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Original Article

On Generalization Of Generalized Star Generalized Continuous Function In Topological Spaces

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ABSTRACT

In this paper we defined and study a new class of continuous function namely generalization of generalized star generalized continuous function (briefly $(gg)^{*}g$-contionuous function) in topological spaces and further we studied the concept of $(gg)^{*}g$ – continuous function and some of its aspects are investigated.

Keywords: $(gg)^{*}g$ - closed sets, $(gg)^{*}g$ - continuous function.

INTRODUCTION

In this paper our aim is to study a based on $(gg)^{*}g$-continuous function. The family of continuous function plays an important role in topology. Observing these, Csaszar introduced the concept of generalized open sets [10]. In 1970, Levin [29] introduced the concept of generalized closed sets and discussed about the properties of sets, closed and open maps, normal and separation axioms, compactness. In 1982, Malghan [22] introduced and studied the concept of generalized closed maps. In 2017, Basavaraj M. Ittanagi and H.G Govardhana Reddy [3] introduced gg-closed sets in topological spaces. In 2018, I. Christal Bai and T. Shyla Isac Mary [9] introduced $(gg)^{*}$- closed sets in topological spaces. In 2026, X. Josphine Selva Rani and T. Shyla Isac Mary [20] introduced $(gg)^{*}g$ – closed sets in topological spaces. The aim of this paper is to be continue the study of $(gg)^{*}g$ – continuous function and analyzed the different aspects.

PRELIMINARIES

Throughout this paper always means the topological spaces (X,τ) and (Y,σ) on which no separation axioms are assumed unless explicitly stated. For a subset A of a topological space (X,τ), the closure of A and the interior of A are denoted by cl(A) and int(A) respectively, A^{c} denotes the compliment of A in (X,τ).

Definition:1

The closure of a subset A of a topological space (X, τ) is the smallest closed set containing A is denoted by $cl(A)$.

The generalized closure (briefly g - closure) of a subset A of a topological space (X, τ) is the smallest g - closed set containing A is denoted by $gcl(A)$.

Definition:2

Generalized - closed set (briefly g - closed) if $cl(A)\subseteq U$ [29] whenever $A\subseteq U$ and U is open in X.

Generalization of generalized closed set (briefly gg - closed) if $gcl(A)\subseteq U$ [3] whenever $A \subseteq U$ and U is regular semi - open in X.

Generalization of generalized star closed set (briefly $(gg)*$ - closed) if $rcl(A)\subseteq U$ [9] whenever $A \subseteq U$ and U is gg - open in X.

Generalization of generalized star generalized closed set (briefly $(gg)^{*}g$ - closed) if $gcl(A)\subseteq U$ [20] whenever $A\subseteq U$ and U is $(gg)^{*}$- open in (X, τ).

Definition:3

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A function $f: (X, \tau) \rightarrow (Y, \sigma)$ is called

(i) Continuous [30] if the inverse image of every closed set V in (Y, σ) is closed in (X, τ).

(ii) regular continuous [31] if the inverse image of every closed set V in (Y, σ) is regular closed in (X, τ).

(iii) π - continuous function [14] if the inverse image of every closed set V in (Y, σ) is π - closed in (X, τ).

(iv) g^* - continuous function [32] if the inverse image of every closed set V in (Y, σ) is g^* - closed in (X, τ).

(v) $(g\alpha r)^{**}$ - continuous function [39] if the inverse image of every closed set V in (Y, σ) is $(g\alpha r)^{**}$ - closed in (X, τ).

(vi) gr^* - continuous function [17] if the inverse image of every closed set V in (Y, σ) is gr^* - closed in (X, τ).

(vii) $(gg)^*$ - continuous function [9] if the inverse image of every closed set V in (Y, σ) is $(gg)^*$- closed in (X, τ).

(viii) $r\beta$- continuous function [23] if the inverse image of every closed set V in (Y, σ) is $r\beta$- closed in (X, τ).

(ix) gp^* - continuous function [18] if the inverse image of every closed set V in (Y, σ) is gp^* - closed in (X, τ).

(x) $(gsp)^*$ - continuous function [33] if the inverse image of every closed set V in (Y, σ) is $(gsp)^*$ - closed in (X, τ).

(xi) $g^\#$ - continuous function [4] if the inverse image of every closed set V in (Y, σ) is $g^\#$ - closed in (X, τ).

(xii) $(gs)^*$ - continuous function [1] if the inverse image of every closed set V in (Y, σ) is $(gs)^*$- closed in (X, τ).

(xiii) g^*sr - continuous function [43] if the inverse image of every closed set V in (Y, σ) is g^*sr - closed in (X, τ).

(xiv) r^*g^* - continuous function [27] if the inverse image of every closed set V in (Y, σ) is r^*g^* - closed in (X, τ).

(xv) $(g^*p)^*$ - continuous function [34] if the inverse image of every closed set V in (Y, σ) is $(g^*p)^*$ - closed in (X, τ).

(xvi) $r^\wedge g - continuous$ function [37] if the inverse image of every closed set V in (Y, σ) is $r^\wedge g$ - closed in (X, τ).

(xvii) rwg – continuous function [26] if the inverse image of every closed set V in (Y, σ) is rwg - closed in (X, τ).

(xviii) R^* - Continuous function [4] if the inverse image of every closed set V in (Y, σ) is R^* - closed in (X, τ).

(xix) g^*p – Continuous function [38] if the inverse image of every closed set V in (Y, σ) is g^*p - closed in (X, τ).

(xx) g^*s^* - Continuous function [1] if the inverse image of every closed set V in (Y, σ) is g^*s^* - closed in (X, τ).

(xxi) strongly g^* - Continuous function [32] if the inverse image of every closed set V in (Y, σ) is strongly g^* - closed in (X, τ).

(xxii) g^*s - Continuous function [43] if the inverse image of every closed set V in (Y, σ) is g^*s - closed in (X, τ).

(xxiii) wg - Continuous function [26] if the inverse image of every closed set V in (Y, σ) is wg - closed in (X, τ).

(xxiv) pg - Continuous function [18] if the inverse image of every closed set V in (Y, σ) is pg - closed in (X, τ).

(xxv) ws - Continuous function [12] if the inverse image of every closed set V in (Y, σ) is ws - closed in (X, τ).

(xxvi) gp - Continuous function [13] if the inverse image of every closed set V in (Y, σ) is gp - closed in (X, τ).

(xxvii) αg - Continuous function [24] if the inverse image of every closed set V in (Y,σ) is αg - closed in (X,τ).

(xxviii) gs - Continuous function [36] if the inverse image of every closed set V in (Y,σ) is gs - closed in (X,τ).

(xxix) gsp - Continuous function [33] if the inverse image of every closed set V in (Y,σ) is gsp - closed in (X,τ).

(xxx) sg - Continuous function [24] if the inverse image of every closed set V in (Y,σ) is sg - closed in (X,τ).

(xxxi) $g\alpha$ - Continuous function [21] if the inverse image of every closed set V in (Y,σ) is $g\alpha$ - closed in (X,τ).

(xxxii) α - Continuous function [42] if the inverse image of every closed set V in (Y,σ) is α - closed in (X,τ).

(xxxiii) b - Continuous function [11] if the inverse image of every closed set V in (Y,σ) is b - closed in (X,τ).

(xxxiv) $semi$ - Continuous function [8] if the inverse image of every closed set V in (Y,σ) is $semi$ - closed in (X,τ).

(xxxv) gb - Continuous function [40] if the inverse image of every closed set V in (Y,σ) is gb - closed in (X,τ).

(xxxvi) gb^* - Continuous function [45] if the inverse image of every closed set V in (Y,σ) is gb^* - closed in (X,τ).

(xxxvii) $g^{\wedge *}s$ - Continuous function [1] if the inverse image of every closed set V in (Y,σ) $g^{\wedge *}s$ - closed in (X,τ).

1. On Generalization of Generalized star generalized continuous function in Topological Spaces

Definition:1.1

A function $f:(X,\tau)\to(Y,\sigma)$ is called $(gg)^*g$-continuous if the inverse image of every closed set V in (Y,σ) is $(gg)^*g$ - closed set in (X,τ).

Proposition:1.2

Every continuous function is $(gg)^*g$ - continuous function.

Proof:

Let $f:(X,\tau)\to(Y,\sigma)$ be a continuous function and let V be a closed set in (Y,σ).

Since f is continuous, then by Definition 3[i], $f^{-1}(V)$ is closed in (X,τ). By Proposition 3.3[20], every closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$-continuous function.

Remark: The converse part of the above proposition need not be true as shown in the following example.

Example:1.3

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{a\},\{b\},\{a,b\},X\}$, $\sigma=\{\varphi,\{c,d\},\{a,c\},Y\}$

and $\tau_c=\{\varphi,\{b,c,d\},\{a,c,d\},\{c,d\},X\}$. A function $f:(X,\tau)\to(Y,\sigma)$ is defined by $f(a)=c, f(b)=a, f(c)=b, f(d)=d$. f is $(gg)^*g$ – continuous function but not continuous function, because for closed set V = $\{c,d\}$ in (Y,σ), $f^{-1}(V)=\{a,d\}$, $\{a,d\}$ is not closed in (X,τ).

Proposition:1.4

Let $f:(X,\tau)\to(Y,\sigma)$ be a function

(i) Every regular continuous function is $(gg)^*g$-continuous function.

(ii) Every π - continuous function is $(gg)^*g$-continuous function.

(iii) Every g^* - continuous function is $(gg)^*g$-continuous function.

(iv) Every $(g\alpha r)^{**}$ - continuous function is $(gg)^*g$- continuous function.

(v) Every $(gr)^*$ - continuous function is $(gg)^*g$-continuous function.

(vi) Every $(gg)^*$ - continuous function is $(gg)^*g$- continuous function.

(vii) Every $r\beta$- continuous function is $(gg)^*g$- continuous function.

(viii) Every gp^* - continuous function is $(gg)^*g$- continuous function.

(ix) Every $(gsp)^*$ - continuous function is $(gg)^*g$- continuous function.

(x) Every $g^\#$ - continuous function is $(gg)^*g$- continuous function.

(xi) Every $(gs)^*$ - continuous function is $(gg)^*g$- continuous function.

(xii) Every g^*sr - continuous function is $(gg)^*g$- continuous function.

(xiii) Every r^*g^* - continuous function is $(gg)^*g$- continuous function.

(xiv) Every $(g^*p)^*$ - continuous function is $(gg)^*g$- continuous function.

Proof:

(i) Let $f:(X,\tau)\to(Y,\sigma)$ be a regular continuous function and let V be a

closed set in (X,τ). Since f is regular continuous function, then by Definition 3[ii], $f^{-1}(V)$ is regular closed in (X,τ). By Proposition 3.3[20], every regular closed set is $(gg)^*g$ - closed. Then $f^{-1}(V)$ is $(gg)^*g$ – closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(ii) Let $f:(X,\tau)\to(Y,\sigma)$ be a π - continuous function and let V be a

closed set in (X,τ). Since f is π - continuous function, then by Definition 3[iii], $f^{-1}(V)$ is a π - closed in (X,τ). By Proposition 3.3[20], every π - closed set is $(gg)^*g$ - closed. Then $f^{-1}(V)$ is $(gg)^*g$ – closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(iii) Let $f:(X,\tau)\to(Y,\sigma)$ be a g^*- continuous function and let V be a

closed set in (Y,σ). Since f is g^*-continuous, then by Definition 3[iv], $f^{-1}(V)$ is g^*-closed in (X,τ). By Proposition 3.3[20], every g^*- closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(iv) Let $f:(X,\tau)\to(Y,\sigma)$ be a $(g\alpha r)^{**}-$ continuous function and let V

be a closed set in (X,σ). Since f is $(g\alpha r)^{**}$- continuous, then by Definition 3[v], $f^{-1}(V)$ is $(g\alpha r)^{**}-$closed in (X,τ). By Proposition 3.3[20], every $(g\alpha r)^{**}-$closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(v) Let $f:(X,\tau)\to(Y,\sigma)$ be a $(gr)^*-$ continuous function and let V be a

closed set in (Y,σ). Since f is $(gr)^*-$continuous, then by Definition 3[vi], $f^{-1}(V)$ is $(gr)^*-$closed in (X,τ). By Proposition 3.3[20], every $(gr)^*-$closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(vi) Let $f:(X,\tau)\to(Y,\sigma)$ be a $(gg)^*-$ continuous function and let V be a

closed set in (Y,σ). Since f is $(gg)^*-$continuous, then by Definition 3[vii], $f^{-1}(V)$ is $(gg)^*-$closed in (X,τ). By Proposition 3.3[20], every $(gg)^*-$closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(vii) Let $f:(X,\tau)\to(Y,\sigma)$ be a $r\beta$ - continuous function and let V be a

closed set in (Y,σ). Since f is $r\beta$ – continuous, then by Definition 3[viii], $f^{-1}(V)$ is $r\beta$- closed in (X,τ). By Proposition 3.3[20], every $r\beta$ - closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(viii) Let $f:(X,\tau)\to(Y,\sigma)$ be a gp^*- continuous function and let V be a

closed set in (Y,σ). Since f is gp^*- continuous, then by Definition 3[ix], $f^{-1}(V)$ is gp^* - closed in (X,τ).

By Proposition 3.3[20], every gp^*- closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(ix) Let $f:(X,\tau)\to(Y,\sigma)$ be a $(gsp)^*$- continuous function and let V be a

closed set in (Y,σ). Since f is $(gsp)^*$- continuous, then by Definition 3[x], $f^{-1}(V)$ is $(gsp)^*$- closed in (X,τ). By Proposition 3.3[20], every $(gsp)^*$- closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By definition 1.1, f is $(gg)^*g$- continuous function.

(x) Let $f:(X,\tau)\to(Y,\sigma)$ be a $g^\#$- continuous function and let V be a

closed set in (Y,σ). Since f is $g^\#$- continuous, then by Definition 3[xi], $f^{-1}(V)$ is $g^\#$- closed in (X,τ). By Proposition 3.3[20], every $g^\#$- closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(xi) Let $f:(X,\tau)\to(Y,\sigma)$ be a $(gs)^*$- continuous function and let V be a

closed set in (Y,σ). Since f is $(gs)^*$ - continuous, then by Definition 3[xii], $f^{-1}(V)$ is $(gs)^*$ - closed in (X,τ). By Proposition 3.3[20], every $(gs)^*$ - closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(xii) Let $f:(X,\tau)\to(Y,\sigma)$ be a g^*sr - continuous function and let V be a

closed set in (Y,σ). Since f is g^*sr – continuous, then by Definition 3[xiii], $f^{-1}(V)$ is g^*sr - closed in (X,τ). By Proposition 3.3[20], every g^*sr - closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(xiii) Let $f:(X,\tau)\to(Y,\sigma)$ be a r^*g^*- continuous function and let V be a

closed set in (Y,σ). Since f is r^*g^*- continuous, then by Definition 3[xiv], $f^{-1}(V)$ is r^*g^*- closed in (X,τ). By proposition 3.3[20], every r^*g^*- closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

(xiv) Let $f:(X,\tau)\to(Y,\sigma)$ be a $(g^*p)^*$- continuous function and let V be a

closed set in (Y,σ). Since f is $(g^*p)^*$- continuous then by Definition 3[xv], $f^{-1}(V)$ is $(g^*p)^*$- closed in (X,τ). By proposition 3.3[20], every $(g^*p)^*$- closed set is $(gg)^*g$ - closed. So $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

Remark: The converse of the above proposition need not be true as shown in the following examples.

Example:1.5

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{c\},\{d\},\{c,d\},\{a,c,d\},X\}$, $\sigma=\{\varphi,\{d\},\{a,c\},Y\}$

and $\tau_c=\{\varphi,\{a,b,d\},\{a,b,c\},\{a,b\},\{b\},X\}$. A function $f:(X,\tau)\to(Y,\sigma)$ is defined by $f(a)=a,f(b)=d,f(c)=b,f(d)=c$. f is $(gg)^*g$ – continuous function but not regular continuous function, because for closed set V = $\{a,b,c\}$ in (Y,σ), $f^{-1}(V)=\{a,c,d\}$, $\{a,c,d\}$ is not regular closed in (X,τ).

Example:1.6

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{a\},\{b\},\{a,b\},X\}$, $\sigma=\{\varphi,\{c,d\},\{a,c\},Y\}$

and $\tau_c=\{\varphi,\{b,c,d\},\{a,c,d\},\{c,d\},X\}$. An identity function $f:(X,\tau)\to(Y,\sigma)$ is defined by $f(a)=a,f(b)=b,f(c)=c,f(d)=d$. By f is $(gg)^*g$ – continuous function but not π *and* g^*- continuous function, because for closed set V = $\{a,d\}$ in (Y,σ), $f^{-1}(V)=\{a,d\}$, $\{a,d\}$ is not π *and* g^*- closed in (X,τ).

Example:1.7

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{c\},\{d\},\{c,d\},\{a,c,d\},X\}$,

$\sigma=\{\varphi,\{a\},\{a,b\},\{b,c,d\},Y\}$ and $\tau_c=\{\varphi,\{a,b,d\},\{a,b,c\},\{a,b\},\{b\},X\}$.

A function $f:(X,\tau)\to(Y,\sigma)$ is defined by $f(a)=b,f(b)=d,f(c)=b,f(d)=c$. f is $(gg)^*g$ – continuous function but not $(gar)^{**}$- continuous function, because for closed set V = $\{a,b,c\}$ in (Y,σ), $f^{-1}(V)=\{b,c,d\}$, $\{b,c,d\}$ is not $(g\alpha r)^{**}$- closed in (X,τ).

Example:1.8

Let $X=Y=\{a,b,c\}$, $\tau=\{\varphi,\{b\},\{a,c\},X\}$, $\sigma=\{\varphi,\{b\},Y\}$, $\tau_c=\{\varphi,\{b\},\{b,c\},X\}$.

A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=b, f(b)=a, f(c)=b, f(c)=c$. By f is $(gg)^*g-$continuous function but not $(gr)^*$ and r^*g^*-continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V)=\{a\}$, $\{a\}$ is not $(gr)^*$ and r^*g^*-closed in (X,τ).

Example:1.9

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{c\},\{d\},\{c,d\},\{a,c,d\},X\}$, $\sigma=\{\varphi,\{a\},\{a,b\},Y\}$

and $\tau_c=\{\varphi,\{a,b,d\},\{a,b,c\},\{a,b\},\{b\},X\}$. A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=c, f(b)=d, f(c)=a, f(d)=b$. f is $(gg)^*g-$continuous function but not $(gg)^*$- continuous function, because for closed set V = $\{a,b\}$ in (Y,σ), $f^{-1}(V)=\{c,d\}$, $\{c,d\}$ is not $(gg)^*$- closed in (X,τ).

Example:1.10

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{b\},\{c\},\{a,b\},\{b,c\},\{b,c,d\},X\}$,

$\sigma=\{\varphi,\{a\},\{b\},Y\}$ and $\tau_c=\{\varphi,\{a,b,d\},\{a,b,c\},\{a,b\},\{b\},X\}$. A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=b, f(b)=d, f(c)=b, f(d)=c$. f is $(gg)^*g-$continuous function but not $r\beta$- continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V)=\{a\}$, $\{a\}$ is not $r\beta$- closed in (X,τ).

Example:1.11

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{b\},\{c\},\{a,b\},\{b,c\},\{b,c,d\},X\}$,

$\sigma=\{\varphi,\{a\},\{d\},\{c,d\},Y\}$, $\tau_c=\{\varphi,\{a,b,d\},\{a,b,c\},\{a,b\},\{b\},X\}$. A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=c, f(b)=d, f(c)=b, f(d)=a$. f is $(gg)^*g$ - continuous function but not gs^*, gp^*, g^*sr and $(gsp)^*$-continuous function, because for closed set V = $\{c,d\}$ in (Y,σ), $f^{-1}(V)=\{a,b\}$, $\{a,b\}$ is not gs^*, gp^*, g^*sr and $(gsp)^*$- closed in (X,τ).

Example:1.12

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{b\},\{c\},\{b,c\},\{b,c,d\},X\}$,

$\sigma=\{\varphi,\{a\},\{c,d\},\{a,c,d\},Y\}$, $\tau_c=\{\varphi,\{a,c,d\},\{a,b,d\},\{a,d\},\{a\},X\}$. A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=a, f(b)=d, f(c)=c, f(d)=b$. f is $(gg)^*g$ - continuous function but not $g^\#$ and $(g^*p)^*$- continuous function, because for closed set V = $\{c,d\}$ in (Y,σ), $f^{-1}(V)=\{a,b\}$, $\{a,b\}$ is not $g^\#$ and $(g^*p)^*$- closed in (X,τ).

Proposition:1.13

Let $f:(X,\tau)\rightarrow(Y,\sigma)$ be a function

(i) Every $(gg)^*g$ - continuous function is $r^\wedge g-continuous$.

(ii) Every $(gg)^*g$ - continuous function is rwg - continuous.

Proof:

(i) Let $f:(X,\tau)\rightarrow(Y,\sigma)$ be a $(gg)^*g$-continuous function and let V be a

closed set in (Y,σ). Since f is $(gg)^*g-$continuous, then by Definition 3[xvi], $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Proposition 3.3[20], every $(gg)^*g$ - closed set is $r^\wedge g$ - closed. So $f^{-1}(V)$ is $r^\wedge g$ - closed in (X,τ). By Definition 1.1, f is $r^\wedge g$ -continuous function.

(ii) Let $f:(X,\tau)\rightarrow(Y,\sigma)$ be a $(gg)^*g$-continuous function and let V be a

closed set in (Y,σ). Since f is $(gg)^*g-$continuous, then by Definition 3[xvii], $f^{-1}(V)$ is $(gg)^*g$ - closed in (X,τ). By Proposition 3.3[20], every $(gg)^*g$ - closed set is rwg - closed. So $f^{-1}(V)$ is rwg - closed in (X,τ). By Definition 1.1, f is rwg -continuous function.

Remark: The converse part of the proposition need not be true as shown in the following examples.

Example:1.14

Let $X = Y = \{a, b, c, d\}$, $\tau = \{\varphi, \{b\}, \{c\}, \{b, c\}, \{b, c, d\}, X\}$,

$\sigma = \{\varphi, \{b\}, \{a, b\}, \{a, b, c\}, \{a, c, d\}, Y\}$, $\tau_c = \{\varphi, \{a, c, d\}, \{a, b, d\}, \{a, d\}, \{a\}, X\}$,

A function $f: (X, \tau) \to (Y, \sigma)$ is defined by $f(a) = d, f(b) = b, f(c) = a, f(d) = c$. f is $r^\wedge g$ - continuous function but not $(gg)^* g$ - continuous function, because for closed set V = $\{a, b\}$ in (Y, σ), $f^{-1}(V) = \{b, c\}$, $\{b, c\}$ is not $(gg)^* g$ - closed in (X, τ).

Example:1.15

Let $X = Y = \{a, b, c, d\}$, $\tau = \{\varphi, \{b\}, \{c\}, \{b, c\}, \{b, c, d\}, X\}$,

$\sigma = \{\varphi, \{a\}, \{a, b\}, \{a, b, c\}, Y\}$, $\tau_c = \{\varphi, \{a, c, d\}, \{a, b, d\}, \{a, d\}, \{a\}, X\}$. A function $f: (X, \tau) \to (Y, \sigma)$ is defined by $f(a) = b, f(b) = c, f(c) = d, f(d) = a$. f is $r^\wedge g$ - continuous function but not $(gg)^* g$ - continuous function, because for closed set V = $\{a\}$ in (Y, σ), $f^{-1}(V) = \{d\}$, $\{d\}$ is not $(gg)^* g$ - closed in (X, τ).

2. Independent set of $(gg)^* g$ - continuous functions with other continuous function

The following example shows that the concept of $(gg)^* g$ - continuous function is independent from R^* - Continuous, $g^* p$ - Continuous, $g^* s^*$ - Continuous, strongly g^* - Continuous, $g^* s$ - Continuous, wg - Continuous, pg - Continuous, ws - Continuous, gp - Continuous, αg - Continuous, gs - Continuous, gsp - Continuous, sg - Continuous, $g\alpha$ - Continuous, α - Continuous, b - Continuous, $semi$ - Continuous, gb - Continuous, gb^* - Continuous, $g^{\wedge *} s$ - Continuous.

Example:2.1

Let $X = Y = \{a, b, c, d\}$, $\tau = \{\varphi, \{a\}, \{c\}, \{a, c\}, \{c, d\}, \{a, c, d\}, X\}$,

$\sigma = \{\varphi, \{b\}, \{a, b\}, \{a, b, c\}, \{a, c, d\}, Y\}$, $\tau_c = \{\varphi, \{b, c, d\}, \{a, b, d\}, \{b, d\}, \{a, b\}, \{b\}, X\}$.

A function $f: (X, \tau) \to (Y, \sigma)$ is defined by $f(a) = a, f(b) = c, f(c) = b, f(d) = d$.

f is R^* - continuous function but not $(gg)^* g$ - continuous function, because for closed set V = $\{a, b\}$ in (Y, σ), $f^{-1}(V) = \{a, c\}$, $\{a, c\}$ is not $(gg)^* g$ - closed in (X, τ).

A function $f: (X, \tau) \to (Y, \sigma)$ is defined by $f(a) = d, f(b) = b, f(c) = a, f(d) = c$.

f is $(gg)^* g$ - continuous function but not R^* - continuous function, because for closed set V = $\{a, b\}$ in (Y, σ), $f^{-1}(V) = \{b, c\}$, $\{b, c\}$ is not R^* - closed in (X, τ).

Example:2.2

Let $X = Y = \{a, b, c, d\}$, $\tau = \{\varphi, \{c\}, \{d\}, \{c, d\}, \{a, c, d\}, X\}$,

$\sigma = \{\varphi, \{d\}, \{a, d\}, \{a, c, d\}, Y\}$, $\tau_c = \{\varphi, \{a, b, d\}, \{a, b, c\}, \{a, b\}, \{b\}, X\}$.

An identity function $f: (X, \tau) \to (Y, \sigma)$ is defined by $f(a) = a, f(b) = b, f(c) =$

$c, f(d) = d$. f is $(gg)^* g$ - continuous function but not $g^* p$ - continuous

function, because for closed set V = $\{a, c, d\}$ in (Y, σ), $f^{-1}(V) = \{a, c, d\}$. $\{a, c, d\}$ is not $g^* p$ - closed in (X, τ).

A function $f: (X, \tau) \to (Y, \sigma)$ is defined by $f(a) = d, f(b) = b, f(c) = c, f(d) = a$.

f is $g^* p$ - continuous function but not $(gg)^* g$ - continuous function, because for closed set V = $\{d\}$ in (Y, σ), $f^{-1}(V) = \{a\}$, $\{a\}$ is not $(gg)^* g$ - closed in (X, τ).

Example:2.3

Let $X = Y = \{a, b, c, d\}$, $\tau = \{\varphi, \{b\}, \{c\}, \{b, c\}, \{b, c, d\}, X\}$,

$\sigma = \{\varphi, \{a\}, \{d\}, \{a, b, c\}, Y\}$, $\tau_c = \{\varphi, \{a, c, d\}, \{a, b, d\}, \{a, d\}, \{a\}, X\}$.

A function $f: (X, \tau) \to (Y, \sigma)$ is defined by $f(a) = d, f(b) = a, f(c) = b, f(d) = c$.

f is $(gg)^* g$ - continuous function but not $g^* s^*$ - continuous function, because for closed set V = $\{a, b, c\}$ in (Y, σ), $f^{-1}(V) = \{b, c, d\}$. $\{b, c, d\}$ is not $g^* s^*$ - closed in (X, τ).

A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=b, f(b)=d, f(c)=c, f(d)=a$.

f is g^*s^* - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{d\}$ in (Y,σ), $f^{-1}(V)=\{b\}$, $\{b\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.4

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{c\},\{d\},\{c,d\},\{a,c,d\},X\}$,

$\sigma=\{\varphi,\{c\},\{a,b,c\},Y\}$, $\tau_c=\{\varphi,\{a,b,d\},\{a,b,c\},\{a,b\},\{b\},X\}$.

A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=a, f(b)=d, f(c)=c, f(d)=b$.

f is $(gg)^*g$ - continuous function but not strongly g^* - continuous function, because for closed set V = $\{a,b,c\}$ in (Y,σ), $f^{-1}(V)=\{a,c,d\}$. $\{a,c,d\}$ is not strongly g^* - closed in (X,τ).

A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=c, f(b)=d, f(c)=b, f(d)=a$.

f is strongly g^* - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{c\}$ in (Y,σ), $f^{-1}(V)=\{a\}$, $\{a\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.5

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{b\},\{c\},\{b,c\},\{b,c,d\},X\}$,

$\sigma=\{\varphi,\{b\},\{a,d\},\{a,b,d\},Y\}$, $\tau_c=\{\varphi,\{a,c,d\},\{a,b,d\},\{a,d\},\{a\},X\}$.

A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=a, f(b)=b, f(c)=d, f(d)=c$.

f is $(gg)^*g$ - continuous function but not g^*s - continuous function, because for closed set V = $\{a,b,d\}$ in (Y,σ), $f^{-1}(V)=\{a,b,c\}$. $\{a,b,c\}$ is not g^*s - closed in (X,τ).

A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=c, f(b)=d, f(c)=b, f(d)=a$.

f is g^*s - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V)=\{c\}$, $\{c\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.6

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{c\},\{d\},\{c,d\},\{a,c,d\},X\}$,

$\sigma=\{\varphi,\{b\}\{a,c,d),Y\}$, $\tau_c=\{\varphi,\{a,b,d\},\{a,b,c\},\{a,b\},\{b\},X\}$.

A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=b, f(b)=a, f(c)=c, f(d)=d$.

f is $(gg)^*g$ - continuous function but not wg - continuous function, because for closed set V = $\{a,c,d\}$ in (Y,σ), $f^{-1}(V)=\{b,c,d\}$. $\{b,c,d\}$ is not wg - closed in (X,τ).

A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=b, f(b)=d, f(c)=c, f(d)=a$.

f is wg - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V)=\{a\}$, $\{a\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.7

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{b\},\{c\},\{a,b\},\{b,c\},\{b,c,d\},X\}$,

$\sigma=\{\varphi,\{d\},\{a,d\},Y\}$, $\tau_c=\{\varphi,\{a,c,d\},\{a,b,d\},\{c,d\}\{a,d\},\{a\},X\}$.

A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=a, f(b)=d, f(c)=b, f(d)=c$.

f is $(gg)^*g$ - continuous function but not pg - continuous function, because for closed set V = $\{a,d\}$ in (Y,σ), $f^{-1}(V)=\{a,b\}$. $\{a,b\}$ is not pg - closed in (X,τ).

Let $X=Y=\{a,b,c,d\}$, $\tau=\{\varphi,\{c\},\{d\},\{c,d\},\{a,c,d\},X\}$,

$\sigma=\{\varphi,\{d\},\{a,d\},Y\}$, $\tau_c=\{\varphi,\{a,c,d\},\{a,b,c\},\{a,b\},\{b\},X\}$.

A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is defined by $f(a)=c, f(b)=b, f(c)=b, f(d)=d$.

f is pg - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{d\}$ in (Y,σ), $f^{-1}(V) = \{d\}$, $\{d\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.8

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{b\},\{c\},\{b,c\},\{b,c,d\},X\}$,

$\sigma = \{\varphi,\{a\}\{b,c,d),Y\}$, $\tau_c = \{\varphi,\{a,b,d\},\{a,b,c\},\{a,b\},\{b\},X\}$.

An identity function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = a, f(b) = b, f(c) =$

$c, f(d) = d$. f is $(gg)^*g$ - continuous function but not ws - continuous function, because for closed set V = $\{b,c,d\}$ in (Y,σ), $f^{-1}(V) = \{b,c,d\}$. $\{b,c,d\}$ is not ws - closed in (X,τ).

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = c, f(b) = b, f(c) = a, f(d) = d$.

f is ws - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{a\}$ in (Y,σ), $f^{-1}(V) = \{c\}$, $\{c\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.9

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{b\},\{c\},\{a,b\},\{b,c\},\{b,c,d\},X\}$,

$\sigma = \{\varphi,\{b\},Y\}$, $\tau_c = \{\varphi,\{a,c,d\},\{a,b,d\},\{c,d\}\{a,d\},\{a\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = d, f(b) = a, f(c) = b, f(d) = c$.

f is $(gg)^*g$ - continuous function but not gp - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V) = \{c\}$. $\{c\}$ is not gp - closed in (X,τ).

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{c\},\{d\},\{c,d\},\{a,c,d\},X\}$,

$\sigma = \{\varphi,\{b\},\{a,d\},Y\}$, $\tau_c = \{\varphi,\{a,c,d\},\{a,b,c\},\{a,b\},\{b\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = b, f(b) = d, f(c) = a, f(d) = c$.

f is gp - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V) = \{a\}$, $\{a\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.10

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{b\},\{c\},\{a,b\},\{b,c\},\{b,c,d\},X\}$,

$\sigma = \{\varphi,\{b\},\{d\},\{b,d\},\{b,c,d\},Y\}$, $\tau_c = \{\varphi,\{a,c,d\},\{a,b,d\},\{c,d\}\{a,d\},\{a\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = d, f(b) = b, f(c) = c, f(d) = a$.

f is $(gg)^*g$ - continuous function but not αg - continuous function, because for closed set V = $\{b,d\}$ in (Y,σ), $f^{-1}(V) = \{a,b\}$. $\{a,b\}$ is not αg - closed in (X,τ).

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{c\},\{d\},\{c,d\},\{a,c,d\},X\}$,

$\sigma = \{\varphi,\{b\},\{b,d\},Y\}$, $\tau_c = \{\varphi,\{a,c,d\},\{a,b,c\},\{a,b\},\{b\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = b, f(b) = a, f(c) = c, f(d) = d$.

f is αg - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V) = \{a\}$, $\{a\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.11

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{b\},\{c\},\{a,b\},\{b,c\},\{b,c,d\},X\}$,

$\sigma = \{\varphi,\{b\},\{d\},\{b,d\},Y\}$, $\tau_c = \{\varphi,\{a,c,d\},\{a,b,d\},\{c,d\}\{a,d\},\{a\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = d, f(b) = b, f(c) = a, f(d) = c$.

f is $(gg)^*g$ - continuous function but not gs - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V) = \{b\}$. $\{b\}$ is not gs - closed in (X,τ).

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = b, f(b) = d, f(c) = c, f(d) = a$.

f is gs - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{b,d\}$ in (Y,σ), $f^{-1}(V) = \{a,b\}$, $\{a,b\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.12

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{b\},\{c\},\{a,b\},\{b,c\},\{b,c,d\},X\}$,

$\sigma = \{\varphi,\{b\},\{b,c,d\},Y\}$, $\tau_c = \{\varphi,\{a,c,d\},\{a,b,d\},\{c,d\}\{a,d\},\{a\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = b, f(b) = a, f(c) = c, f(d) = d$.

f is $(gg)^*g$ - continuous function but not gsp - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V) = \{a\}$. $\{a\}$ is not gsp - closed in (X,τ).

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{b\},\{c\},\{b,c\},\{b,c,d\},X\}$,

$\sigma = \{\varphi,\{b\},\{b,d\},Y\}$, $\tau_c = \{\varphi,\{a,c,d\},\{a,b,d\},\{a,d\},\{a\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = c, f(b) = b, f(c) = a, f(d) = d$.

f is αg - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V) = \{b\}$, $\{b\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.13

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{b\},\{c\},\{b,c\},\{b,c,d\},X\}$,

$\sigma = \{\varphi,\{a\},\{a,b,c\},Y\}$, $\tau_c = \{\varphi,\{a,c,d\},\{a,b,d\},\{a,d\},\{a\},X\}$.

An identity function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = a, f(b) = b, f(c) =$

$c, f(d) = d$. f is $(gg)^*g$ - continuous function but not sg- continuous function, because for closed set V = $\{a,b,c\}$ in (Y,σ), $f^{-1}(V) = \{a,b,c\}$. $\{a,b,c\}$ is not sg - closed in (X,τ).

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = c, f(b) = d, f(c) = a, f(d) = b$.

f is sg - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{a\}$ in (Y,σ), $f^{-1}(V) = \{c\}$, $\{c\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.14

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{a\},\{c\},\{a,c\},\{c,d\},\{a,c,d\},X\}$,

$\sigma = \{\varphi,\{b\},\{b,c\}\{b,c,d),Y\}$, $\tau_c = \{\varphi,\{b,c,d\},\{a,b,d\},\{b,d\},\{a,b\},\{b\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = b, f(b) = c, f(c) = a, f(d) = d$.

f is $(gg)^*g$ - continuous function but not $g\alpha$ - continuous function, because for closed set V = $\{b,c\}$ in (Y,σ), $f^{-1}(V) = \{a,b\}$. $\{a,b\}$ is not $g\alpha$ - closed in (X,τ).

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = c, f(b) = d, f(c) = a, f(d) = b$.

f is $g\alpha$ - continuous function but not $(gg)^*g$ - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V) = \{d\}$, $\{d\}$ is not $(gg)^*g$ - closed in (X,τ).

Example:2.15

Let $X = Y = \{a,b,c\}$, $\tau = \{\varphi,\{b\},\{a,c\},X\}$,

$\sigma = \{\varphi,\{a\},\{a,b\},Y\}$, $\tau_c = \{\varphi,\{a,c\},\{b\},X\}$,

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = c, f(b) = b, f(c) = a$.

f is $(gg)^*g$ - continuous function but not α - continuous function, because for closed set V = $\{a,b\}$ in (Y,σ), $f^{-1}(V) = \{b,c\}$. $\{b,c\}$ is not α - closed in (X,τ).

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{b\},\{c\},\{b,c\},\{b,c,d\},X\}$,

$\sigma = \{\varphi,\{a\},\{b,d\},Y\}$, $\tau_c = \{\varphi,\{a,c,d\},\{a,b,d\},\{a,d\},\{a\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = d, f(b) = c, f(c) = b, f(d) = a$.

f is α - continuous function but not $(gg)^{*}g$ - continuous function, because for closed set V = $\{a\}$ in (Y,σ), $f^{-1}(V) = \{d\}$, $\{d\}$ is not $(gg)^{*}g$ - closed in (X,τ).

Example:2.16

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{c\},\{d\},\{c,d\},\{a,c,d\},X\}$,

$\sigma = \{\varphi,\{b\},\{a,b\},\{b,c,d\},Y\}$, $\tau_c = \{\varphi,\{a,b,d\},\{a,b,c\},\{a,b\},\{b\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = b, f(b) = a, f(c) = c, f(d) = d$.

f is $(gg)^{*}g$ - continuous function but not b - continuous function, because for closed set V = $\{b,c,d\}$ in (Y,σ), $f^{-1}(V) = \{a,c,d\}$. $\{b,c,d\}$ is not b - closed in (X,τ).

f is b - continuous function but not $(gg)^{*}g$ - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V) = \{a\}$, $\{a\}$ is not $(gg)^{*}g$ - closed in (X,τ).

Example:2.17

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{a\},\{c\},\{a,c\},\{c,d\},\{a,c,d\},X\}$,

$\sigma = \{\varphi,\{a\},\{b,c\},Y\}$, $\tau_c = \{\varphi,\{b,c,d\},\{a,b,d\},\{b,d\},\{a,b\},\{b\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = a, f(b) = c, f(c) = b, f(d) = d$.

f is $(gg)^{*}g$ - continuous function but not semi continuous function, because for closed set V = $\{b,c\}$ in (Y,σ), $f^{-1}(V) = \{b,c\}$. $\{b,c\}$ is not semi closed in (X,τ).

f is semi continuous function but not $(gg)^{*}g$ - continuous function, because for closed set V = $\{a\}$ in (Y,σ), $f^{-1}(V) = \{a\}$, $\{a\}$ is not $(gg)^{*}g$ - closed in (X,τ).

Example:2.18

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{c\},\{d\},\{c,d\},\{a,c,d\},X\}$,

$\sigma = \{\varphi,\{b\}\{b,c,d),Y\}$, $\tau_c = \{\varphi,\{a,b,d\},\{a,b,c\},\{a,b\},\{b\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = c, f(b) = a, f(c) = b, f(d) = d$.

f is $(gg)^{*}g$ - continuous function but not gb^{*} *and* gb continuous function, because for closed set V = $\{b,c,d\}$ in (Y,σ), $f^{-1}(V) = \{a,c,d\}$. $\{a,c,d\}$ is not gb^{*} *and* gb - closed in (X,τ).

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = b, f(b) = d, f(c) = c, f(d) = a$.

f is gb^{*} *and* gb - continuous function but not $(gg)^{*}g$ - continuous function, because for closed set V = $\{b\}$ in (Y,σ), $f^{-1}(V) = \{c\}$, $\{c\}$ is not $(gg)^{*}g$ - closed in (X,τ).

Example:2.19

Let $X = Y = \{a,b,c,d\}$, $\tau = \{\varphi,\{b\},\{c\},\{b,c\},\{b,c,d\},X\}$,

$\sigma = \{\varphi,\{a\},\{a,b,d\},Y\}$, $\tau_c = \{\varphi,\{a,c,d\},\{a,b,d\},\{a,d\},\{a\},X\}$.

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = c, f(b) = a, f(c) = b, f(d) = d$.

f is $(gg)^{*}g$ - continuous function but not $g^{\wedge *}s$ - continuous function, because for closed set V = $\{a,b,d\}$ in (Y,σ), $f^{-1}(V) = \{b,c,d\}$. $\{b,c,d\}$ is not $g^{\wedge *}s$ - closed in (X,τ).

A function $f:(X,\tau) \to (Y,\sigma)$ is defined by $f(a) = c, f(b) = a, f(c) = d, f(d) = b$.

f is $g^{\wedge *}s$ - continuous function but not $(gg)^{*}g$ - continuous function, because for closed set V = $\{a\}$ in (Y,σ), $f^{-1}(V) = \{b\}$, $\{b\}$ is not $(gg)^{*}g$ - closed in (X,τ).

Remark: From the above discussion and known results for the relationship between $(gg)^{*}g$ - continuous function and other existing continuous function are established in figure 1.

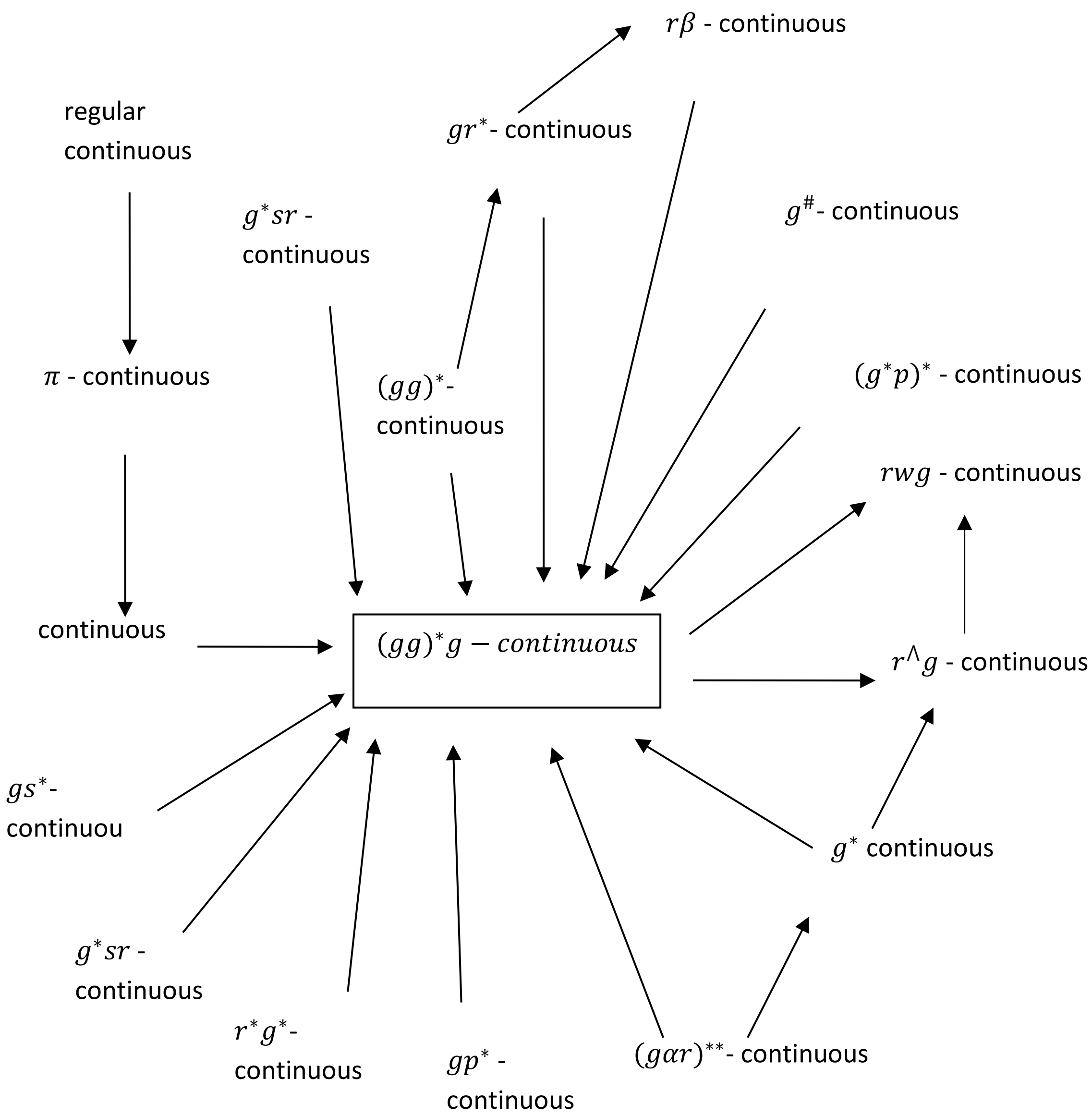

Figure 1

In the Figure 1, $A \rightarrow B$ means the set A implies B, but not conversely.

In the Figure 2, $A \nleftrightarrow B$ means the set A and B are independent of each other.

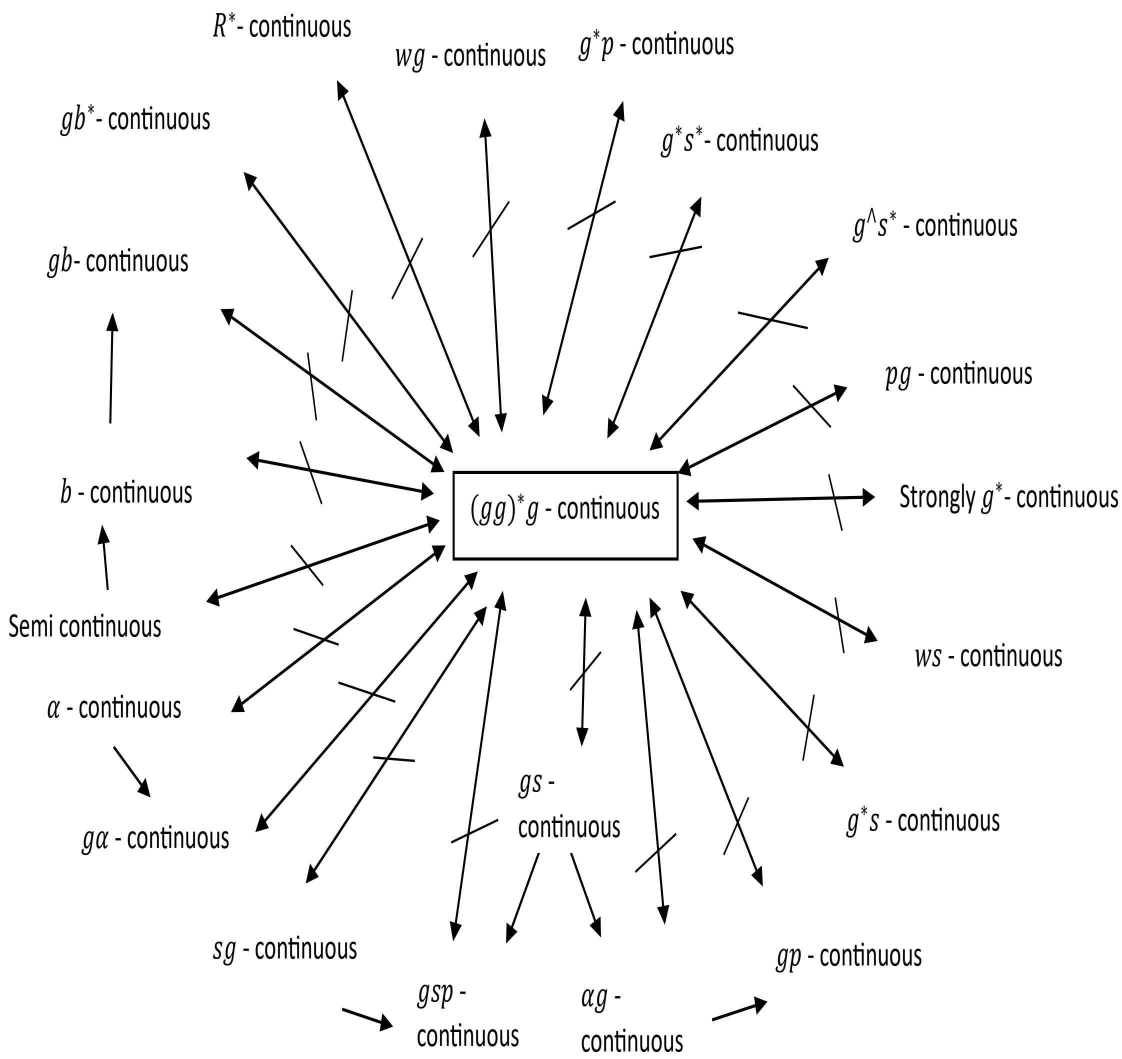

Figure 2

3. Aspects of $(gg)^*g$ - continuous function

Theorem:3.1 If $f:(X,\tau)\to(Y,\sigma)$ is $(gg)^*g$ - continuous function and

$g:(Y,\sigma)\to(Z,\eta)$ is continuous function then $(gof):(X,\sigma)\longrightarrow(Z,\eta)$ is $(gg)^*g$ – continuous function.

Proof:

Let us take U be any closed set in (Z,η). Since g is continuous function then by

Definition 3[i], $g^{-1}(U)$ is closed in (Y,σ). Since f is $(gg)^*g$ - continuous function then by Definition 1.1, $f^{-1}(g^{-1}(U))$ is $(gg)^*g$ - closed set in (X,τ). Therefore $(gof)^{-1}(U)$ is $(gg)^*g$ - closed set in (X,τ). Hence (gof) is $(gg)^*g$ -continuous function.

Remark: Composition of two $(gg)^*g$ - continuous function need not be $(gg)^*g$ - continuous function.

Example:3.2

Let $X=Y=Z=\{a,b,c,d\}$, $\tau=\{\varphi,\{b\},\{c\},\{b,c\},\{b,c,d\},X\}$

$\sigma=\{\varphi,\{a\},\{c\},\{a,c\},\{c,d\},\{a,c,d\},Y\}$. A functions $f:(X,\tau)\to(Y,\sigma)$ and $g:(Y,\sigma)\to(Z,\eta)$ are defined by $f(a)=a, f(b)=b, f(c)=c, f(d)=d$ and $g(a)=a, g(b)=b, g(c)=d, g(d)=c$. f and g are $(gg)^*g$ - continuous function but not $(gof)^{-1}$ is $(gg)^*g$ - continuous function, because for closed set V = $\{c,d\}$ in (Y,σ), $(gof)^{-1}(V)=\{c,d\}$. $\{c,d\}$ is not $(gg)^*g$ - closed in (X,τ).

Theorem:3.3

A function $f:(X,\tau) \to (Y,\sigma)$. Then the following statements are equivalent.

(i) f is $(gg)^*g$ – continuous function.

(ii) $f^{-1}(U)$ is $(gg)^*g$ - open set in (X,τ) for every open set U in (Y,σ).

(iii) $f^{-1}(V)$ is $(gg)^*g$ - closed set in (X,τ) for every closed set V in (Y,σ).

Proof:

(i)⇒(ii) Let f be a $(gg)^*g$ – continuous function and U be an open set in (Y,σ).Then U^c is closed set in (Y,σ). Since f is $(gg)^*g$ – continuous function, by Definition 1.1, $f^{-1}(U^c)$ is $(gg)^*g$ - closed set in (X,τ). Therefore $f^{-1}(U^c) = X - f^{-1}(U)$ is $(gg)^*g$ - closed set in (X,τ) and hence $f^{-1}(U)$ is $(gg)^*g$ - open set in (X,τ).

(ii)⇒(iii) Let us assume that $f^{-1}(V)$ is $(gg)^*g$ - open set in (X,τ) for every open set U in (Y,σ). Let V be a closed set in (Y,σ). Then V^c is open set in (Y,σ).

By assumption $f^{-1}(V^c)$ is $(gg)^*g$ - open set in (X,τ). Therefore $f^{-1}(V^c) = X - f^{-1}(V)$ is $(gg)^*g$ - open set in (X,τ) and hence $f^{-1}(V)$ is $(gg)^*g$ - closed set in (X,τ).

(ii)⇒(iii) Let f be a $(gg)^*g$ - continuous function and let V be a closed set in (Y,σ). Then V^c is open set in (Y,σ). Since f is $(gg)^*g$ – continuous function, by Definition 1.1, $f^{-1}(V^c) = X - f^{-1}(V)$ is $(gg)^*g$ - open set in (X,τ). Hence $f^{-1}(V)$ is $(gg)^*g$ - closed set in (X,τ).

(iii)⇒(i) Let us assume that $f^{-1}(V)$ is $(gg)^*g$ - closed set in (X,τ) for every closed set V in (Y,σ). Let W be an open set in (Y,σ), then W^c is closed set in (Y,σ). By assumption $f^{-1}(W^c)$ is $(gg)^*g$ - closed set in (X,τ). Therefore $f^{-1}(W^c) = X - f^{-1}(W)$ is $(gg)^*g$ - closed set in (X,τ) and hence f is $(gg)^*g$ – continuous function.

Theorem:3.4

Let (X,τ) be a topological space in which every singleton set is $(gg)^*$ - closed.

Then the function $f:(X,\tau) \to (Y,\sigma)$ is $(gg)^*g$ - continuous if $x \in gint(f^{-1}(V))$ for every open sub set V of (Y,σ) containing $f(x)$.

Proof:

Assume that a function $f:(X,\tau) \to (Y,\sigma)$ is $(gg)^*g$ – continuous function.

To prove $x \in gint(f^{-1}(V))$. Let $x \in X$ and V be an open set in (Y,σ) containing $f(x)$. That is $f(x) \in U$. Since f is $(gg)^*g$ – continuous function, by Theorem 3.3 $f^{-1}(V)$ is $(gg)^*g$ - open set in (X,τ) and since $\{x\}$ is $(gg)^*$ - closed, then $x \in gint(f^{-1}(V))$.

Conversely assume that $x \in gint(f^{-1}(V))$ for every open subset V of (Y,σ) containing $f(x)$. To prove f is $(gg)^*g$ – continuous function.

Let V be an open set in (Y,σ). Suppose that $G \subseteq f^{-1}(V)$ and G is $(gg)^*g$ - closed. Let $x \in G \subseteq f^{-1}(V)$

$$\Rightarrow x \in f^{-1}(V)$$

$$\Rightarrow f(x) \in V$$

By hypothesis, $x \in gint(f^{-1}(V))$ and from the assumption $f^{-1}(V)$ is an $(gg)^*g$ - open set in (X,τ). By Theorem 3.3, f is $(gg)^*g$ – continuous function.

Theorem:3.5

If f is $(gg)^*g$ - continuous function then $f((gg)^*g\ cl(A)) \subseteq cl(f(A))$ for every subset A of (X,τ).

Proof:

Let $f:(X,\tau) \to (Y,\sigma)$ is $(gg)^*g$ - continuous function and let $A \subseteq X$ then $cl(f(A))$

is closed in (Y,σ).

Since $f(A) \subseteq cl(f(A))$, $A \subseteq f^{-1}(cl(f(A)))$

We know that $cl(f(A))$ is closed in (Y,σ) and also f is $(gg)^*g$ – continuous function.

By Definition 1.1, $f^{-1}(cl(f(A)))$ is $(gg)^*g$ - closed in (X,τ).

Let us assume that $y \in f^{-1}((gg)^*g - cl(A))$. Then $y = f(x)$, where $x \in (gg)^*g - cl(A)$. Let G be an open set containing $y = f(x)$. Since f is $(gg)^*g$ – continuous function, by Theorem 3.3, $f^{-1}(G)$ is $(gg)^*g$ - open set in (X, τ). By Theorem 5.8[20], $f^{-1}(G) \cap A \neq \varphi$.

$$\Rightarrow f(f^{-1}(G) \cap A) \neq \varphi$$

$$\Rightarrow f(f^{-1}(G)) \cap f(A) \neq \varphi.$$

$$f(f^{-1}(G)) \in G$$

$$\Rightarrow G \cap f(A) \neq \varphi.$$

Therefore $y \in cl(f(A))$ because for any open set G containing y, $G \cap f(A) \neq \varphi$ is a characterization of y being in the closure of f(A). Hence $f((gg)^*g - cl(A)) \subseteq cl(f(A))$.

Theorem:3.6

Let a function $f: (X, \tau) \to (Y, \sigma)$ then the following statements are equivalent.

(i) For every point $x \in (X, \tau)$ and each open set V containing $f(x)$ in (Y, σ), there is an

$(gg)^*g$ - open set U in (X, τ) such that $x \in U$ and $f(U) \subseteq V$.

(ii) For each $A \subseteq (X, \tau), f\left((gg)^*g - cl(A)\right) \subseteq cl\, f(A)$.

(iii) For each $B \subseteq (X, \tau), (gg)^*gcl\left(f^{-1}(B)\right) \subseteq f^{-1}\left(cl(B)\right)$.

Proof:

(i)⇒(ii) Suppose (i) is hold. Let us assume that $y \in f((gg)^*g - cl(A))$. Then there exists an element $x \in (gg)^*g - cl(A)$ such that $y = f(x)$. Let V be an open set containing y that is $y \in V, f(x) \in V$. Since $x \in (gg)^*gcl(A)$, by Theorem 5.8[20], there exists an $(gg)^*g$ - open set U containing a point x such that $U \cap A \neq \varphi$.

$$\Rightarrow f(U \cap A) \neq \varphi$$

$$\Rightarrow f(U) \cap f(A) \neq \varphi$$

By hypothesis $f(U) \subseteq V$

$$\Rightarrow f(U) \cap f(A) \subseteq V \cap f(A) \neq \varphi$$

$$\Rightarrow V \cap f(A) \neq \varphi$$

Thus $y \in cl\left(f(A)\right)$, because for any open set V containing y, $V \cap f(A) \neq \varphi$ is a characterization of y being in the closure of $f(A)$.

Therefore $f\left((gg)^*g - cl(A)\right) \subseteq cl\left(f(A)\right)$.

(ii)⇒(i) Suppose (ii) is hold. Let V be an open set containing $f(x)$ and let $x \in (X, \tau)$. And let $A = f^{-1}(V^c)$. Since $f\left((gg)^*g - cl(A)\right) \subseteq cl\left(f(A)\right)$

$$= cl((V^c))$$

$$= V^c$$

Therefore $f\left((gg)^*gcl(A)\right) \subseteq V^c$

$$\Rightarrow (gg)^*gcl(A) \subseteq f^{-1}(V^c) = A$$

$$\Rightarrow (gg)^*gcl(A) \subseteq A$$

Also we know that $A \subseteq (gg)^*gcl(A)$ that implies $(gg)^*gcl(A) = A$.

Since $f(x) \in V, x \in f^{-1}(V)$

This $x \notin A$ then $x \notin (gg)^*gcl(A)$

By Theorem 5.8[20], there exists $(gg)^*g$ open set U containing x such that $U \cap A \neq \varphi$

That implies $V \subseteq A^c \Rightarrow f(U) \subseteq f(A^c) \subseteq V$.

Hence $f(U) \subseteq V$.

(ii)⇒(iii) Suppose (ii) is hold. Let $B \subseteq (Y, \sigma)$ and replacing A by $f^{-1}(B)$ in (ii).

We get $f((gg)^*gcl(f^{-1}(B))) \subseteq cl(f(f^{-1}(B))) = cl(B)$

$$\Rightarrow f((gg)^*gcl\,(f^{-1}(B)) \subseteq cl(B)$$

$$\Rightarrow (gg)^*gcl\,(f^{-1}(B)) \subseteq f^{-1}(cl(B))$$

(iii)⇒(ii) Suppose (iii) is hold. Let $A \subseteq (X, \sigma)$ and take $f(A) = B$ in (iii)

We get $(gg)^*gcl(f^{-1}\left(f(A)\right)) \subseteq f^{-1}(cl(f(A)))$

$$\Rightarrow (gg)^*gcl(A) \subseteq f^{-1}(cl(f(A)))$$

$$\Rightarrow f((gg)^*gcl(A)) \subseteq cl\left(f(A)\right).$$

Theorem:3.7

If $f:(X,\tau)\to(Y,\sigma)$ is closed and $(gg)^*g$ -continuous function and B is $(gg)^*g-$

closed set of (y,σ) then $f^{-1}(B)$ is $(gg)^*g$ - closed set in (x,τ).

Proof:

Let B be $(gg)^*g$ - closed set of (Y,σ) and let $f^{-1}(B)\subseteq U$, where U is an open set of

(X,τ). Since f is closed, there is an open set V such that $B\subseteq V$ and $f^{-1}(B)\subseteq U$. Since B is $(gg)^*g$ - closed set $gcl(B)\subseteq U$, that implies $f^{-1}(gcl(B))\subseteq U$. Since $gcl(B)\subseteq cl(B)$,

by assumption f is closed and $(gg)^*g$ - continuous, $f^{-1}\big(cl(B)\big)$ is $(gg)^*g$ - closed set in (X,τ).

$$\Rightarrow gcl(f^{-1}(cl(B)))\subseteq U$$

$\Rightarrow gcl(f^{-1}(B))\subseteq U$.

Therefore $f^{-1}(B)$ is $(gg)^*g$ - closed set in (X,τ).

Theorem:3.8

If $f:(X,\tau)\to(Y,\sigma)$ is $(gg)^*g$ - continuous function, closed and

$g:(Y,\sigma)\to(Z,\eta)$ is $(gg)^*g$ - continuous function then $gof:(X,\tau)\to(Z,\eta)$ is $(gg)^*g$ – continuous function.

Proof:

Let us take U be any closed set in (Z,η). Then $f^{-1}(U)$ is closed set in (Y,σ).

Since g is $(gg)^*g$ - continuous function and closed then $g^{-1}(U)$ is closed in (Y,σ) and also f is $(gg)^*g$ – continuous function $f^{-1}(g^{-1}(U))$ is $(gg)^*g$ - closed set in (X,τ). Hence gof is $(gg)^*g$ – continuous function.

Theorem:3.9

In extremely disconnected space (X,τ), If $f:(X,\tau)\to(Y,\sigma)$ is g - continuous function and open then $(gg)^*g$ - continuous function.

Proof:

Let $f:(X,\tau)\to(Y,\sigma)$ be a g-continuous function and let V be a

closed set in (X,τ). Since f is g-continuous function and open, then $f^{-1}(V)$ is g-closed in (X,τ). By Theorem 5.4[20], $f^{-1}(V)$ is $(gg)^*g$ – closed, then $f^{-1}(V)$ is $(gg)^*g$ – closed in (X,τ). By Definition 1.1, f is $(gg)^*g$- continuous function.

CONCLUSION

The study of $(gg)^*g$ – continuous function in topological spaces literary investigated. The concept of $(gg)^*g$ – continuous function will be extended to strongly $(gg)^*g$ – continuous function, perfectly $(gg)^*g$ – continuous function, contra $(gg)^*g$ – continuous function. Also this study can be elaborated to bitopological spaces and fuzzy topological spaces.

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