Almost Slightly *rg*-continuity

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Abstract: In this paper we discuss new type of continuous functions called almost slightly *rg*-continuous its properties and interrelation with other such functions are studied.
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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.

1. 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**:**$X\rightarrow Y$ is said to be
(i) continuous[resp**:** nearly-continuous; rα-continuous; *v*-continuous; α-continuous; semi-continuous; β−continuous; pre-continuous] if inverse image of each open set is open[resp**:** regular-open; rα-open; *v*-open; α-open; semi-open; β -open; preopen].
(ii) nearly-irresolute[resp**:** rα-irresolute; *v*-irresolute; α-irresolute; irresolute; β−irresolute; pre-irresolute] if inverse image of each regular-open[resp**:** rα-open; *v*-open; α-open; semi-open; β-open; preopen] set is regular-open[resp**:** rα-open; *v*-open; α-open; semi-open; β-open; preopen].
(iii) almost continuous[resp**:** almost nearly-continuous; almost rα-continuous; almost *v*-continuous; almost α-continuous; almost semi-continuous; almost β−continuous; almost pre-continuous] if for each x

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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 $f(U) \subset (cl(V))^o$.
(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→ Y is said to be almost slightly *rg*-continuous at x in X if for each r-clopen subset V in Y containing $f(x)$, $\exists$ $U \in RGO(X)$ containing x such that $f(U) \subseteq V$ and almost slightly *rg*-continuous if it is almost slightly *rg*-continuous at each x in X.

Note 1: Here after we call almost slightly *rg*-continuous function as al.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 al.sl.rg.c.

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

Corollary 3.1: The following are equivalent.
(i) f is al.sl.rg.c.
(ii) For each x in X and each r-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 al.sl.rg.c. iff $f_{/U_i}$: is al.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 $V \in RCO(Y, f_{U_i}(x))$ Since f is al.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 al.sl.rg.c.

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

Theorem 3.3:

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

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

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

Only if part**:** Let A be r-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 al.sl.rg.c.

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

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

Proof: Let $V\in RCO(Y)$, then $X\times V$ is r-clopen in $X\times Y$. Since *g* is al.sl.rg.c., $f^{-1}(V) = f^{-1}(X\times V)$ $\in RGO(X)$. Thus *f* is al.sl.rg.c.

Conversely, let x in X and F be a r-clopen subset of $X\times Y$ containing $g(x)$. Then $F\cap(\{x\}\times Y)$ is r-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 r-clopen subset of Y. Since *f* is al.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:$X\rightarrow Y$ is al.sl.rg.c.

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

Remark 1:

(i) Composition of two al.sl.*rg*.c functions is not in general al.sl.*rg*.c.
(ii) Algebraic sum and product of al.sl.*rg*.c functions is not in general al.sl.*rg*.c.
(iii) The pointwise limit of a sequence of al.sl.*rg*.c functions is not in general al.sl.*rg*.c.

However we can prove the following**:**

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

Note 2: Pasting Lemma is not true for al.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 $f_{/A}$: $A\rightarrow Y$ and $g_{/B}$: $B \rightarrow Y$ are al.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: $X\rightarrow Y$ is al.sl.*rg*.c continuous.

Theorem 3.9: Pasting Lemma Let X and Y be spaces such that $X = A\cup B$ and let $f_{/A}$: $A\rightarrow Y$ and $g_{/B}$: $B \rightarrow Y$ are al.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: $X\rightarrow Y$ is al.sl.*rg*.c.

Proof: Let F∈RCO(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→Y is al.sl.*rg*.c.

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

Theorem 4.1: If *f* is al.sl.rg.c.[resp: al.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 r-clopen in Y. Since *f* is al.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 al.sl.*sp*.c.[resp: al.sl.r.c] surjection and X is *rg*-compact, then Y is compact.

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

(ii) If *f* is al.sl.rg.c.[resp: al.sl.c; al.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 al.sl.rg.c.[al.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 al.sl.rg.c., surjection and X is s-closed then Y is mildly compact[mildly lindeloff].

Proof: Let $\{V_i : V_i\in RCO(Y); i\in I\}$ 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 al.sl.r.c., surjection and X is s-closed then Y is mildly compact[mildly lindeloff].

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

Proof: If Y is disconnected, then Y = A∪ B where A and B are disjoint r-clopen sets in Y. Since *f* is al.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 al.sl.rg.c.,[resp: al.sl.r.c.] surjection is *rg*-disconnected.

Theorem 4.5: If *f* is al.sl.rg.c..[resp: al.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 $\exists\ V_j\in RCO(Y)$ 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 al.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 r-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 r-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 al.sl.r*g*.c.[resp**:** al.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 al.sl.r*g*.c.[resp**:** al.sl.c; al.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; $W\in RCO(Y)$ such that $f(x)\in V$ and $y\in W$. Since f is al.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 al.sl.rg.c.[resp**:** al.sl.c; al.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 $V_j\in RCO(Y)$ such that $f(x_j)\in V_j$, and since f is al.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 al.sl.r.c.[resp**:** al.sl.c.]; g is al.sl.r*g*.c[resp**:** al.sl.c;]; and Y is UT_2, then $E = \{x\in X\mathbf{:}f(x) = g(x)\}$ is *rg*-closed in X.

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

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