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ON PRE Rg-CONTINUOUS FUNCTIONS IN TOPOLOGY

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Abstract: -

In this paper we define and study the concept of pre-Rg-continuous functions using preopen sets due to Mashhour et.al (1982) and rg-open sets due to N. Palaniappan (1993). Also,we study the pre-g-regular spaces.
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1. INTRODUCTION

In 1982, A. S. Mashhour et.al [8] has defined and studied the concepts of preopen sets and precontinuous functions in topology. For the first time the concept of generalized closed sets was considered by Levine in 1970 [7]. Later many generalized closed sets have been defined and studied by various Authors in the literature. In 1993, 1997 and 1998 respectively, N. Palaniappan [13], T. Noiri [12] et.al have defined and studied the concepts of rg-closed sets, rg-continuous functions, rg-irresolute functions, gpr-closed sets, gp-closed sets and gp-closed functions in topology. In this paper we define and study the concept of pre-Rg-continuous functions using preopen sets due to Mashhour et.al [8] and rg-open sets due to N. Palaniappan [13].

2. Preliminaries

In what follows, spaces X and Y are always topological spaces. Cl(A) and Int(A) designate the closure and the interior of A which is a subset of X. A subset A is said to be regular open (resp. regular closed) if A = Int (Cl(A)) (resp. A = Cl (Int (A))).

The following definitions and results are useful in sequel.

Definition 2.1: A subset A of a space X is called:

(i) Preopen [8] if $A \subset Int\left(Cl(A)\right)$,

(ii) $Preclosed$ [5] $if\ Cl\left(Int(A)\right) \subset A.$

The collection of all preopen (resp. preclosed) sets of space X will be denoted by PO(X) (resp. PF(X)).

Definition 2.2: A subset A of X is called preregular [11] if it is both preopen and preclosed set.

The family of all preregular sets of X is denoted by PR(X). The complement of a preregular set is also preregular.

Definition 2.3: Let A be a subset of a space X then

i. The intersection of all preclosed sets containing A is called the pre-closure [5] of A and is denoted by $pCl(A)$.
ii. The intersection of all regular closed sets containing A is called the r-closure [3] of A and is denoted by $rCl(A)$.
iii. The union of all preopen sets contained in A is called the preInterior [9] of A and is denoted by $pInt(A)$.
iv. The union of all regular open sets contained in A is called the r -Interior[3] of A and is denoted by $rInt(A)$.

Definition 2.4: A function f: X → Y is said to be precontinuous [8] if $f^{-1}(V)$ is preopen in X for each open set V of Y.

Definition 2.5: A subset A of a space X is said to be:

i. a generalized closed set (briefly g – closed) [7] if $Cl(A) \subset$ U whenever $A \subseteq U$ and U is open in X.
ii. a generalized preclosed set (briefly gp – closed) [12] if $pCl(A) \subset$ U whenever $A \subseteq U$ and U is open in X.
iii. a r-generalized closed set (briefly rg – closed) [13] if $rCl(A) \subset$ U whenever $A \subseteq U$ and U is open in X.
iv. a generalized pre-regular closed set (briefly gore – closed) [6] if $pCl(A) \subset$ U whenever $A \subseteq U$ and U is regular open in X.

The complement of a g-closed (resp. gp-closed,rg-closed and gpr-closed) set ofa space X is called g-open (resp. gp-open, rg-open and gpr-open) set in X.

Definition 2.6: A function f: X → Y is said to be:

(i) g-continuous [4] if $f^{-1}(V)$ is g-closed in X for each closed set V of Y.
(ii) rg-continuous [13] if $f^{-1}(V)$ is rg-closed in X for each closed set V of Y.
(iii) rg-irresolute [13] if $f^{-1}(V)$ is rg-open in X for each rg-open set V of Y.
(iv) gp-continuous [2] if $f^{-1}(V)$ is gp-closed in X for each closed set V of Y.
(v) gp-irresolute [2] if $f^{-1}(V)$ is gp-open in X for each gp-open set V of Y.

Definition 2.7: A topological space X is said to be:

(i) p-regular [5] if for each closed set A and each point x ϵ X-A$there exist preopen sets U, V$such that x εU, A ⊂V and U∩V = Φ.
(ii) g-regular [10] if for each closed set A and each point x ϵ X-A there exist generalized open sets U, V such that x ϵ U, A ⊂ V and U∩V = Φ.
(iii) pre-connected [14] if X cannot be written as disjoint union of two non- empty preopen sets.
(iv) rg-connected [1] if X cannot be written as disjoint union of two non-empty rg-open sets.

3. Properties of pre-Rg-continuous functions

In this section we define the following.

Definition 3.1: A function f: X → Y is called pre-Rg-continuous if the inverse image of each rg-open set of Y is preopen in X.

We have the following implications:
(i) Every strongly rg-continuous function is pre-Rg-continuous.
(ii) Every pre-Rg-continuous function is almost precontinuous.

We prove the following.

Theorem 3.2: Let f: X → Y be a single valued function, where X and Y are topological spaces, then the following are equivalent
(i) The function f is pre-Rg-continuous.
(ii) For each point $x \in X$ and each rg-open set V in Y with $f(x) \in V$, there is a preopen set U in X such that $x \in U$, $f(U) \subset V$.

Proof :(i) ⇒ (ii):

Let $f(x) \in V$ and $V \subset Y$ an rg-open set then $x \in f^{-1}(V) \in PO(X)$ as f is pre-Rg-continuous. Let U = $f^{-1}(V)$, then x∈ U and $f(U) \subset V$. Conversely, Let V be rg-open in Y and $x \in f^{-1}(V)$ then $f(x) \subset V$, there exists a Up∈ $PO(X)$ such that p∈ Up and f(Up) $\subset V$. Then x∈ $U_x \subset f^{-1}(V)$ and $f^{-1}(V) = \bigcup U_x \in PO(X)$. This implies f is pre-Rg-continuous.
We define the following.

Definition 3.3 :A function f : X → Y is called gp-rg-continuous if the inverse image of each rg- open subset of Y is gp-open in X.
Clearly, Every pre-rg-continuous function is gp-rg-continuous function.

Theorem 3.4: Let f : X → Y be pre-Rg-continuous then f is gp-rg-continuous.
Proof: Let $V \subset Y$ be rg-open. Then $f^{-1}(V)$ is preopen in X, since f is pre-Rg-continuous. Since every preopen set is gp-open set, then $f^{-1}(V)$ is gp-open set in X. Thus, f is gp-rg-continuous.
We define the following.

Definition 3.5: A function f : X → Y is called gp-gpr-continuous if the inverse image of each gpr-open subset of Y is gp-open in X.
Clearly, Everygp-gpr-continuous function is gpr-irresolute.

Definition 3.6: A function f : X → Y is called pre-strongly-gpr-continuous if the inverse image of each gpr-open set of Y is preopen in X.

Note 3.7:
(i) Every strongly rg-continuous function is pre-Rg-continuous.
(ii) Every pre-Rg-continuous function is almost precontinuous.

Theorem 3.8: Let f : X → Y be a function. Then the following are equivalent.
(i) f is pre-Rg-continuous.
(ii) The inverse image of each rg-open set in Y is preopen in X.
(iii)The inverse image of each rg-closed set in Y is preclosed in X.
Proof :(i) ⇒(ii) :
Let G be any rg-openset of Y. Then, Y-Gisrg-closed in Y. By the assumption of (i),$f^{-1}(Y - G)$is preclosed set in X. But $f^{-1}(Y - G) = X - f^{-1}(G)$ which implies that X-$f^{-1}(G)$is preclosed in X. Therefore $f^{-1}(G)$ is preopen in X.
(ii)⇒(iii) : Obvious.
(iii) ⇒(i) : Obvious.

Theorem 3.9: Let f: X → Y is pre-Rg-continuous surjection and X is preconnected then Y is rg-connected.
Proof: Suppose Y is not rg-connected. Let Y = A∪B, where A and B are disjoint non-empty rg- open sets in Y. Since f is pre-Rg-continuous and onto, $X = f^{-1}(A) \cup f^{-1}(B)$, where $f^{-1}(A)$ and $f^{-1}(B)$are disjoint non-empty and preopen sets in X. This contradicts the fact that X is preconnected. Hence Y is rg-connected.

Theorem 3.10: Let f: X → Y is gp-rg-continuous surjection and X is gp-connected then Y is rg-connected.
Proof: Suppose Y is not rg-connected. Let Y = A∪B, where A and B are disjoint non-empty rg- open sets in Y. Since f is gp-rg-continuous and onto, $X = f^{-1}(A) \cup f^{-1}(B)$, where $f^{-1}(A)$ and $f^{-1}(B)$are disjoint non-empty and gp-open sets in X. This contradicts the fact that X is gp-connected. Hence Y is rg-connected.

Theorem 3.11: Let f : X → Y is pre-strongly-gpr-continuous surjection and X is preconnected then Y is gpr-connected.
Proof: Suppose Y is not gpr-connected. Let Y = A∪B, where A and B are disjoint non-empty gpr-open sets in Y. Since f is pre-strongly-gpr-continuous and Onto, $X = f^{-1}(A) \cup f^{-1}(B)$, where $f^{-1}(A)$ and $f^{-1}(B)$ are disjoint non-empty and preopen sets in X. This contradicts the fact that Y is preconnected. Hence Y is gpr-connected.

Theorem 3.12: Let f: X → Y is strongly rg-continuous surjection and X is connected then Y is rg-connected.
Proof: Suppose Y is not rg-connected. Let Y = A∪B, where A and B are disjoint non-empty rg- open sets in Y. Since f is strongly-rg-continuous and Onto, $X = f^{-1}(A) \cup f^{-1}(B)$,where $f^{-1}(A)$ and $f^{-1}(B)$ are disjoint non-empty and open sets in X. This contradicts the fact that X is connected. Hence Y is rg-connected.
We define the following.

Definition 3.13: A function f: X → Y is said to be contra-pre-Rg-continuous if the inverse image of each rg-open set of Y is preclosed in X.
Definition 3.14: A function f : X → Y is said to be contra strongly-rg-continuous if the inverse image of each rg-open set of Y is closed in X.
Since every open set is rg-open set and every closed set is preclosed set and hence we have the following implications.
(i) Every contra strongly rg-continuous function is contra-pre-Rg-continuous.
(ii) Every contra-pre- Rg-continuous function is contra-precontinuous.

Theorem 3.15 : The following are equivalent for a function f : X → Y :
(i) f is contra-pre-Rg-continuous.
(ii) For each rg-closed subset F of Y, $f^{-1}(F) \in PO(X)$,
(iii)For each x ∈ X and rg-closed subset of Y containing f(x), there exists preopen set U in X containing point x such that f(U) ⊂ F.
Proof : (i) ⇒(ii) :
Let F be any rg-closed subset of Y. Then, Y-F be any rg-open subset of Y. Since by (i), $f^{-1}(Y - F) = X - f^{-1}(F)$is preclosed set in X. Hence, $f^{-1}(F)$ is is preopen set in X. Thus, (ii) holds.
(ii)⇒(i) : Obvious.
(ii) ⇒(iii) : Obvious.
(iii) ⇒(ii) :
Let F be any rg-closed subset of Y and x ∈ $f^{-1}(F)$. Then f(x) 000∈ F and there exists a preopen set $U_X$in X containing point x such that $f(U_X) \subset F$. Therefore, we obtain $f^{-1}(F) = \cup\{ U_X \backslash x \in f^{-1}(F)\} \in PO(X)$. This shows that (ii) holds. We define the following.

Definition 3.16 : A topological space X is said to be pre-rg-regular if for each rg-closed set A and each point x ∈ $X - A$ there exists preopen sets U,V such that x ∈ $U, A \subset V$ and
$U \cap V = \Phi$.

Definition 3.17 : A topological space X is said to be pre-g-regular if for each g-closed set A and each point x ∈ $X - A$ there exists preopen sets U,V such that x ∈ $U,\ A \subset V$ and $U \cap V = \Phi$.
Since every closed set is g-closed set and every g-closed set is rg-closed set and every closed set is rg-closed set. Thus we have the following implications.
(i) Every pre- Rg-regular space is p-regular.
(ii) Every pre- g-regular space is p-regular.
(iii)Every pre- Rg-regular space is pre-g-regular.

We state the following.

Theorem 3.18: For a topological space X the following hold:
(i) X is a pre-rg-regular.
(ii) For each x ∈ X and each rg-open set U of X containing x, there exists V∈ $PO(X)$ such that x∈ $V \subset pCl(V) \subset U$.
(iii) For each rg-closed set F of X, $\cap\{pCl(V) / F \subset V \in PO(X)\} = F$.

Theorem 3.19: For a topological space X the following hold:
(i) X is a pre- g-regular.
(ii) For each x ∈ X and each g-open set U of X containing x, there exists V∈ $PO(X)$ such that x∈ $V \subset pCl(V) \subset U$.
(iii) For each g-closed set F of X, $\cap\{pCl(V) / F \subset V \in PO(X)\} = F$.

Theorem 3.20: If a function f : X → Y is said to be contra-pre-rg-continuous and Y is pre- rg- regular, then f is pre- rg-continuous.
Proof : Let x be any arbitrary point of X and V be an rg-open set of Y containing f(x). Since Y is pre- rg-regular, there exists an pre-open set w in Y containing f(x) such that pCl(w)⊂V. Since f is contra- pre-rg-continuous, so by Theorem 3.15 there exists preopen set U in X containing point x such that f(U)⊂ pCl(w). Then f(U) ⊂ pCl(w) ⊂ V. Hence f is pre-

rg-continuous.
We define the following

Definition 3.21 : A function f : X → Y is said to be perfectly pre-Rg-continuous if $f^{-1}(V)$ is pre-regular set in X for each rg-open set V in Y.
Lemma 3.22 : Let f : X → Y be a function. Then,
(i) If f is perfectly pre-Rg-continuous, then f is pre-rg-continuous.
(ii) If f is perfectly pre-Rg-continuous, then f is Contra pre-Rg-continuous.
Proof:

(i) Let U be an rg-open set in Y, since f is perfectly pre-Rg-continuous, then $f^{-1}(U)$ is pre-regular in X. But every pre-regular set is pre-open, then $f^{-1}(U)$ is pre-open in X.Hence f is perfectly pre- Rg-continuous.

(ii) Let U be an rg-open set in Y, Since f is perfectly pre-Rg-continuous, then $f^{-1}(U)$ is pre-regular in X. But every pre-regular set is pre-closed, then $f^{-1}(U)$ is preclosed in X.Hence f is Contra pre- Rg-continuous.

Theorem 3.23: Let f : X → Y be a function. Then the following are equivalent.
(i) If f is perfectly pre-Rg-continuous.
(ii) The inverse image of every rg-open set in Y is both preopen and preclosed in X.
(iii)The inverse image of every rg-closed set in Y is both preopen and preclosed in X.
Proof :
(i) ⇒(ii) : Clearly from the definition.
(ii) ⇒(iii) :Let F be any rg-closed set in Y. Then, (Y-F) is rg-open in Y. Hence by assumption
(iii) $f^{-1}(Y-F)$ is both pre-open and pre-closed in X.
(iv) ⇒(i) : Let G be any rg-open set in Y. Then, (Y-G) is rg-closed in Y. Hence by the condition
(v) $f^{-1}(Y-G)$ is both pre-open and pre-closed in X which implies that $f^{-1}(G)$ is both preopen and preclosed in X. Hence f is perfectly pre-Rg-continuous.

Theorem 3.25 : Let f : X → Y and g : X→Y be two functions. Then
(i) gof is pre-Rg-continuous, if g is gp-rg-continuous and f is pre-Rg-continuous.
(ii) gof is pre-Rg-continuous, if g is gp-rg-continuous and f is pre-strongly-gp- continuous.
(iii)gof is pre-Rg-continuous, if g is strongly-rg-continuous and f is pre-continuous.

Proof :

i. Let V be arg-open set in Z. As g : Y → Z is rg-irresolute, $g^{-1}(V)$ is rg-open in Y. Again, f is pre-Rg-continuous and $g^{-1}(V)$ is rg-open in Y. Then $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V)$ Preopen set in X. Therefore gof is pre-Rg-continuous.
ii. Let V be arg-open set in Z. As g : Y → Z is gp-rg-continuous, $g^{-1}(V)$ is gp-open in Y. Again, f is pre-strongly-gp-continuous and $g^{-1}(V)$ is gp-open in Y. Then $f^{-1}(g^{-1}(V))=(gof)^{-1}(V)$ is Preopen set in X. Therefore gof is pre-Rg-continuous.
iii. Let V be arg-open set in Z. As g : Y → Z is strongly-rg-continuous, $g^{-1}(V)$ is open in Y. Again, f is pre-continuous and $g^{-1}(V)$ is open in Y. Then $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V)$ Preopen set in X. Therefore gof is pre-Rg-continuous.

Theorem 3.25 : Let f : X → Y and g : X→Y be two functions. Then
(i) gof is precontinuous, if f is pre-Rg-continuous and g is rg-continuous.
(ii) gof is precontinuous, if f is pre-strongly-rg-continuous and g is rg-continuous.
(iii)gof is continuous, if f is strongly-rg-continuous and g is rg -continuous.
Proof :

i. Let V ⊂Z be an arbitrary open set. Since g is rg-continuous, $g^{-1}(V)$ is rg-open set in Y. Again, as $g^{-1}(V)$ is rg-open set in Y and f is pre-Rg-continuous function, $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V)$ is preopen set in X. This shows that gof is precontinuous function.
ii. Let V ⊂Z be an arbitrary open set. Since g is rg-continuous function, $g^{-1}(V)$ is rg- open set in Y. Again, as $g^{-1}(V)$ is rg-open set in Y and f is pre-strongly-rg- continuous function, $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V)$ is preopen set in X. This shows that gof is precontinuous function.
iii. Let V ⊂Z be an arbitrary open set. Since g is rg-continuous function, $g^{-1}(V)$ is rg- open set in Y. Again, as $g^{-1}(V)$ is rg-open set in Y and f is strongly-rg-continuous function, $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V)$ is open set in X. This shows that gof is continuous function.

Lemma 3.26 : If f : X → Y is strongly preopen surjective and g : Y → Z is a function such that gof : X → Z is pre-Rg-continuous then g is strongly -rg-continuous.
Proof : Let V be an arbitrary open set in Z. Since gof is pre-Rg-continuous, $(gof)^{-1}(U) = f^{-1}(g^{-1}(U))$ is preopen in X. Since f is strongly preopen surjective, f($f^{-1}(g^{-1}(U))) = g^{-1}(U)$ is open in Y. Therefore g is strongly- rg-continuous.

Lemma 3.28 : If f : X → Y and g : Y → Z be two functions. If f is precontinuous, α-open and g is pre- Rg –continuous, then gof : X → Z is pre-Rg-continuous .
Proof: Let V be an arbitrary rg-open subset of Z. Then $g^{-1}(V)$ is preopen set in Y, since g is pre-Rg-continuous. As, f is precontinuous and α-open and $g^{-1}(V)$ is preopen, $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V)$ is preopen in X . This shows that gof is pre-Rg-continuous.

Lemma 3.28: If f : X → Y is surjective M-preopen and g : Y → Z is a function such that gof : X → Z is pre-Rg-continuous then g is pre-Rg-continuous.
Proof : Let U be an rg-open set in Z. Since gof is pre-Rg-continuous, $(gof)^{-1}(U)=f^{-1}(g^{-1}(U))$ is preopen in X. Since f is surjective M-preopen, if$(f^{-1}(g^{-1}(U))) = g^{-1}(U)$ is preopen in Y. Therefore, g is pre- Rg-continuous.

Theorem 3.29: If f : X → Y is rg-irresolute and g : Y → Z be g-rg-continuous, then gof : X → Z is g-rg-continuous.
Proof: Let V be an arbitrary g-open subset of Z. Then $g^{-1}(V)$ is rg-open set n Y, Since g is g- rg-continuous. As, f is rg-irresolute and $g^{-1}(V)$is rg-open, $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V)$ is rg- open in X. This shoes that gof is g-rg-continuous.

Theorem 3.30 : If f : X → Y be strongly g-continuous with Y be Trgspace and g : Y → Z be g- rg-continuous, then gof : X → Z is strongly g-continuous.
Proof : Let V ⊂ Z be an arbitrary g-open set. Since g is g-rg-continuous,then $g^{-1}(V)$ is rg-open set n Y. Given that Y is Trgspace ,$g^{-1}(V)$ is g-open in Y and f is strongly g-continuous, $f^{-1}(g^{-1}(V))=(gof)^{-1}(V)$ is open in X. This shows that gof is strongly g-continuous.

Theorem 3.31 : If f : X → Y be pre-Rg-continuous and g : Y → Z be pre-rg-continuous, then gof : X → Z is almost precontinuous.
Proof : Let V be an arbitrary regular-open set of Z. Since g is pre-rg-continuous,then $g^{-1}(V)$ is rg-open set n Y, As f is pre-Rg-continuous function and $g^{-1}(V)$ is rg-open in Y. Then, $f^{-1}(g^{-1}(V))=(gof)^{-1}(V)$ is preopen in X. This shows that gof is almost precontinuous.

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