - F)$ is *clopen* set in X. Because of $f^{-1}(Y - F) = X - f^{-1}(F)$, $f^{-1}(F)$ is *clopen* set in X.
$(c) \Rightarrow (a)$ is proved in a similar way $(b) \Rightarrow (c)$.

Remark 4.24 *By Definitions 4.14, 4.21, 4.22 we have the following diagram in which none of the implications is reversible as shown by four examples stated below.*



Example 4.25 *Let* $X = \{a, b, c, d\}$, $\tau = \{X, \emptyset, \{d\}, \{a, c\}\{a, c, d\}, \{a, b, c\}\}$ *and* $I = \{\emptyset, \{a\}, \{c\}, \{a, c\}\}$, $Y = \{p, q\}$ $\varphi = \{Y, \emptyset, \{p, q\}\}$ *and* $J = \{\emptyset, \{p\}\}$. *Define a function* $f : (X, \tau, I) \to (Y, \varphi, J)$ *as follows:* $f(a) = f(c) = f(d) = p$, $f(b) = q$. *Then,* f *is strongly-*$r_I g$*-continuous but not perfectly* $r_I g$*-continuous.*

Example 4.26 (i) *Let* $X = \{a, b, c, d\}$, $\tau = \{X, \emptyset, \{a\}, \{b, d\}, \{a, b, d\}\}$ *and* $I = \{\emptyset, \{a\}, \{c\}, \{a, c\}\}$, $Y = \{p, q\}$ $\varphi = \{Y, \emptyset, \{p\}\}$ *and* $J = \{\emptyset, \{p\}\}$. *Let we define a function* $f : (X, \tau, I) \to (Y, \varphi, J)$, $f(a) = f(c) = q$, $f(b) = f(d) = p$. *Then,* f *is* $R_I C$*-continuous but not perfectly* $r_I g$*-continuous.*
(ii) *Let* $X = \{a, b, c\}$, $\tau = \{X, \emptyset, \{a\}, \{a, b\}\}$ *and* $I = \{\emptyset, \{a\}, \{b\}, \{a, b\}\}$, $Y = \{p\}$ $\varphi = \{Y, \emptyset, \{p\}\}$ *and* $J = \{\emptyset, \{p\}\}$. *Define a function* $f : (X, \tau, I) \to (Y, \varphi, J)$ *as follows:* $f(a) = f(b) = p$, $f(c) = q$. *Then* f *is* Ic*-continuous but it is not strongly* $R_I C$*-continuous.*
(iii) *Let* $X = \{a, b, c, d\}$, $\tau = \{X, \emptyset, \{a\}, \{b, d\}, \{a, b, d\}\}$ *and* $I = \{\emptyset, \{a\}, \{c\}, \{a, c\}\}$, $Y = \{p, q\}$ $\varphi = \{Y, \emptyset, \{p\}\}$. *Define a function* $f : (X, \tau, I) \to (Y, \varphi)$ *as follows:* $f(a) = f(c) = p$, $f(b) = q$. *Then* f *is* $R_I C$*-continuous but it is not strongly strongly-*I*-continuous.*

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