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On $G^{\#}$P-Continuous Maps In Topological Spaces

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Abstract: *The aim of this paper is to introduce and study $g^{\#}$p-continuous maps. Basic characterizations and several properties concerning them are obtained.Further,$g^{\#}$p-irresolute map is also defined. Some of the properties are investigated.*
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I. INTRODUCTION

N.Levine **[16] introduced** the class of g-closed sets. M.K.R.S.Veerakumar introduced several generalized closed sets namely, g^*-closed sets , $g^{\#}$-closed sets , g^* p- closed sets , g^*p-continuous maps , g^*p-irresolute maps and their properties. The authors [26] have already introduced $g^{\#}$p-closed sets and their properties. In this paper we study the new class of map called as $g^{\#}$p-continuous maps .Different characterizations of the introduced concepts are also found.In this direction $g^{\#}$p-irresolute maps are defined and some of their properties are studied by giving some counter example.

II. PRELIMINARIES

Throughout this paper (X,τ)(or X) represent topological spaces on which no separation axioms are assumed unless otherwise mentioned. For a subset A of a space (X,τ), cl(A), int (A) and C(A) denote the closure of A, the interior of A and the complement of A respectively.

We recall the following definitions which are useful in the sequel.

Definition2.1:
A subset A of a space (X,τ) is called
(i) a semi-open set [17] if $A \subseteq cl(int(A))$ and a semi-closed [17] set if $int(cl(A)) \subseteq A$.
(ii) a preopen set [21] if $A \subseteq int(cl(A))$ and a preclosed [21] set if $cl(int(A)) \subseteq A$.
(iii) an α-open set [23] if $A \subseteq int(cl(int(A)))$ and an α-closed [23] set if $cl(int(cl(A)))\subseteq A$.
(iv) a semi-preopen set [2] (=β-open [1]) if $A \subseteq cl(int(cl(A)))$ and a semi-preclosed set [2] (=β-closed [1]) if $int(cl(int(A)))\subseteq A$and
(v) a regular open [15] set if $A = int(cl(A))$ and a regular closed[15] set if $cl(int(A)) =A$.

The semi-closure (resp. preclosure, α-closure, semi-preclosure) of a subset A of a space (X, τ) is the intersection of all semi-closed (resp. preclosed, α-closed, semi-preclosed) sets that contain A and is denoted by scl (A) (resp. pcl (A), αcl(A),spcl (A)).

Definition 2.2:
A subset A of a space (X,τ) is called
(i) a generalized closed (briefly g-closed) set [16] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X, τ).
(ii) a semi-generalized closed (briefly sg-closed) set [6] if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi-open in (X, τ). The complement of a sg-closed set is called a sg-open [6] set.
(iii) a generalized semi-closed (briefly gs-closed) set [4] if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X, τ).
(iv) an α-generalized closed (briefly αg-closed) set [18] if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X, τ).
(v) a generalized α-closed (briefly gα-closed) set [19] if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is α-open in (X, τ).
The complement of a gα-closed set is called a gα-open [7] set.
(vi) a generalized preclosed (briefly gp-closed) set [20] if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X, τ)
(vii) a generalized semi-preclosed (briefly gsp-closed) set [10] if $spcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X,τ).
(viii) a generalized preregular closed (briefly gpr-closed) set [13] if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is regular open in (X,τ).
(ix) a $g^{\#}$-closed set [27] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is αg- open in (X, τ).
(x) a g^*-pre closed set [28] (briefly g^*p-closed)set if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is a g- open set in (X, τ).
(xi) a $g^{\#}$-pre closed set [26] (briefly $g^{\#}$p-closed) set if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is a $g^{\#}$- open set in (X, τ).

Definition2.3:
A function f: $(X, \tau) \rightarrow (Y, \sigma)$ is said to be
(i) Semi-continuous [17] if $f^{-1}(V)$ is semi-open in (X, τ) for every open set V of (Y, σ).
(ii) Pre-continuous [21] if $f^{-1}(V)$ is preclosed in (X,τ) for every closed set V of (Y, σ).
(iii) α-continuous [22] if $f^{-1}(V)$ is α-closed in (X, τ) for every closed set V of (Y, σ).
(iv) β-continuous [1] if $f^{-1}(V)$ is semi-preopen in (X, τ) for every open set V of (Y, σ),
(v) g-continuous [5] if $f^{-1}(V)$ is g-closed in (X, τ) for every closed set V of (Y, σ).
(vi) sg-continuous [25] if $f^{-1}(V)$ is sg-closed in (X, τ) for every closed set V of (Y, σ).
(vii) gs-continuous [8] if $f^{-1}(V)$ is gs-closed in (X, τ) for every closed set V of (Y, σ).
(viii) gα-continuous [19] if $f^{-1}(V)$ is gα-closed in (X, τ) for every closed set V of (Y, σ).
(ix) αg-continuous [13] if $f^{-1}(V)$ is αg-closed in (X, τ) for every closed set V of (Y, σ).
(x) gsp-continuous [10] if $f^{-1}(V)$ is gsp-closed in (X, τ) for every closed set V of (Y, σ).
(xi) gp-continuous [24] if $f^{-1}(V)$ is gp-closed in (X, τ) for every closed set V of (Y, σ).
(xii) gpr-continuous [13] if $f^{-1}(V)$ is gpr-closed in (X, τ) for every closed set V of (Y, σ).
(xiii) gc-irresolute [5] if $f^{-1}(V)$ is g-closed in (X, τ) for every g-closed set V of (Y, σ).
(xiv) gp-irresolute [3] if $f^{-1}(V)$ is gp-closed in (X, τ) for every gp-closed set V of (Y, σ).
(xv) gsp-irresolute [10] if $f^{-1}(V)$ is gsp-closed in (X, τ) for every gsp-closed set V of (Y, σ).
(xvi) p-open [14] if f(U) is preopen in (Y, σ) for every preopen set U in (X, τ).
(xvii) pre-α-open [7] if f(U) is α-closed in (Y, σ) for every α-closed set U in (X,τ).
(xviii)$g^{\#}$-continuous [27]if $f^{-1}(V)$ is $g^{\#}$-closed in (X, τ) for every closed set V of (Y, σ).
(xix) $g^{\#}$-irresolute [27] if $f^{-1}(V)$ is $g^{\#}$-closed in (X, τ) for every $g^{\#}$-closed set V of (Y, σ).
(xx) g*p-continuous [28] if $f^{-1}(V)$ is g^{*}p-closed in (X, τ) for every closed set V of (Y, σ).
(xxi) g*p- irresolute [28]if $f^{-1}(V)$ is g^{*}p-closed in (X, τ) for every g^{*}p closed set V of (Y, σ).

Definition 2.4:
A space (X,τ) is called a
(i) $T_{1/2}$ space [16] if every g-closed set is closed.
(ii)semi-$T_{1/2}$ space [6] if every sg-closed set is semi-closed.
(iii)semi-pre-$T_{1/2}$ space [10] if every gsp-closed set is semi-preclosed.
(iv)preregular $T_{1/2}$ space [13] if every gpr-closed set is preclosed.
(v)$T_p^{\#}$ space [26] if every $g^{\#}$p-closed set is closed.
(vi)${}^{\#}T_p$ space [26] if every gp-closed set is $g^{\#}$p-closed
(vii)$T_p^{\#\#}$ space [26] if every $g^{\#}$p-closed set is gα- closed.
(viii) ${}_{\alpha}T_p^{\#}$ space [26] if every $g^{\#}$p-closed set is preclosed.
(ix) ${}_{\alpha}T_p^{\#\#}$ space [26] if every $g^{\#}$p-closed set is α-closed.

III. $g^{\#}$-PRE –CONTINUOUS MAPS AND $g^{\#}$-PRE- IRRESOLUTE MAPS

We introduce the following definition

Definition 3.1:
A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is said to be $g^{\#}$p-continuous if $f^{-1}(V)$ is a $g^{\#}$p- closed set of (X,τ) for every closed set V of (Y,σ).

Theorem 3.2:
(i) Every pre-continuous map [resp.α-continuous,gα-continuous and every continuous map]is $g^{\#}$p-continuous .
(ii) Every $g^{\#}$p-continuous map is gpr-continuous and gsp-continuous.

Proof: Follows from the theorem 3.02 [26]
the converse of the theorem 3.2 need not be true as can be seen from the following examples.

Example 3.3:
Let $X=\{a,b,c\}=Y,\tau=\{ \varphi,X,\{a\},\{a,c\}\}$and $\sigma=\{\varphi,Y,\{a\},\{b\},\{a,b\},\{a,c\}\}$.Define $f:(X, \tau)\rightarrow(Y, \sigma)$ by f(a)=a,f(b)=c and f(c)=b.f is not a pre-continuous map, since {a,c} is a closed set of (Y, σ) but $f^{-1}\{a,c\}=\{a,b\}$ is not a preclosed set of(X,τ).But it is $g^{\#}$p-continuous map.

Example3.4:
Let $X=\{a,b,c\}=Y,\tau=\{ \varphi,X,\{a\},\{a,b\}\}$. Define $g:(X, \tau)\rightarrow(X, \tau)$ by g(a)=b,g(b)=c and g(c)=a.g is not a $g^{\#}$p-continous map,since {b,c} is a closed set of (X,τ) but $g^{-1}(\{b,c\})=\{a,b\}$ is not a $g^{\#}$p-closed set of (X,τ). But it is gpr-continuous.

Example3.5:
Let $X=\{a,b,c\}=Y,\tau=\{ \varphi,X,\{a\},\{b\},\{a,b\}\}$ and $\sigma=\{X,\Phi,\{b,c\},\{b\}\}$.Define $g:(X, \tau)\rightarrow(Y, \sigma)$ by g(a)=a,g(b)=b and g(c)=c.g is not a $g^{\#}$p-continous map,since {a} is a closed set of (Y,σ) but $g^{-1}(\{a\})=\{a\}$ is not a $g^{\#}$p-closed set of (X,τ). But it is gsp-continuous.

Thus the class of $g^{\#}$p-continuous maps properly contains the classes of pre-continuous maps, gα –continuous maps,α-continuous maps and the class of continuous maps .Next we show that the class of $g^{\#}$p-continuous maps is properly contained in the classes of gpr- continuous and gsp-continuous maps.

Theorem 3.6:
(i)$g^{\#}$p-continuity is independent of semi –continuity and β-continuity.
(ii) $g^{\#}$p-continuity is independent of gs-continuity and sg-continuity .

Example3.7:
Let X={a,b,c}=Y,τ={ φ,X,{a}}.Define f:(X, τ)→(Y, τ) by f(a)=b,f(b)=c and f(c)=a.f is $g^{\#}$p-continuous but not β-continuity and semi –continuity maps.

Example 3.8:
Let X={a,b,c}=Y,τ={ φ,X,{a},{b},{a,b}}and σ={ φ,Y,{a,b}}.Define h:(X, τ)→(Y, σ) by h(a)=c,h(b)=b and h(c)=a. h is not $g^{\#}$p-continuous map,since {c} is a closed set of (Y,σ) but h^{-1}{c}={a} is not a $g^{\#}$p-closed set of (X,τ). But it is semi-continuous and β-continuous map.

Example 3.9:
Let X={a,b,c},τ={ φ,X,{a,b}}. Define θ:(X,τ)→ (X,τ) by θ(a)=c, θ(b)=b, θ(c)=a. θ is a $g^{\#}$p-continuous map but it is not gs-continuous and sg-continuous.

Example 3.10:
Let X,Y,τ as in the example 3.8 and σ={ φ,Y,{a},{a,c}}.Define h:(X, τ)→(Y, σ) by h(a)=b,h(b)=c and h(c)=a. h is not $g^{\#}$p-continuous map,since {b} is a closed set of (Y,σ) but h^{-1}{b}={a} is not a $g^{\#}$p-closed set of (X,τ). But it is gs-continuous and sg-continuous maps .

Remark3.11:
Composition of two $g^{\#}$p-continuous maps need not be $g^{\#}$p-continuous maps as seen in the following example.

Example 3.12:
Let X={a,b,c}=Y=Z ,τ={ φ,X,{a},{b},{a,b}}and σ={ φ,Y,{a},{a,c}} and η={ φ,Z,{a},{b},{a,b},{a,c}}.Define f:(X,τ)→(Y,σ) by f(a)=c, f(b)=a, f(c)=b. Define g: (Y,σ)→(Z,η) by g(a)=a, g(b)=c, g(c)=b. clearly f and g are $g^{\#}$p-continuous maps . g o f :(X,τ)→(Z,η) is not $g^{\#}$p-continuous, since {b} is a closed set of (Z,η) but $(g \text{ o } f)^{-1}$({b})=f^{-1}(g^{-1}{b})= f^{-1}({c})={a} is not a $g^{\#}$p-closed set of (X,τ).
We introduce the following definition.

Definition 3.13:
A function f:(X,τ)→(Y,σ) is said to be $g^{\#}$p-irresolute if f^{-1}(V) is a $g^{\#}$p-closed set of (X,τ) for every $g^{\#}$p-closed set V of (Y, σ).
Clearly every $g^{\#}$p-irresolute map is $g^{\#}$p-continuous. The converse is not true as it can be seen by the following example.

Example 3.14:
Let X, Y, τ, σ and f be as in the above example 3.12. f is not $g^{\#}$p-irresolute, since {c} is a $g^{\#}$p-closed set of (Y, σ) but f^{-1}({c})={a} is not a $g^{\#}$p-closed set of (X, τ). But it is $g^{\#}$p-continuous.

Theorem 3.15:
Let f: (X, τ)→(Y,σ) and g: (Y, σ) →(Z,η) be any two functions. Then
(i) g o f : (X, τ)→(Z,η) is $g^{\#}$p-continuous if g is continuous and f is $g^{\#}$p-continuous.
(ii) g o f : (X, τ)→(Z,η) is $g^{\#}$p-irresolute if g is $g^{\#}$p-irresolute and f is $g^{\#}$p-irresolute.
(iii) g o f : (X, τ)→(Z,η) is $g^{\#}$p-continuous if g is $g^{\#}$p-continuous and f is $g^{\#}$p-irresolute.
The proof is obvious from the definitions 3.1 and 3.13.

Theorem 3.16:
Let f: (X, τ) →(Y, σ) be a bijective $g^{\#}$ -irresolute and p-open map. Then f(A) is $g^{\#}$p-closed in (Y, σ) for every $g^{\#}$p-closed set A of (X, τ).

Proof: Let A be a $g^{\#}$p-closed set of (X, τ). Let V be a $g^{\#}$-open set of (Y,σ) containing f(A). Since f is $g^{\#}$-irresolute, then f^{-1}(V) is a $g^{\#}$-open set of (X,τ). Since A ⊆ f^{-1}(V) and A is $g^{\#}$p-closed, then pcl(A) ⊆ f^{-1}(V). Then f(pcl(A)) ⊆ V. Then f(pcl(A))= pcl (f(pcl(A))) since f is a bijection and p-open map. Now pcl(f(A)) ⊆pcl (f(pcl(A))) = f(pcl(A))⊆V. Hence f(A) is a $g^{\#}$p-closed set in (Y,σ).

Theorem 3.17:
Let (X,τ)->(Y,σ) be a $g^{\#}$p-continuous map.
(i)If (X,τ) is a $T_p{}^{\#}$ space, then f is continuous.
(ii) If (X,τ) is a $T_p{}^{\#\#}$ space ,then f is gα-continuous.
(iii)If (X,τ) is a ${}_{\alpha}T_p{}^{\#}$ space ,then f is pre-continuous.
(iv)If (X,τ) is a ${}_{\alpha}T_p{}^{\#\#}$ space, then f is α-continuous.

Theorem 3.18:
Let (X,τ)->(Y,σ) be a gp-continuous map. If (X,τ) is a ${}^{\#}T_p$ space, then f is $g^{\#}$p-continuous.

Theorem 3.19:
Let (X,τ)->(Y,σ) be a gsp-continuous map. If (X,τ) is a ${}^{\#}{}_{s}T_P$ space, then f is $g^{\#}$p-continuous.

Theorem 3.20:
Let (X,τ)->(Y,σ) be onto,$g^{\#}$p- irresolute and closed. If (X,τ) is a $T_p{}^{\#}$space , then (Y,σ) is also a $T_p{}^{\#}$ space.
Proof: Let A be a $g^{\#}$p-closed set of (Y,σ) . Since f is $g^{\#}$p-irresolute, then $f^{-1}(A)$ is $g^{\#}$p-closed in(X,τ). Since (X,τ) is a $T_p{}^{\#}$ space, then $f^{-1}(A)$ is closed in (X,τ). Since f is closed and onto ,then A=f ($f^{-1}(A)$) is closed in (Y,σ). Hence (Y,σ) is also a $T_p{}^{\#}$ space.

Definition 3.21:
A function f: (X,τ) ->(Y,σ) is said to be pre- $g^{\#}$p-closed if f(U) is $g^{\#}$p-closed in (Y,σ) for every $g^{\#}$p-closed set U in (X,τ).

Definition 3.22:
A function f: (X,τ) ->(Y,σ) is said to be pre- gα-closed if f(U) is gα-closed in (Y,σ) for every gα-closed set U in (X,τ).

Theorem 3.23:
Let (X,τ)->(Y,σ) be onto, $g^{\#}$p- irresolute and pre-gα-closed. If (X,τ) is a $T_p{}^{\#\#}$ space , then (Y,σ) is also a $T_p{}^{\#\#}$ space.
Proof: Let A be a $g^{\#}$p-closed set of (Y,σ).Since f is $g^{\#}$p- irresolute, then $f^{-1}(A)$ is $g^{\#}$p- closed in (X,τ). Since (X,τ) is a $T_p{}^{\#\#}$ space , then $f^{-1}(A)$ is gα-closed in (X,τ). Since f is pre-gα-closed and onto, then A=f($f^{-1}(A)$) is gα-closed in (Y,σ). Hence (Y,σ) is also a $T_p{}^{\#\#}$ space.

Theorem 3.24:
Let (X,τ)->(Y,σ) be onto, $g^{\#}$p- irresolute and p-closed. If (X,τ) is an ${}_{\alpha}T_p{}^{\#}$ space, then (Y,σ) is also an ${}_{\alpha}T_p{}^{\#}$ space.

Theorem 3.25:
Let (X,τ)->(Y,σ) be onto, $g^{\#}$p- irresolute and pre-α-closed. If (X,τ) is an ${}_{\alpha}T_p{}^{\#\#}$ space, then (Y,σ) is also an ${}_{\alpha}T_p{}^{\#\#}$ space.

Theorem 3.26:
Let (X,τ)->(Y,σ) be onto, gp- irresolute and pre- $g^{\#}$p –closed. If (X,τ) is a ${}^{\#}T_p$ space, then (Y,σ) is also a ${}^{\#}T_p$ space.

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