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g^*b-Continuous Maps and Pasting Lemma in Topological Spaces

D. Vidhya

Department of Science and Humanities
Karpagam college of Engineering
Coimbatore-32, India
vidhya_abc@yahoo.com

R. Parimelazhagan

Department of Science and Humanities
Karpagam college of Engineering
Coimbatore-46, India
pari_kce@yahoo.com

Abstract

In this paper, the authors introduce a new class of maps g^*b-continuous maps and g^*b-irresolute maps in topological spaces and study some of its basic properties and relations among them.

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1 Introduction

Biswas[3], Husain[10], Ganster and Reilly[9], Levine[11,13], Marcus[15], Mashour [16]et al, Noiri[18], Noiri and Ahmed[19] and Tong[15,16,17] have introduced and investigated simple continuous, almost continuous, LC-continuity, weak continuity, semi-continuity, quasi-continuity, α-continuity, strong semi-continuity, semi-weak continuity, weak almost continuity, A-continuity and B-continuity respectively. Balachandran et al have introduced and studied generalized semi-continuous maps, semi locally continuous maps, semi-generalized locally continuous maps and generalized locally continuous maps. Maki and Noiri studied the pasting lemma for α-continuous mappings. El Etik[7] also introduced

the concept of gb-continuous functions with the aid b-open sets. Omari and Noorani [20] introduced and studied the concept of generalized b-closed sets and gb-continuous maps in topological spaces. Vidhya and Parimelazhagan[26] introduced and studied the properties of g^*b-closed set in topological spaces.
Crossley and Hildebrand[5] introduced and investigated irresolute functions which are stronger than semi continuous maps but are independent of continuous maps. Since then several researchers have introduced several strong and weak forms of irresolute functions. Di Maio and Noiri[6], Faro[8],Cammaroto and Noiri [4], Maheswari and Prasad[16] and sundaram [21] have introduced and studied quasi-irresolute and strongly irresolute maps strongly α-irresolute maps, almost irresolute maps, α-irresolute maps and gc-irresolute maps are respectively.
The aim of this paper is to introduce and study the concepts of new class of maps namely g^*b-continuous maps and g^*b-irresolute maps.
Throughout this paper (X, τ) and (Y, σ)(or simply X and Y) represents the non-empty topological spaces on which no separation axiom are assumed, unless otherwise mentioned. For a subset A of X, cl(A) and int(A) represents the closure of A and interior of A respectively.

2 Preliminaries

We recall the following definitions.

Definition 2.1 [1]: *A subset A of a topological space (X, τ) is called a b-open set if $A \subseteq cl(int(A)) \cup int(cl(A))$ and b-closed set if $cl(int(A)) \cup int(cl(A)) \subseteq A$.*

Definition 2.2 [12]: *A subset A of a topological space (X, τ) is called a generalized closed set(briefly g-closed) if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is open in X.*

Definition 2.3 [25]: *A subset A of a topological space (X, τ) is called a g^*-closed set if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is g-open in X.*

Definition 2.4 [20]: *A subset A of a topological space (X, τ) is called a generalized b-closed set(briefly gb-closed) if $bcl(A) \subseteq U$, whenever $A \subseteq U$ and U is open in X.*

Definition 2.5 [26]: *A subset A of a topological space (X, τ) is called a g^*b-closed set if $bcl(A) \subseteq U$, whenever $A \subseteq U$ and U is g-open in X.*

Definition 2.6 [14]: *A subset A of a topological space (X, τ) is called a generalized closed set(briefly g-closed) if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is open in X.*

Definition 2.7 [7]: *A map $f : (X, \tau) \to (Y, \sigma)$ from a topological space X into a topological space Y is called b-continuous if $f^{-1}(V)$ is b-closed in X for every closed set V of Y.*

Definition 2.8 [20]: *A map $f : (X, \tau) \to (Y, \sigma)$ from a topological space X into a topological space Y is called gb-continuous if $f^{-1}(V)$ is gb-closed in X for every closed set V of Y.*

Definition 2.9 [5]: *A map $f : (X, \tau) \to (Y, \sigma)$ from a topological space X into a topological space Y is called irresolute if $f^{-1}(V)$ is semi-closed in X for every semi-closed set V of Y.*

3 g^*b-Continuous Maps

In this section we introduce the concept of g^*b-Continuous maps in topological spaces.

Definition 3.1 *Let $f : X \to Y$ from a topological space X into a topological space Y is called g^*b-continuous if the inverse image of every closed set in Y is g^*b-closed in X.*

Theorem 3.2 *If a map $f : X \to Y$ from a topological space X into a topological space Y is continuous, then it is g^*b-continuous but not conversely.*

Proof: Let $f : X \to Y$ be continuous. Let F be any closed set in Y. Then the inverse image f^{-1}(F) is closed in X. Since every closed set is g^*b-closed, f^{-1}(F) is g^*b-closed in X. Therefore f is g^*b-continuous.

Remark 3.3 *The converse of the theorem 3.2 need not be true as seen from the following example.*

Example 3.4 *Let $X = Y = \{a, b, c\}$ with topologies $\tau = \{X, \phi, \{b\}, \{a, b\}\}$ and $\sigma = \{Y, \phi, \{c\}, \{a, b\}\}$. Let $f : X \to Y$ be a map defined by $f(a) = c, f(b) = b, f(c) = a$. Here f is g^*b-continuous. But f is not continuous since for the closed set F=$\{a, b\}$ in Y, f^{-1}(F)=$\{b, c\}$ is not closed in X.*

Theorem 3.5 *If a map $f : X \to Y$ from a topological space X into a topological space Y is b-continuous, then it is g^*b-continuous but not conversely.*

Proof: Let $f : X \to Y$ be b-continuous. Let F be any closed set in Y. Then the inverse image f^{-1}(F) is b-closed in X. Since every b-closed set is g^*b-closed, f^{-1}(F) is g^*b-closed in X. Therefore f is g^*b-continuous.

Remark 3.6 *The converse of the theorem 3.5 need not be true as seen from the following example.*

Example 3.7 *Let $X = Y = \{a, b, c\}$ with topologies $\tau = \{X, \phi, \{a\}, \{a, c\}\}$ and $\sigma = \{Y, \phi, \{c\}, \{a, c\}\}$. Let $f : X \to Y$ be the identity map. Here f is g^*b-continuous. But f is not b-continuous since for the closed set F=$\{a, b\}$ in Y, f^{-1}(F)=$\{a, b\}$ is not b-closed in X.*

Theorem 3.8 *If a map $f : X \to Y$ from a topological space X into a topological space Y is g^*b-continuous, then it is gb-continuous but not conversely.*

Proof: Let $f : X \to Y$ be g^*b-continuous. Let F be any closed set in Y. Then the inverse image f^{-1}(F) is g^*b-closed in X. Since every g^*b-closed set is gb-closed, f^{-1}(F) is gb-closed in X. Therefore f is gb-continuous.

Remark 3.9 *The converse of the theorem 3.8 need not be true as seen from the following example.*

Example 3.10 *Let $X = Y = \{a, b, c\}$ with topologies $\tau = \{X, \phi, \{a\}\}$ and $\sigma = \{Y, \phi, \{b\}, \{a, b\}\}$. Let $f : X \to Y$ be the identity map. Here f is gb-continuous. But f is not g^*b-continuous since for the closed set F=$\{a, c\}$ in Y, f^{-1}(F)=$\{a, c\}$ is not g^*b-closed in X.*

Theorem 3.11 *If a map $f : X \to Y$ from a topological space X into a topological space Y.*
(i) The following statements are equivalent.
(a) f is g^*b-continuous.
(b) The inverse image of each open set in Y is g^*b-open in X.
(ii) If $f : X \to Y$ is g^*b-continuous, then $f(b^*(A)) \subset cl(f(A))$ for every subset A of X.
(iii) The following statements are equivalent.
(a) For each point $x \in X$ and each open set V in Y with $f(x) \in V$, there is a g^*b-open set U in X such that $x \in U$, $f(U) \subset V$.
(b) For every subset A of X, $f(b^*(A)) \subset cl(f(A))$ holds.
(c) For each subset B of Y, $b^*(f^{-1}(B)) \subset f^{-1}(cl(B))$.

Proof: (i) Assume that $f : X \to Y$ be g^*b-continuous. Let G be open in Y. Then G^c is closed in Y. Since f is g^*b-continuous, $f^{-1}(G^c)$ is g^*b-closed in X. But $f^{-1}(G^c) = X - f^{-1}(G)$. Thus $X - f^{-1}(G)$ is g^*b-closed in X and so $f^{-1}(G)$ is g^*b-open in X. Therefore (a) implies (b).
Conversely assume that the inverse image of each open set in Y is g^*b-open in X. Let F be any closed set in Y. The F^c is open in Y. By assumption, $f^{-1}(F^c)$ is g^*b-open in X. But $f^{-1}(F^c) = X - f^{-1}(F)$. Thus $X - f^{-1}(F)$ is g^*b-open in X and so $f^{-1}(F)$ is g^*b-closed in X. Therefore f is g^*b-continuous. Hence (b) implies (a). Thus (a) and (b) are equivalent.
(ii) Assume that f is g^*b-continuous. Let A be any subset of X. Then $cl(f(A))$

is closed in Y. Since f is g^*b-continuous, $f^{-1}(cl(f(A)))$ is g^*b-closed in X and it contains A. But $b^*(A)$ is the intersection of all g^*b-closed sets containing A. Therefore $b^*(A) \subset f^{-1}(cl(f(A)))$ and so $f(b^*(A)) \subset cl(f(A))$.
(iii) $(a) \Rightarrow (b)$
Let $y \in b^*(A)$ and $x \in X$, $f(x) \in V$. Let V be any neighbourhood of y. Then there exists a point $x \in X$ and a g^*b-open set U such that $f(x) = y$, $x \in U$, $x \in b^*(A)$ and $f(U) \in V$. Since $x \in b^*(A)$, $U \cap A \neq \phi$ holds and hence $f(A) \cap V \neq \phi$. Therefore we have $y = f(x) \in cl(f(A))$.
$(b) \Rightarrow (a)$
Let $x \in X$ and V be any open set containing $f(x)$. Let $A = f^{-1}(V^c)$, then $x \notin A$. Since $f(b^*(A)) \subset cl(f(A)) \subset V^c$. Then, since $x \notin b^*(A)$, there exist a g^*b-open set U containing x such that $U \cap A \in \phi$ and hence $f(U) \subset f(A^c) \subset V$.
$(b) \Rightarrow (c)$
Let B be any subset of Y. Replacing A by $f^{-1}(B)$ we get from (b), $f(b^*(f^{-1}(B))) \subseteq cl(ff^{-1}(B)) \subset B$. Hence $b^*(f^{-1}(B)) \subset f^{-1}(cl(B))$.
$(c) \Rightarrow (b)$
Let $B = f(A)$ where A is a subset of X. Then $b^*(A) \subset b^*(f^{-1}(B)) \subset f^{-1}(cl(f(A)))$. Therefore $f(b^*(A)) \subset cl(f(A))$.

Remark 3.12 *The converse of the theorem 3.11(ii) need not be true as seen from the following example.*

Example 3.13 *Let $X = Y = \{a, b, c\}$ with topologies $\tau = \{X, \phi, \{b\}\}$ and $\sigma = \{Y, \phi, \{b, c\}\}$. Let $f : X \to Y$ be a map defined by $f(a) = b, f(b) = a, f(c) = c$. Then for every subset A of X, $f(b^*(A)) \subset cl(f(A))$ holds but it is not g^*b-continuous, since for the closed set $\{a\}$ in Y, $f^{-1}(\{a\})=\{b\}$ is not g^*b-closed in X.*

Theorem 3.14 *If $f : X \to Y$ and $g : Y \to Z$ be any two functions, then $g \circ f : X \to Z$ is g^*b-continuous if g is continuous and f is g^*b-continuous.*

Proof: Let V be any closed set in Z. Since g is continuous, $g^{-1}(V)$ is closed in Y and since f is g^*b-continuous, $f^{-1}(g^{-1}(V))$ is g^*b-closed in X. Hence $(g \circ f)^{-1}(V)$ is g^*b-closed in X. Thus $g \circ f$ is g^*b-continuous.

Remark 3.15 *The composition of two g^*b-continuous map need not be g^*b-continuous. Let us prove the remark by the following example.*

Example 3.16 *Let $X = Y = Z = \{a, b, c\}$ with topologies $\tau = \{X, \phi, \{a\}, \{b\}, \{a, b\}\}$, $\sigma = \{Y, \phi, \{a\}, \{a, c\}\}$ and $\eta = \{Z, \phi, \{a\}, \{b\}, \{a, b\}, \{a, c\}\}$. Let $g : (X, \tau) \to (Y, \sigma)$ be a map defined by $g(a) = a, g(b) = b$ and $g(c) = c$,let $f : (Z, \eta) \to (X, \tau)$ be a map defined by $f(a) = b, f(b) = a$ and $f(c) = c$. Both f and g are g^*b-continuous.*
Define $g \circ f : (Z, \eta) \to (Y, \sigma)$. Here $\{b\}$ is a closed set of (Y, σ). Therefore $(g \circ f)^{-1}(\{b\}) = \{a\}$ is not a g^*b-closed set of (Z, η). Hence $g \circ f$ is not g^*b-continuous.

Theorem 3.17 *Let $f : X \to Y$ be a g^*b-continuous map from a topological space X into a topological space Y and let H be a closed subset of X. Then the restriction $f/H : H \to Y$ is g^*b-continuous where H is endowed with the relative topology.*

Proof: Let F be any closed subset in Y. Since f is g^*b-continuous, $f^{-1}(F)$ is g^*b-closed in X. If $f^{-1}(F) \cap H = H_1$ then H_1 is a g^*b-closed set in X, since intersection of two g^*b-closed set is g^*b-closed set. Since $(f/H)^{-1}(F) = H_1$, it is sufficient to show that H_1 is g^*b-closed set in H. Let G_1 be any open set of H such that G_1 contains H_1. Let $G_1 = G \cap H$ where G is open in X. Now $H_1 \subset G \cap H \subset G$. Since H_1 is g^*b-closed set in X. $\overline{H_1} \subset G$. Now $Cl_H(H_1) = \overline{H_1} \cap H \subset G \cap H = G_1$ where $Cl_H(A)$ is the closure of a subset A of the subspace H of X. Therefore f/H is g^*b-continuous.

4 g^*b-Irresolute Maps

Definition 4.1 *Let $f : X \to Y$ from a topological space X into a topological space Y is called g^*b-irresolute if the inverse image of every g^*b-closed set in Y is g^*b-closed in X.*

Theorem 4.2 *A map $f : X \to Y$ is g^*b-irresolute if and only if the inverse image of every g^*b-open set in Y is g^*b-open in X.*

Proof: Assume that f is g^*b-irresolute. Let A be any g^*b-open set in Y. Then A^c is g^*b-closed set in Y. Since f is g^*b-irresolute, $f^{-1}(A^c)$ is g^*b-closed in X. But $f^{-1}(A^c) = X - f^{-1}(A)$ and so $f^{-1}(A)$ is g^*b-open in X. Hence the inverse image of every g^*b-open set in Y is g^*b-open in X.
Conversely assume that the inverse image of every g^*b-open set in Y is g^*b-open in X. Let A be any g^*b-closed set in Y. Then A^c is g^*b-open in Y. By assumption, $f^{-1}(A^c)$ is g^*b-open in X. But $f^{-1}(A^c) = X - f^{-1}(A)$ and so $f^{-1}(A)$ is g^*b-closed in X. Therefore f is g^*b-irresolute.

Theorem 4.3 *If a map $f : X \to Y$ is g^*b-irresolute, then it is g^*b-continuous but not conversely.*

Proof: Assume that f is g^*b-irresolute. Let F be any closed set in Y. Since every closed set is g^*b-closed, F is g^*b-closed in Y. Since f is g^*b-irresolute, $f^{-1}(F)$ is g^*b-closed in X. Therefore f is g^*b-continuous.

Remark 4.4 *The converse of the theorem 4.3 need not be true as seen from the following example.*

Example 4.5 *Let $X = Y = \{a, b, c\}$ with topologies $\tau = \{X, \phi, \{a\}\}$ and $\sigma = \{Y, \phi, \{a\}, \{a, b\}\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be the identity map. Here f is g^*b-continuous. But $\{a, c\}$ is g^*b-closed in Y but $f^{-1}(\{a, c\}) = \{a, c\}$ is not g^*b-closed in X. Therefore f is not g^*b-irresolute.*

Theorem 4.6 *Let X, Y and Z be any topological spaces. For any g^*b-irresolute map $f : X \to Y$ and any g^*b-continuous map $g : Y \to Z$, the composition $g \circ f : (X, \tau) \to (Z, \eta)$ is g^*b-continuous.*

Proof: Let F be any closed set in Z. Since g is g^*b-continuous, $g^{-1}(F)$ is g^*b-closed in Y. Since f is g^*b-irresolute, $f^{-1}(g^{-1}(F))$ is g^*b-closed in X. But $f^{-1}(g^{-1}(F))$=$(g \circ f)^{-1}(F)$. Therefore $g \circ f : X \to Z$ is g^*b-continuous.

Remark 4.7 *The irresolute maps and g^*b-irresolute maps are independent of each other. Let us prove the remark by the following two examples.*

Example 4.8 *Let $X = Y = \{a, b, c\}$ with topologies $\tau = \{X, \phi, \{a\}, \{b\}, \{a, b\}\}$ and $\sigma = \{Y, \phi, \{a\}, \{b, c\}\}$. Then the identity map $f : (X, \tau) \to (Y, \sigma)$ is irresolute, but it is not g^*b-irresolute. Since $G = \{a, b\}$ is g^*b-closed in (Y, σ), where $f^{-1}(G) = \{a,b\}$ is not g^*b-closed in (X, τ).*

Example 4.9 *Let $X = Y = \{a, b, c\}$ with topologies $\tau = \{X, \phi, \{a, b\}\}$ and $\sigma = \{Y, \phi, \{a\}\}$. Then the identity map $f : (X, \tau) \to (Y, \sigma)$ is g^*b-irresolute, but it is not irresolute. Since $G = \{a, c\}$ is semi-open in (Y, σ), where $f^{-1}(G)$ $= \{a,c\}$ is not semi-open in (X, τ).*

5 Pasting Lemma for g^*b-Continuous Maps

Theorem 5.1 *Let $X = A \cup B$ be a topological space with topology τ and Y be a topological space with topology σ. Let $f : (A, \tau/A) \to (Y, \sigma)$ and $g : (B, \tau/B) \to (Y, \sigma)$ be g^*b-continuous maps such that $f(x) = g(x)$ for every $x \in A \cap B$. Suppose that A and B are g^*b-closed sets in X. Then the combination $\alpha : (X, \tau) \to (Y, \sigma)$ is g^*b-continuous.*

Proof: Let F be any closed set in Y. Clearly $\alpha^{-1}(F) = f^{-1}(F) \cup g^{-1}(F)$ $=C \cup D$ where $C = f^{-1}(F)$ and $D = g^{-1}(F)$. But C is g^*b-closed in A and A is g^*b-closed in X and so C is g^*b-closed in X. Since we have proved that if $B \subseteq A \subseteq X$, B is g^*b-closed in A and A is g^*b-closed in X then B is g^*b-closed in X. Also $C \cup D$ is g^*b-closed in X. Therefore $\alpha^{-1}(F)$ is g^*b-closed in X. Hence α is g^*b-continuous.

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