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Slightly *rg*-continuity

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Abstract

In this paper we discuss new type of continuous functions called slightly rg-continuous; somewhat rg-continuous and somewhat rg-open functions; its properties and interrelation with other such functions are studied.

Keywords: *slightly continuous functions; slightly semi-continuous functions; slightly pre-continuous; slightly β-continuous functions; slightly γ-continuous functions and slightly ν-continuous functions; somewhat continuous functions; somewhat semi-continuous functions; somewhat pre-continuous; somewhat β-continuous functions; somewhat γ-continuous functions and somewhat ν-continuous functions; somewhat open functions; somewhat semi-open functions; somewhat pre-open; somewhat β-open functions; somewhat γ-open functions and somewhat ν-open functions*

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1. Introduction

In 1995 T.M. Nour introduced slightly semi-continuous functions. After him T.Noiri and G.I. Chae further studied slightly semi-continuous functions in 2000. T.Noiri individually studied about slightly β-continuous functionsin 2001. C.W.Baker introduced slightly precontinuous functions in 2002. Erdal Ekici and M. Caldas studied slightly γ-continuous functions in 2004. Arse Nagli Uresin and others studied slightly δ−continuous functions in 2007. Recently S. Balasubramanian and P.A.S. Vyjayanthi studied slightly ν−continuous functions in 2011. Inspired with these developments we introduce in this paper slightly *rg*-continuous functions and study its basic properties and interrelation with other type of such functions. Throughout the paper (X,τ) and (Y,σ) (or simply X and Y) represent topological spaces on which no separation axioms are assumed unless otherwise mentioned.

2. Preliminaries

Definition 2.1: $A\subset X$ is called
(i) g-closed [rg-closed] if cl $A\subseteq U$ whenever $A\subseteq U$ and U is open in X.
(ii) b-open if $A\subset(cl\{A\})^{o}\cap cl\{A^{o}\}$.

Definition 2.2: A function f: X→ Y is said to be
(i) continuous [resp: nearly-continuous; rα-continuous; *ν*-continuous; α-continuous; semi-continuous; β-continuous; pre-continuous] if inverse image of each open set is open[resp: regular-open; rα-open; *ν*-open; α-open; semi-open; β -open; preopen].

(ii) nearly-irresolute[resp: rα-irresolute; *ν*-irresolute; α-irresolute; irresolute; β-irresolute; pre-irresolute] if inverse image of each regular-open[resp: rα-open; *ν*-open; α-open; semi-open; β-open; preopen] set is regular-open[resp: rα-open; *ν*-open; α-open; semi-open; β-open; preopen].

(iii) almost continuous[resp: almost nearly-continuous; almost rα-continuous; almost *ν*-continuous; almost α-continuous; almost semi-continuous; almost β-continuous; almost pre-continuous] if for each x in X and each open set (V, f(x)), ∃ an open[resp: regular-open; rα-open; *ν*-open; α-open; semi-open; β-open; preopen] set (U, x) such that $f(U)\subset(cl(V))^{o}$.

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(iv) weakly continuous[resp**:** weakly nearly-continuous; weakly rα-continuous; weakly v-continuous; weakly α-continuous; weakly semi-continuous; weakly β-continuous; weakly pre-continuous] if for each x in X and each open set (V, f(x)), $\exists$ an open[resp**:** regular-open; rα-open; v-open; α-open; semi-open; β-open; preopen] set (U, x) such that $f(U) \subset cl(V)$.

(v) slightly continuous[resp**:** slightly semi-continuous; slightly pre-continuous; slightly β-continuous; slightly γ-continuous; slightly α-continuous; slightly r-continuous; slightly v-continuous] at x in X if for each clopen subset V in Y containing f(x), $\exists$ U$\in \tau$ (X)[$\exists$ U$\in$ SO(X); $\exists$ U$\in$ PO(X); $\exists$ U$\in \beta$O(X); $\exists$ U$\in \gamma$ O(X); $\exists$ U$\in \alpha$ O(X); $\exists$ U$\in$ RO(X); $\exists$ U$\in$ v O(X)] containing x such that $f(U) \subseteq V$.

(vi) slightly continuous[resp**:** slightly semi-continuous; slightly pre-continuous; slightly β-continuous; slightly γ-continuous; slightly α-continuous; slightly r-continuous; slightly v-continuous] if it is slightly-continuous[resp**:**slightly semi-continuous; slightly pre-continuous; slightly β-continuous; slightly γ-continuous; slightly α-continuous; slightly r-continuous; slightly v-continuous] at each x in X.

(vii) almost strongly θ-semi-continuous[resp**:** strongly θ-semi-continuous] if for each x in X and for each V$\in \sigma$(Y, f(x)), $\exists$ U$\in$ SO(X, x) such that $f(scl(U)) \subset scl(V)$[resp**:** $f(scl(U)) \subset V$].

Lemma 2.1:
(i) Let A and B be subsets of a space X, if A$\in$*RGO*(X) and B$\in$RO(X), then A$\cap$B$\in$*RGO*(B).
(ii)Let A$\subset$ B$\subset$ X, if A$\in$ *RGO* (B) and B$\in$ RO(X), then A$\in$*RGO*(X).

3. Slightly *rg*-continuous functions

Definition 3.1: A function f**:**X$\rightarrow$ Y is said to be slightly *rg*-continuous at x in X if for each clopen subset V in Y containing f(x), $\exists$ U$\in$*RGO*(X) containing x such that $f(U) \subseteq V$ and slightly *rg*-continuous if it is slightly *rg*-continuous at each x in X.

Note 2: Here after we call slightly *rg*-continuous function as sl.*rg*.c function shortly.

Example 3.1: X = Y = {a, b, c}; τ = {ϕ, {a}, {b}, {a, b}, X} and σ = {ϕ, {a}, {b, c}, Y}. Let f be defined as f(a) = b; f(b) = c and f(c) = a, then f is sl.rg.c.

Theorem 3.1: The following are equivalent:
(i) f is sl.rg.c.
(ii) f^{-1}(V) is *rg*-open for every clopen set V in Y.
(iii) f^{-1}(V) is *rg*-closed for every clopen set V in Y.
(iv) $f(rgcl(A)) \subseteq rgcl(f(A))$.

Corollary 3.1: The following are equivalent.
(i) f is sl.rg.c.
(ii) For each x in X and each clopen subset V$\in$ (Y, f(x)) $\exists$ U$\in$ *RGO*(X, x) such that $f(U) \subseteq V$.

Theorem 3.2: Let $\sum$ = {U_i**:**i$\in$ I} be any cover of X by regular open sets in X. A function f is sl.rg.c. iff $f_{/U_i}$**:** is sl.rg.c., for each i$\in$ I.

Proof: Let i$\in$ I be an arbitrarily fixed index and $U_i \in$ RO(X). Let x$\in U_i$ and V$\in$ CO(Y, f_{U_i}(x)) Since f is sl.rg.c, $\exists$ U$\in$ *RGO*(X, x) such that $f(U) \subset V$. Since $U_i \in$ RO(X), by Lemma 2.1 x$\in U \cap U_i \in$ *RGO* (U_i) and $(f_{/U_i})U \cap U_i = f(U \cap U_i) \subset f(U) \subset V$. Hence $f_{/U_i}$ is sl.rg.c.'

Conversely Let x in X and V$\in$ CO(Y, f(x)), $\exists$ i$\in$ I such that x$\in U_i$. Since $f_{/U_i}$ is sl.*rg*.c, $\exists$ U$\in$*RGO* (U_i, x) such that $f_{/U_i}(U) \subset V$. By Lemma 2.1, U$\in$ *RGO*(X) and $f(U) \subset V$. Hence f is sl.rg.c.

Theorem 3.3:
(i) If f is *rg*-irresolute and g is sl.rg.c.[sl.c.; g.c], then $g \bullet f$ is sl.rg.c.
(ii) If f is *rg*-irresolute and g is g-continuous, then $g \bullet f$ is sl.rg.c.
(iii) If f is rg-continuous and g is sl.rg.c. [sl.c.,] then $g \bullet f$ is sl.rg.c.
'

Theorem 3.4: If f is *rg*-irresolute, *rg*-open and *RGO*(X) = τ and g be any function, then $g \bullet f$**:**X$\rightarrow$ Z is sl.rg.c iff g is sl.rg.c.

Proof: If part**:** Theorem 3.3(i)

Only if part: Let A be clopen subset of Z. Then $(g\bullet f)^{-1}(A)$ is a *rg*-open subset of X and hence open in X[by assumption]. Since *f* is *rg*-open $f(g\bullet f)^{-1}(A)$ is *rg*-open Y $\Rightarrow g^{-1}(A)$ is *rg*-open in Y. Thus *g* is sl.rg.c.

Corollary 3.2: If *f* is *rg*-irresolute, *rg*-open and bijective, *g* is a function. Then *g* is sl.rg.c. iff $g\bullet f$ is sl.rg.c.

Theorem 3.5: If g: X $\to$ X$\times$ Y, defined by $g(x) = (x, f(x))$ for all x in X be the graph function of f:X$\to$Y. Then g:X$\to$ X$\times$Y is sl.*rg*.c iff *f* is sl.*rg*.c.

Proof: Let V$\in$CO(Y), then X$\times$ V is clopen in X$\times$ Y. Since *g* is sl.rg.c., $f^{-1}(V) = f^{-1}(X\times V) \in RGO(X)$. Thus *f* is sl.rg.c. Conversely, let x in X and F be a clopen subset of X$\times$ Y containing $g(x)$. Then F$\cap$ ({x}$\times$ Y) is clopen in {x}$\times$ Y containing $g(x)$. Also {x}$\times$ Y is homeomorphic to Y. Hence $\{y\in Y:(x, y) \in F\}$ is clopen subset of Y. Since *f* is sl.rg.c. $\cup\{f^{-1}(y):(x, y) \in F\}$ is *rg*-open in X. Further $x\in \cup\{f^{-1}(y):(x, y) \in F\}\subseteq g^{-1}(F)$. Hence $g^{-1}(F)$ is *rg*-open. Thus g:X$\to$ Y is sl.rg.c.

Theorem 3.6: (i) f: $\Pi X_\lambda\to \Pi Y_\lambda$ is sl.*rg*.c, iff f_λ: $X_\lambda\to Y_\lambda$ is sl.*rg*.c for each $\lambda\in\Gamma$.
(ii) If f: X$\to \Pi Y_\lambda$ is sl.*rg*.c, then $P_\lambda\bullet f$: X$\to Y_\lambda$ is sl.*rg*.c for each $\lambda\in\Gamma$, where $P_\lambda:\Pi Y_\lambda$ onto Y_λ.

Remark 1:
(i) Composition of two sl.*rg*.c functions is not in general sl.*rg*.c.
(ii) Algebraic sum and product of sl.*rg*.c functions is not in general sl.*rg*.c.
(iii) The pointwise limit of a sequence of sl.*rg*.c functions is not in general sl.*rg*.c.
However we can prove the following:

Theorem 3.7: The uniform limit of a sequence of sl.*rg*.c functions is sl.*rg*.c.

Note 3: Pasting Lemma is not true for sl.*rg*.c functions. However we have the following weaker versions.

Theorem 3.8: Let X and Y be topological spaces such that X = A$\cup$ B and let $f_{/A}$: A$\to$ Y and $g_{/B}$: B $\to$ Y are sl.r.c maps such that $f(x) = g(x)$ for all x$\in$ A$\cap$B. Suppose A and B are r-open sets in X and RO(X) is closed under finite unions, then the combination α: X$\to$ Y is sl.*rg*.c continuous.

Theorem 3.9: Pasting Lemma Let X and Y be spaces such that X = A$\cup$ B and let $f_{/A}$: A$\to$ Y and $g_{/B}$: B $\to$ Y are sl.*rg*.c maps such that $f(x) = g(x)$ for all x$\in$ A$\cap$ B. Suppose A, B are r-open sets in X and *RGO*(X) is closed under finite unions, then the combination α: X$\to$ Y is sl.*rg*.c.

Proof: Let F$\in$CO(Y), then $\alpha^{-1}(F) = f^{-1}(F)\cup g^{-1}(F)$, where $f^{-1}(F)\in RGO(A)$ and $g^{-1}(F)\in RGO(B) \Rightarrow f^{-1}(F)$; $g^{-1}(F)\in RGO(X) \Rightarrow f^{-1}(F)\cup g^{-1}(F)\in RGO(X)$[by assumption]. Therefore $\alpha^{-1}(F)\in RGO(X)$. Hence α: X$\to$Y is sl.*rg*.c.

4. Covering and Separation properties of sl.*rg*.c. Functions:

Theorem 4.1: If *f* is sl.rg.c.[resp: sl.rg.c] surjection and X is *rg*-compact, then Y is compact.

Proof: Let $\{G_i:i\in I\}$ be any open cover for Y. Then each G_i is open in Y and hence each G_i is clopen in Y. Since *f* is sl.rg.c., $f^{-1}(G_i)$ is *rg*-open in X. Thus $\{f^{-1}(G_i)\}$ forms a *rg*-open cover for X and hence have a finite subcover, since X is *rg*-compact. Since *f* is surjection, $Y = f(X) = \cup^{n}_{i=1}G_i$. Therefore Y is compact.

Corollary 4.1: If *f* is sl.*sp*.c.[resp: sl.r.c] surjection and X is *rg*-compact, then Y is compact.

Theorem 4.2: If *f* is sl.rg.c., surjection and X is *rg*-compact [*rg*-lindeloff] then Y is mildly compact[mildly lindeloff].

Proof: Let $\{U_i:i\in I\}$ be clopen cover for Y. For each x in X, $\exists\ \alpha_x\in I$ such that $f(x) \in U_{\alpha x}$ and $\exists\ V_x\in RGO(X, x)$ such that $f(V_x)\subset U_{\alpha x}$. Since the family $\{V_i:i\in I\}$ is a cover of X by *rg*-open sets of X, $\exists$ a finite subset I_0 of I such that X$\subset$ $\{V_x:x\in I_0\}$. Therefore Y$\subset \cup \{f(V_x):x\in I_0\}\subset \cup \{U_{\alpha x}:x\in I_0\}$. Hence Y is mildly compact.

Corollary 4.2:
(i) If *f* is sl.rg.c[resp: sl.r.c] surjection and X is *rg*-compact[*rg*-lindeloff] then Y is mildly compact[mildly lindeloff].

(ii) If *f* is sl.rg.c.[resp: sl.c; sl.r.c] surjection and X is locally *rg*-compact{resp:*rg*-Lindeloff; locally *rg*-lindeloff}, then Y is locally compact{resp: Lindeloff; locally lindeloff}.

(iii) If *f* is sl.rg.c.[sl.r.c.], surjection and X is locally *rg*-compact{resp: *rg*-lindeloff; locally *rg*-lindeloff} then Y is locally mildly compact{resp: locally mildly lindeloff}.

Theorem 4.3: If f is sl.rg.c., surjection and X is s-closed then Y is mildly compact[mildly lindeloff].

Proof: Let $\{V_i : V_i \in CO(Y); i \in I\}$ be a cover of Y, then $\{f^{-1}(V_i) : i \in I\}$ is *rg*-open cover of X[by Thm 3.1] and so there is finite subset I_0 of I, such that $\{f^{-1}(V_i): i \in I_0\}$ covers X. Therefore $\{V_i: i \in I_0\}$ covers Y since f is surjection. Hence Y is mildly compact.

Corollary 4.3: If f is sl.r.c., surjection and X is s-closed then Y is mildly compact[mildly lindeloff].

Theorem 4.4: If f is sl.rg.c.,[resp: sl.rg.c.; sl.r.c.] surjection and X is *rg*-connected, then Y is connected.

Proof: If Y is disconnected, then $Y = A \cup B$ where A and B are disjoint clopen sets in Y. Since f is sl.rg.c. surjection, $X = f^{-1}(Y) = f^{-1}(A) \cup f^{-1}(B)$ where $f^{-1}(A)$ $f^{-1}(B)$ are disjoint *rg*-open sets in X, which is a contradiction for X is *rg*-connected. Hence Y is connected.

Corollary 4.4: The inverse image of a disconnected space under a sl.rg.c., [resp: sl.r.c.] surjection is *rg*-disconnected.

Theorem 4.5: If f is sl.rg.c..[resp: sl.c.], injection and Y is UT_i, then X is rg_i i = 0, 1, 2.

Proof: Let $x_1 \neq x_2 \in X$. Then $f(x_1) \neq f(x_2) \in Y$ since f is injective. For Y is UT_2 $\exists$ $V_j \in CO(Y)$ such that $f(x_j) \in V_j$ and $\cap V_j = \phi$ for j = 1,2. By Theorem 3.1, $x_j \in f^{-1}(V_j) \in RGO(X)$ for j = 1,2 and $\cap f^{-1}(V_j) = \phi$ for j = 1,2. Thus X is rg_2.

Theorem 4.6: If f is sl.rg.c., injection; closed and Y is UT_i, then X is rgg_i i = 3, 4.

Proof:(i) Let x in X and F be disjoint closed subset of X not containing x, then $f(x)$ and $f(F)$ be disjoint closed subset of Y not containing $f(x)$, since f is closed and injection. Since Y is ultraregular, $f(x)$ and f (F) are separated by disjoint clopen sets U and V respectively. Hence $x \in f^{-1}(U)$; $F \subseteq f^{-1}(V)$, $f^{-1}(U)$; $f^{-1}(V) \in RGO(X)$ and $f^{-1}(U) \cap f^{-1}(V) = \phi$. Thus X is rgg_3.

(ii) Let F_j and $f(F_j)$ are disjoint closed subsets of X and Y respectively for j = 1,2, since f is closed and injection. For Y is ultranormal, $f(F_j)$ are separated by disjoint clopen sets V_j respectively for j =1,2. Hence $F_j \subseteq f^{-1}(V_j)$ and $f^{-1}(V_j) \in RGO(X)$ and $\cap f^{-1}(V_j) = \phi$ for j = 1,2. Thus X is rgg_4.

Theorem 4.7: If f is sl.*rg*.c.[resp: sl.c.], injection and
(i) Y is UC_i[resp: UD_i] then X is rgC_i[resp: rgD_i] i = 0, 1, 2.
(ii)Y is UR_i, then X is rg-R_i i = 0, 1.

Theorem 4.8: If f is sl.*rg*.c.[resp: sl.c; sl.r.c] and Y is UT_2, then the graph $G(f)$ of f is *rg*-closed in X×Y.

Proof: Let $(x, y) \notin G(f)$ implies $y \neq f(x)$ implies $\exists$ disjoint V; $W \in CO(Y)$ such that $f(x) \in V$ and $y \in W$. Since f is sl.rg.c., $\exists$ $U \in RGO(X)$ such that $x \in U$ and $f(U) \subset W$ and $(x, y) \in U \times V \subset X \times Y - G(f)$. Hence $G(f)$ is *rg*-closed in X×Y.

Theorem 4.9: If f is sl.rg.c.[resp: sl.c; sl.r.c] and Y is UT_2, then $A = \{(x_1, x_2) | f(x_1) = f(x_2)\}$ is *rg*-closed in X× X.

Proof: If $(x_1, x_2) \in X \times X - A$, then $f(x_1) \neq f(x_2)$ implies $\exists$ disjoint $V_j \in CO(Y)$ such that $f(x_j) \in V_j$, and since f is sl.rg.c., $f^{-1}(V_j) \in RGO(X, x_j)$ for j = 1,2. Thus $(x_1, x_2) \in f^{-1}(V_1) \times f^{-1}(V_2) \in RGO(X \times X)$ and $f^{-1}(V_1) \times f^{-1}(V_2) \subset X \times X - A$. Hence A is *rg*-closed.

Theorem 4.10: If f is sl.r.c.[resp: sl.c.]; g is sl.*rg*.c[resp: sl.c;]; and Y is UT_2, then $E = \{x \in X: f(x) = g(x)\}$ is *rg*-closed in X.

CONCLUSION:

In this paper we defined slightly-*rg*-continuous functions, studied its properties and their interrelations with other types of slightly-continuous functions.

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