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Fuzzy contra $\theta g'''$-continuous and irresolute functions in fuzzy topological spaces

A. Saivarajan[1]*

Abstract

In this paper, we introduce a new class of generalized mappings namely fuzzy contra $\theta g'''$-continuous and fuzzy contra $\theta g'''$-irresolute mappings in fts's. Some of their properties have been investigated.

Keywords

Fuzzy $\theta g'''$-continuous, fuzzy contra $\theta g'''$-continuous and fuzzy contra $\theta g'''$-irresolute mappings.

AMS Subject Classification

03E72, 54A40.

[1] *Department of Mathematics, Rajah Serfoji Government College, Thanjavur-613005, Tamil Nadu, India.*

*Corresponding author: [1] saivam.a20@gmail.com

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Contents

1. Introduction

Levine [14] introduced generalized closed sets (g-closed sets) in general topology as a generalization of closed sets. Applying the concepts of g-closed sets in general topological spaces, several results in general topology were improved by introducing and studying g-closed maps by Malghan in 1984 [15] and g-continuous maps by Balachandran et al. [2] in 1991. Further generalized preregular closed sets, generalized preregular continuous maps were introduced and studied by Gnanambal [11] in the year 1997 for general topological spaces. Ekici and Kerre [10] introduced fuzzy contra continuous in 2006. In this paper, we have introduced a new class of generalized mappings namely fuzzy $\theta g'''$-continuous and fuzzy $\theta g'''$-irresolute mappings in fuzzy topological spaces. Some of their properties have been investigated. As an application of these mappings fuzzy $T_{\theta g'''}$ space, fuzzy $T_{g'''\theta}$ space are introduced and investigated.

2. Preliminaries

Throughout this paper, (P,τ) or simply P mean fuzzy topological space (abbreviated as fts). We denote and define the closure and interior for a fuzzy set (briefly, fs) λ by

$$fCl(\lambda) = \bigwedge\{\mu : \mu \geq \lambda,\ 1-\mu \in \tau\}$$

$$\text{and } fInt(\lambda) = \bigvee\{\mu : \mu \leq \lambda, \mu \in \tau\}.$$

Fuzzy θ-closure of λ [9] and fuzzy semi-θ-closure of λ [17] are defined by

$$fCl_\theta(\lambda) = \bigwedge\{fCl(\mu) : \lambda \leq \mu,\ \mu \in \tau\} \text{ and}$$

$$fsCl_\theta(\lambda) = \bigwedge\{fsCl(\mu) : \lambda \leq \mu,\ \mu \text{ is a fuzzy semi-open}$$
$$(i.e.,\ \mu \leq fCl(fInt(\mu))) \text{ in } \tau\} \text{ respectively.}$$

Definition 2.1. A fs λ of (P,τ) is called a fuzzy

(i) θ-closed (briefly, $f\theta c$) [9] if $\lambda = fCl_\theta(\lambda)$

(ii) semi-θ-closed (briefly, $fs\theta c$) [17] $\lambda = fsCl_\theta(\lambda)$

(iii) regular (resp. θ, semi, semi θ & α)-open (briefly, fro [1] (resp. $f\theta o$ [9], fso [1], $fs\theta o$ [17] & $f\alpha o$ [5])) if $\lambda = fInt(fCl(\lambda))$ (resp. $\lambda = fInt_\theta(\lambda)$ [9], $\lambda \leq fCl(fInt(\lambda))$, $\lambda = fsInt_\theta(\lambda)$ & $\lambda \leq fInt(fCl(fInt(\lambda)))$); $f\alpha Cl(\lambda)$ (resp. $fsCl(\lambda)$ denoted and defined by $\cap\{\nu : \nu \supseteq \lambda, \nu \text{ is } f\alpha c(\text{ resp. } fsc)\}$).

Definition 2.2. A fs λ of (P,τ) is called a fuzzy

(i) generalized (resp. generalized semi, θ-generalized & θ generalized semi) closed (in short, fgc [3] (resp. $fgsc$ [16], $f\theta gc$ [9] & $f\theta gsc$ [12])) if $fCl(\lambda) \leq \nu$ (resp. $fsCl(\lambda) \leq \nu$, $fCl_\theta(\lambda) \leq \nu$ & $fsCl_\theta(\lambda) \leq \nu$), whenever $\lambda \leq \nu$ and ν is fo set in P.

(ii) semi (resp. θ-semi) generalized closed (in short , $fsgc$ [4] (resp. $f\theta sgc$ [17])) if $fsCl(\lambda) \leq \nu$ (resp. $fsCl_\theta(\lambda) \leq \nu$), whenever $\lambda \leq \nu$ and ν is fso set in P.

(iii) g''' (resp. g^*s & g'''_α)-closed (briefly, $fg'''c$ [13] (resp. fg^*sc [13] & $fg'''_\alpha c$ [13])) if $fCl(\lambda) \leq \nu$ (resp. $fsCl(\lambda) \leq \nu$ & $f\alpha Cl(\lambda) \leq \nu$), whenever $\lambda \leq \nu$ and ν is fuzzy generalized semi open (briefly, $fgso$) set in P.

(iv) generalized (resp. generalized semi, θ-generalized, semi generalized, θ-semi generalized, g''', g^*s, g'''_α & θ generalized semi) open set (in short, fgo [3] (resp. $fgso$ [16], $f\theta go$ [9], $fsgo$ [4], $f\theta sgo$ [17], $fg'''o$ [13], fg^*so [13], $fg'''_\alpha o$ [13] & $f\theta gso$ [12])) if λ^c is fgc (resp. $fgsc$, $f\theta gc$, $fsgc$, $f\theta sgc$, $fg'''c$, fg^*sc, $fg'''_\alpha c$ & $f\theta gsc$).

(v) fuzzy $\theta g'''$ (resp. θg^*s, $g'''\theta$, $g^*s\theta$ & $g'''_\alpha\theta$)-closed [6, 7] (briefly, $f\theta g'''c$ (resp. $f\theta g^*sc$, $fg'''\theta c$, $fg^*s\theta c$ & $fg'''_\alpha\theta c$)) set if $fCl_\theta(\lambda)$ (resp. $fsCl_\theta(\lambda)$, $fCl(\lambda)$, $fsCl(\lambda)$ and $f\alpha Cl(\lambda)$) $\leq \mu$ whenever $\lambda \leq \mu$ and μ is fuzzy θ generalized semi open (briefly, $f\theta gso$) in X.

Definition 2.3. A function $h : (P,\tau) \to (Q,\sigma)$ is called a fuzzy

(i) continuous [8] (in short $fCts$) if $h^{-1}(U)$ is a fo set in P, $\forall$ fo set U in Q.

(ii) g (resp. θ & θgs)-continuous (in short $fgCts$ [3] (resp. $f\theta Cts$ [17] & $f\theta gsCts$ [12])) function if $h^{-1}(U)$ is a fgc (resp. $f\theta c$ & $f\theta gsc$) in P, $\forall$ fc set U in Q.

(iii) fuzzy $\theta g'''$ (resp. $g'''\theta$, $g'''_\alpha\theta$ & θg^*s)-continuous [6, 7] (briefly, $f\theta g'''Cts$ (resp. $fg'''\theta Cts$, $fg'''_\alpha\theta Cts$ & $f\theta g^*s$ Cts) if $h^{-1}(U)$ is a $f\theta g'''c$ (resp. $fg'''\theta c$, $fg'''_\alpha\theta c$ & $f\theta g^*sc$) in P for every fc set U in Q.

(iv) fuzzy $\theta g'''$ (resp. $g'''\theta$)-irresolute [6, 7] (briefly, $f\theta g'''$ Irr (resp. $fg'''\theta Irr$)) if $h^{-1}(V)$ is a $f\theta g'''c$ (resp. fg''' θc) in P $\forall$ $f\theta g'''c$ (resp. $fg'''\theta c$) V in Q.

Definition 2.4. A function $h : (P,\tau) \to (Q,\sigma)$ is called a fuzzy contra continuous [10] (in short $fcCts$) if $h^{-1}(U)$ is a fc set in P, $\forall$ fo set U in Q.

3. Fuzzy contra $\theta g'''$-continuous and irresolute functions

Definition 3.1. A function $h : P \to Q$ is called

(i) fuzzy contra $\theta g'''$ (resp. $g'''\theta$, $g'''_\alpha\theta$ & θg^*s)-continuous (briefly, $fc\theta g'''Cts$ (resp. $fcg'''\theta Cts$, $fcg'''_\alpha\theta Cts$ & $fc\theta$ g^*sCts)) if $h^{-1}(\lambda)$ is a $f\theta g'''c$ (resp. $fg'''\theta c$, $fg'''_\alpha\theta c$ & $f\theta g^*sc$) in P for every fo set λ in Q.

(ii) fuzzy contra $\theta g'''$ (resp. $g'''\theta$)-irresolute (briefly, $fc\theta g'''$ Irr (resp. $fcg'''\theta Irr$)) if $h^{-1}(\eta)$ is a $f\theta g'''c$ (resp. $fg'''\theta c$) in P $\forall$ $f\theta g'''o$ (resp. $fg'''\theta o$) η in Q.

Theorem 3.2. A function $h : P \to Q$ is $fc\theta g'''Cts$ iff $\forall$ fc set, η in Q, $h^{-1}(\eta)$ is a $f\theta g'''o$ in P.

Proof. Let η be any fc set Q. Since $1-\eta$ is fo, then by assumption it follows that $h^{-1}(1-\eta) = 1-h^{-1}(\eta)$ is $f\theta g'''o$ in P. Converse is similar. □

Theorem 3.3. (i) Every $fc\theta Cts$ function is a $fc\theta g'''Cts$.

(ii) Every $fc\theta g'''Cts$ function is a $fc\theta g^*sCts$.

(iii) Every $fc\theta g'''Cts$ function is a $fcg'''\theta Cts$.
But not conversely.

Proof. Let $h : P \to Q$ be a $fc\theta Cts$ (resp. $fc\theta g'''Cts$ and $fc\theta g'''Cts$) function. Let λ be a fo set in Q. Since h is a $fc\theta Cts$ (resp. $fc\theta g'''Cts$ and $fc\theta g'''Cts$), $h^{-1}(\lambda)$ is a $f\theta c$ (resp. $f\theta g'''c$ and $f\theta g'''c$) in P and every $f\theta c$ (resp. $f\theta g'''c$ and $f\theta g'''c$) set is a $f\theta g'''c$ (resp. $f\theta g^*sc$ and $fg'''\theta c$) in [6, 7], therefore for a fo set λ in Q, $h^{-1}(\lambda)$ is a $f\theta g'''c$ (resp. $f\theta g^*sc$ and $fg'''\theta c$) set in P. Hence h is a $fc\theta g'''Cts$ (resp. $fc\theta g^*sCts$ and $fcg'''\theta Cts$). □

Example 3.4. Let $P = \{l\} = Q$ and the fs's A & B are defined by $A(l) = 0.6$, $B(l) = 0.5$. Consider $\tau = \{0, A, 1\}$ and $\sigma = \{0, B, 1\}$. Then (P,τ) and (Q,σ) are fts. Then the identity (denoted by, i) i : $(P,\tau) \to (Q,\sigma)$ is a $fc\theta g'''Cts$ map but not a $fc\theta Cts$, since for the fo set B^c in Q, $\mathrm{i}^{-1}(B^c)$ is not a $f\theta c$ but it is a $f\theta g'''c$ set in (P,τ).

Example 3.5. Let $P = \{l,m\} = Q$ and the fs's A, B & K are defined by $A(l) = 0.5$, $A(m) = 0.4$; $B(l) = 0.2$, $B(m) = 0.1$ & $K(l) = 0.1$, $K(m) = 0.2$. Consider $\tau = \{0, A, 1\}$ and $\sigma = \{0, B, 1\}$. Then $h : (P,\tau) \to (Q,\sigma)$, $h(l) = m$, $h(m) = l$, h is a $fc\theta g^*sCts$ map but not a $fc\theta g'''Cts$, since for the fo set B^c in Q, $h^{-1}(B^c) = K$ is not a $f\theta g'''c$ but it is a $f\theta g^*sc$ set in (P,τ).

Example 3.6. Let $P = \{p,q\} = Q$ and the fs's L, M, R & S are defined by $L(p) = 0.4$, $L(q) = 0.4$; $M(p) = 0.5$, $M(q) = 0.4$; $R(p) = 0.6$, $R(q) = 0.5$ & $S(p) = 0.5$, $S(q) = 0.6$. Consider $\tau = \{0, L, M, 1\}$ and $\sigma = \{0, R, 1\}$. Then $h : (P,\tau) \to (Q,\sigma)$, $h(p) = q$, $h(q) = p$, is a $fcg'''\theta Cts$ map but not a $fc\theta g'''Cts$, since for the fo set D^c in Q, $h^{-1}(D^c) = S$ is not a $f\theta g'''c$ but it is a $fg'''\theta c$ set in (P,τ).

Remark 3.7. The following examples shows that the $fc\theta g'''$ Cts function and $fc\theta g'''Irr$ function are independent.

Example 3.8. Let $P = \{u,v\} = Q$ and the fs's U, V & W are defined by $U(u) = 0.3$, $U(v) = 0.4$; $V(u) = 0.5$, $V(v) = 0.6$; $W(u) = 0.3$, $W(v) = 0.4$. Consider $\tau = \{0, U, 1\}$ and $\sigma = \{0, V, 1\}$. Then i : $(P,\tau) \to (Q,\sigma)$ is a $fc\theta g'''Cts$ map but not a $fc\theta g'''Irr$, since for the $f\theta g'''o$ set W in (Q,σ), $\mathrm{i}^{-1}(W)$ is not a $f\theta g'''c$ in (P,τ).

Example 3.9. Let $P = \{u\} = Q$ and the fs's U, V & W are defined by $U(u) = 0.3$, $V(u) = 0.8$, $W(u) = 0.3$. Consider $\tau = \{0, U, V, 1\}$ and $\sigma = \{0, W, 1\}$. Then $\mathrm{i} : (X, \tau) \to (Y, \sigma)$ is a $fc\theta g'''Irr$ map but not a $fc\theta g'''Cts$, since for the fo set W^c in Q, $\mathrm{i}^{-1}(W^c)$, is not a $f\theta g'''c$ in (P, τ).

Theorem 3.10. The map $g \circ h : P \to R$ with $h : P \to Q$ and $g : Q \to R$, is a

(i) $fc\theta g'''Cts$ if h is a $fc\theta g'''Cts$ and g is a $fcCts$.

(ii) $fc\theta g'''Irr$ if h is a $fc\theta g'''Irr$ and g is a $fc\theta g'''Irr$.

(iii) $fc\theta g'''Irr$ if h is a $fc\theta g'''Irr$ and g is a $fc\theta g'''Cts$.

Definition 3.11. A fts's P is called fuzzy $T_{\theta g'''}$-space (briefly $fT_{\theta g'''}s$) [6, 7] if every $f\theta g'''c$ set in P is a fc set.

Theorem 3.12. Let P be any fts and Q be $fT_{\theta g'''}s$ and $h : P \to Q$ be a $fc\theta g'''Irr$ function. Then h is a $fc\theta g'''Cts$.

Proof. Obvious. □

Theorem 3.13. Let $h : P \to Q$ be a $fc\theta g'''Cts$ with P (resp. Q) be a $fT_{\theta g'''}s$, then h is a $fcCts$ (resp. $fc\theta g'''Irr$).

Theorem 3.14. The map $g \circ h : P \to R$ is a $fc\theta g'''Cts$, if $h : P \to Q$ is a $f\theta g'''Cts$ and $g : Q \to R$ is a $fc\theta g'''Cts$ with Q as a $fT_{\theta g'''}s$.

Proof. Since g is $fc\theta g'''Cts$, $g^{-1}(\lambda)$ is a $f\theta g'''c$ set in Q $\forall$ fo, λ, in R. Since Q is a $fT_{\theta g'''}s$, $g^{-1}(\lambda)$ is a fc in Q implies $h^{-1}(g^{-1}(\lambda)) = (g \circ h)^{-1}(\lambda)$ is $f\theta g'''c$ set in P. Hence a $g \circ h$ is a $fc\theta g'''Cts$. □

Theorem 3.15. A function $h : P \to Q$ is a $fcg'''\theta Cts$ iff the inverse image of each fc set in Q is a $fcg'''\theta o$ in P.

Theorem 3.16. Every

(i) $fcCts$ function is a $fcg'''\theta Cts$.

(ii) $fcg'''\theta Cts$ function is a $fcg'''_{\alpha}\theta Cts$.

(iii) $fcg'''\theta Irr$ function is a $fcg'''\theta Cts$.

But not conversely.

Proof. We prove only (i) and (ii). Suppose $h : P \to Q$ be a $fcCts$ (resp. $fcg'''\theta Cts$). Then $h^{-1}(\lambda)$ is fc (resp. $fg'''\theta c$) $\forall$ fo, λ in Q. Since every fo (resp. $fg'''\theta o$) set is a $fg'''\theta o$ (resp. $fg'''_{\alpha}\theta o$), for a fo set λ in Q, $h^{-1}(\lambda)$ is a $fg'''\theta c$ (resp. $fg'''_{\alpha}\theta c$) set in P. Hence h is a $fcg'''\theta Cts$ (resp. $fcg'''_{\alpha}\theta Cts$). □

Example 3.17. Let $P = \{p, q\} = Q$ and the fs's L, M, R & S are defined by

$$L(p) = 0.4,\ L(q) = 0.4;$$

$$M(p) = 0.5,\ M(q) = 0.4;$$

$$R(p) = 0.3,\ R(q) = 0.4;$$

$$S(p) = 0.6,\ S(q) = 0.7.$$

Consider $\tau = \{0, L, M, 1\}$ and $\sigma = \{0, R, 1\}$. Then (P, τ) and (Q, σ) are fts. Define $h : (P, \tau) \to (Q, \sigma)$ as $h(p) = q$, $h(q) = p$. Then h is a $fcg'''\theta Cts$ map but not a $fcCts$, since for the fo set R^c in Q, $h^{-1}(R^c) = S$ is not a fc but it is a $fg'''\theta c$ set in (P, τ).

Example 3.18. Let $P = \{u\}$ and the fs's U, V & W are defined by $U(u) = 0.5$; $V(u) = 0.3$; $W(u) = 0.4$. Consider $\tau = \{0, U, V, 1\}$ & $\sigma = \{0, W, 1\}$. Then $\mathrm{i} : (P, \tau) \to (Q, \sigma)$ is a $fcg'''_{\alpha}\theta Cts$ map but not a $fcg'''\theta Cts$, since for the fo set W^c in Q, $\mathrm{i}^{-1}(W^c) = W^c$ is not a $fg'''\theta c$ but it is a $fg'''_{\alpha}\theta c$ set in (P, τ).

Example 3.19. Let $P = \{u, v\} = Q$ and the fs's U, V & W are defined by

$$U(u) = 0.3,\ U(v) = 0.3;$$

$$V(u) = 0.6,\ V(v) = 0.5;$$

$$W(u) = 0.6,\ W(v) = 0.6.$$

Consider $\tau = \{0, U, 1\}$ & $\sigma = \{0, V, 1\}$. Then $\mathrm{i} : (P, \tau) \to (Q, \sigma)$ is a $fcg'''\theta Cts$ map but not a $fcg'''\theta Irr$, since for the $fg'''\theta o$ set W in (Q, σ), $i^{-1}(W)$ is not a $fg'''\theta c$ in (P, τ).

Theorem 3.20. The map $g \circ h : P \to R$ with $h : P \to Q$ and $g : Q \to R$, is a

(i) $fcg'''\theta Cts$ if h is a $fcg'''\theta Cts$ & g is a $fCts$.

(ii) $fcg'''\theta Irr$ if h is a $fcg'''\theta Irr$ & g is a $fg'''\theta Irr$ functions.

(iii) $fcg'''\theta Cts$ if h is a $fcg'''\theta Irr$ & g is a $fg'''\theta Cts$ functions.

Definition 3.21. A fts's P is called fuzzy $T_{g'''\theta}$-space (briefly $fT_{g'''\theta}s$) if every $fg'''\theta c$ (resp. $fg'''\theta o$) set in P is a fc (resp. fo) set.

Theorem 3.22. Let P be any fts & Q be a $fT_{g'''\theta}s$ and $h : P \to Q$ be $fcg'''\theta Irr$ function. Then h is a $fcg'''\theta Cts$.

Proof. Obvious. □

Theorem 3.23. Every $fT_{\theta g'''}s$ is a $fT_{g'''\theta}s$.

Proof. Let X be a $fT_{\theta g'''}s$ and let λ be a $f\theta g'''c$ set in X. Then by definition, λ is a fc set in P. Since every $f\theta g'''c$ set is a $fg'''\theta c$ set. Thus λ is a $fg'''\theta c$ in P. Hence P is a $fT_{g'''\theta}s$. □

Theorem 3.24. Let $h : P \to Q$ be a $fcg'''\theta Cts$ & P (resp. Q) be a $fT_{g'''\theta}s$, then h is a $fcCts$ (resp. $fcg'''\theta Irr$).

Proof. Obvious. □

Theorem 3.25. If $h : P \to Q$ is $fcg'''\theta Cts$ & $g : Q \to R$ is $fg'''\theta Cts$ & Q be a $fT_{g'''\theta}s$, then $g \circ h : P \to R$ is a $fg'''\theta Cts$.

Proof. Suppose g is a $fg'''\theta Cts$, then $g^{-1}(\lambda)$ is a $fg'''\theta c$ in Q, $\forall$ fc λ in R. Since Q is a $fT_{g'''\theta}s$, $g^{-1}(\lambda)$ is fc in Q. Also since $h: P \to Q$ is $fcg'''\theta Cts$, $h^{-1}(g^{-1}(\lambda))$ is a $fg'''\theta o$ in P. i.e., $h^{-1}(g^{-1}(\lambda)) = (g \circ h)^{-1}(\lambda)$ is a $fg'''\theta o$ set in P. □

Theorem 3.26. Let $h: P \to Q$ be an onto, $fcg'''\theta Irr$ & a fC map. If P is a $fT_{g'''\theta}s$ then Q is also a $fT_{g'''\theta}s$.

Proof. Let λ, in Q, be a $fcg'''\theta o$. $h^{-1}(\lambda)$, in P, is a $fg'''\theta c$ set, since h is a $fcg'''\theta Irr$. Also since P is a $fT_{g'''\theta}s$, $h^{-1}(\lambda)$ is a fc in P. And so $h(h^{-1}(\lambda)) = \lambda$ is a fc in Q as h is both fC and onto function. Hence Q is a $fT_{g'''\theta}s$. □

Theorem 3.27. Let $h: P \to Q$ be an onto, $fc\theta g'''Irr$ & a fC map. If P is a $fT_{\theta g'''}s$ then Q is also a $fT_{\theta g'''}s$.

Proof. Let λ, in Q, be a $f\theta g'''o$. $h^{-1}(\lambda)$, in P, is a $f\theta g'''c$ and fc, since h is a $f\theta g'''Irr$ and $fT_{\theta g'''}s$. And so $h(h^{-1}(\lambda)) = \lambda$ is a fc in Q as h is both fC and onto function. Hence Q is a $fT_{\theta g'''}s$. □

Conclusion

In this paper, we introduced a new class of generalized mappings in a contra part namely fuzzy contra $\theta g'''$-continuous and fuzzy contra $\theta g'''$-irresolute mappings in fts's. Further, some of their properties in contra mappings have been investigated. Also, an application of these mappings fuzzy $T_{\theta g'''}$-space, fuzzy $T_{g'''\theta}$-space are introduced and investigated in fts. These can be carried out to open mappings and closed mappings in their future work.

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