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GENERALIZED FUZZY $\mathcal{Z}$-CLOSURE IRRESOLUTE MAPPINGS IN DOUBLE FUZZY TOPOLOGICAL SPACES

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ABSTRACT. We introduce and investigate some new class of mappings called double fuzzy generalized $\mathcal{Z}$-open irresolute map, double fuzzy generalized $\mathcal{Z}$-closed irresolute map, double fuzzy generalized $\mathcal{Z}$-continuous map, double fuzzy generalized $\mathcal{Z}$-irresolute map and double fuzzy generalized $\mathcal{Z}$-closure irresolute map in double fuzzy topological spaces. Also, some of their fundamental properties are studied.

1. INTRODUCTION AND PRELIMINARIES

In 1986, Atanassov [2] started 'Intuitionistic fuzzy sets' and Coker [3] in 1997, initiated Intuitionistic fuzzy topological space". The term “double" instead of “intuitionistic" coined by Garcia and Rodabaugh [5] in 2005. In the previous two decades many analysts [8, 9] accomplishing more applications on double fuzzy topological spaces. From 2011, $\mathcal{Z}$-open sets and maps were introduced in topological spaces by El-Maghrabi and Mubarki [7].

X denotes a non-empty set, $I_1 = [0, 1)$, $I_0 = (0, 1]$, $I = [0, 1]$, $0 = \underline{0}(X)$, $1 = \underline{1}(X)$, $r \in I_0$ & $\kappa \in I_1$ and always $1 \geq r + \kappa$. I^X is a family of all fuzzy sets on X. In 2002, double fuzzy topological spaces (briefly, dfts), (X, η, η^*), (r, κ)-fuzzy open (resp. (r, κ)-fuzzy closed) (briefly (r, κ)-fo (resp. (r, κ)-fc)) were defined.

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All other undefined notions are from [1,4,6,7,9–11] and cited there in.

2. GENERALIZED DOUBLE FUZZY $\mathcal{Z}$-CLOSURE IRRESOLUTE FUNCTIONS

In this section, some characterisations of generalized double fuzzy $\mathcal{Z}$-continuous (resp. (open, closed, closure) irresolute) functions are studied.

Definition 2.1. *A map $f:(X,\rho_1,\rho_1^*)\to(Y,\rho_2,\rho_2^*)$ is called as ageneralized double fuzzy*

(i) $\mathcal{Z}$-open irresolute (briefly, $gDF\mathcal{Z}oIrr$) if for every (r,κ)-$gf\mathcal{Z}o$ set $\gamma\in I^X$, $\kappa\in I_1$ and $r\in I_0$, $f(\gamma)$ is an (r,κ)-$gf\mathcal{Z}o$ in I^Y.

(ii) $\mathcal{Z}$-closed irresolute (briefly, $gDF\mathcal{Z}cIrr$) if for every (r,κ)-$gf\mathcal{Z}c$ set $\gamma\in I^X$, $\kappa\in I_1$ and $r\in I_0$, $f(\gamma)$ is an (r,κ)-$gf\mathcal{Z}c$ in I^Y.

(iii) $\mathcal{Z}$-continuous (briefly, $gDF\mathcal{Z}Cts$) if for every (r,κ)-fo set $\gamma\in I^Y$, $r\in I_0$ and $\kappa\in I_1$, $f^{-1}(\gamma)$ is an (r,κ)-$gf\mathcal{Z}o$ in I_X.

(iv) $\mathcal{Z}$-irresolute (briefly, $gDF\mathcal{Z}Irr$) if $f^{-1}(\mu)$ is (r,κ)-$gf\mathcal{Z}o$ set $\forall(r,\kappa)$-$gf\mathcal{Z}o$ set $\mu\in I^Y$.

(v) $\mathcal{Z}$-closure irresolute (briefly, $gDF\mathcal{Z}Cl\ Irr$) if $f^{-1}(G\mathcal{Z}C_\rho,\rho^*(f(\gamma),r,\kappa)$ is an (r,κ)-$gf\mathcal{Z}c$ set for every (r,κ)-$gf\mathcal{Z}c$ set $\gamma\in I^Y$, $r\in I_0$ and $\kappa\in I_1$.

Theorem 2.1. *For any bijective map $f:(X,\rho_1,\rho_1^*)\to(Y,\rho_2,\rho_2^*)$, the below stated statements are equivalent.*

(i) f is $gDF\mathcal{Z}Cl\ Irr$ function.

(ii) For every fuzzy set $\gamma\in I^X$, $f(G\mathcal{Z}C_{\rho_1,\rho_1^*}(\gamma,r,\kappa))\le G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa)$.

(iii) For every fuzzy set γ in I^Y, $G\mathcal{Z}C_{\rho_1,\rho_1^*}(f^{-1}(\gamma),r,\kappa)\le f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(\gamma,r,\kappa))$.

Proof.

$(i)\Rightarrow(ii)$: Suppose $\gamma\in I^X$ and $G\mathcal{Z}C_{\rho_1,\rho_1^*}(f(\gamma),r,\kappa)\in I^Y$ is an (r,κ)-$gf\mathcal{Z}c$, then by (i), we have $f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa)\in I^X$ is an (r,κ)-$gf\mathcal{Z}c$ set, $r\in I_0$ and $\kappa\in I_1$. Therefore, $G\mathcal{Z}C_{\rho_2,\rho_2^*}(f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa)),r,\kappa)=f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa))$. Since $\gamma\le f^{-1}(f(\gamma))$ and $G\mathcal{Z}C_{\rho_1,\rho_1^*}(\gamma,r,\kappa)\le G\mathcal{Z}C_{\rho_2,\rho_2^*}(f^{-1}(f(\gamma),r,\kappa))$. Also, $f(\gamma)\le G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa)$. Then $G\mathcal{Z}C_{\rho_1,\rho_1^*}(\gamma,r,\kappa)\le G\mathcal{Z}C_{\rho_2,\rho_2^*}(f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa),r,\kappa))=f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa))$.

$(ii)\Rightarrow(iii)$: Suppose $\gamma\in I^Y$, by (ii), $f(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f^{-1}(\gamma),r,\kappa))\le G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(f^{-1}(\gamma)),r,\kappa)\le G\mathcal{Z}C_{\rho_2,\rho_2^*}(\gamma,r,\kappa)$. That is, $f(G\mathcal{Z}C_{\rho_1,\rho_1^*}(f^{-1}(\gamma),r,\kappa))\le G\mathcal{Z}C_{\rho_2,\rho_2^*}$

(γ, r, κ). Therefore, $f^{-1}(f(G\mathcal{Z}C_{\rho_1,\rho_1^*}(f^{-1}(\gamma), r, \kappa))) \leq f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(\gamma, r, \kappa))$. Hence, $G\mathcal{Z}C_{\rho_1,\rho_1^*}(f^{-1}(\gamma), r, \kappa) \leq f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(\gamma, r, \kappa))$.

$(iii) \Rightarrow (i)$: Suppose $\gamma \in I^Y$ is an (r, κ)-$gf\mathcal{Z}c$ set. Then, $G\mathcal{Z}C_{\rho_2,\rho_2^*}(\gamma, r, \kappa) = \gamma$. By (iii), $G\mathcal{Z}C_{\rho_1,\rho_1^*}(f^{-1}(\gamma), r, \kappa) \leq f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(\gamma, r, \kappa)) = f^{-1}(\gamma)$. But $f^{-1}(\gamma) \leq G\mathcal{Z}C_{\rho_1,\rho_1^*}(f^{-1}(\gamma), r, \kappa)$. Therefore, $f^{-1}(\gamma) = G\mathcal{Z}C_{\rho_2,\rho_2^*}(\gamma, r, \kappa)$ i.e., $f^{-1}(\gamma) \in I^X$ is (r, κ)-$gf\mathcal{Z}c$. Thus f is $gDF\mathcal{Z}Cl\ Irr$ map. □

Proposition 2.1. *The map $f : (X, \rho_1, \rho_1^*) \to (Y, \rho_2, \rho_2^*)$ is a $gDF\mathcal{Z}cIrr$ iff $\forall \gamma \in I^X$, $G\mathcal{Z}C_{\rho_1,\rho_1^*}(f(\gamma), r, \kappa) \leq f(G\mathcal{Z}C_{\rho_1,\rho_1^*}(\gamma, r, \kappa))$.*

Proposition 2.2. *For any $gDF\mathcal{Z}Cl\ Irr$ function $f : (X, \rho_1, \rho_1^*) \to (Y, \rho_2, \rho_2^*)$, $G\mathcal{Z}\mathcal{B}_{\rho_1,\rho_1^*}(f^{-1}(\gamma), r, \kappa)$ is zero for every (r, κ)-$gf\mathcal{Z}o$ set $\gamma \in I^Y$.*

Definition 2.2. *A $dfts$ (X, ρ, ρ^*) is said to be a double fuzzy $\mathcal{Z}$-$(\rho, \rho^*)_{1/2}$ space (briefly, $DF\mathcal{Z}$-$(\rho, \rho^*)_{1/2}$), if each (r, κ)-$f\mathcal{Z}c$ set is (r, κ)-fc set in X.*

Proposition 2.3. *For any $dfts$ (X, ρ_1, ρ_1^*) and $DF\mathcal{Z}$-$(\rho, \rho^*)_{1/2}$ space (Y, ρ_2, ρ_2^*), if the map $f : (X, \rho_1, \rho_1^*) \to (Y, \rho_2, \rho_2^*)$ is a bijective, then*

(i) *f and f^{-1} are $gDF\mathcal{Z}Cl\ Irr$*
(ii) *f is $gDF\mathcal{Z}Cts$ and $gDF\mathcal{Z}oIrr$.*
(iii) *f is $gDF\mathcal{Z}Cts$ and $gDF\mathcal{Z}cIrr$.*
(iv) *$f(G\mathcal{Z}C_{\rho_1,\rho_1^*}(\gamma, r, \kappa)) = G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa)$, for every $\gamma \in I^X$.*

are equivalent.

Proof.

$(i) \Rightarrow (ii)$: Suppose γ is an (r, κ)-$gf\mathcal{Z}o$ set in X. Since f^{-1} is $gDF\mathcal{Z}Cl\ Irr$, $(f^{-1})^{-1}(\gamma) \in I^Y$ is (r, κ)-$gf\mathcal{Z}o$ set, so f is $gDF\mathcal{Z}oIrr$. Now, let $\nu \in I^Y$ be an (r, κ)-$f\mathcal{Z}o$ set, then it is an (r, κ)-$gf\mathcal{Z}o$. But by hypothesis, f^{-1} are $gDF\mathcal{Z}Cl\ Irr$, then $f^{-1}(\nu) \in I^X$ is an (r, κ)-$gf\mathcal{Z}o$, i.e, f is $gDF\mathcal{Z}Cts$.

$(ii) \Rightarrow (iii)$: Obvious.

$(iii) \Rightarrow (iv)$: If $\gamma \in I^X$, then $\gamma \leq f^{-1}(f(\gamma))$ and $f(\gamma) \leq G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa)$ $\Rightarrow \gamma \leq f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa)$. Now, $G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa) \in I^Y$ is an (r, κ)-$gf\mathcal{Z}c$ set. But (Y, ρ_2, ρ_2^*) is a $DF\mathcal{Z}$-$(\rho, \rho^*)_{1/2}$ space, and $G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa)$ is an (r, κ)-fc set, then $G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa) \in I^Y$ is an (r, κ)-$f\mathcal{Z}c$ set. Since f is $gDF\mathcal{Z}Cts$, $f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa))$ is an (r, κ)-$gf\mathcal{Z}c$ set, which implies, $G\mathcal{Z}C_{\rho_2,\rho_2^*}(f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa)), r, \kappa) = f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa))$. But $G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa) \leq G\mathcal{Z}C_{\rho_2,\rho_2^*}(f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma), r, \kappa)), r, \kappa)$ and

$G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa) \leq f^{-1}(G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa))$. Therefore, $f(G\mathcal{Z}\ C_{\rho_1,\rho_1^*}(\gamma,r,\kappa)) \leq G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa)$. Also,

$G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa) \leq f(G\mathcal{Z}C_{\rho_1,\rho_1^*}(\gamma,r,\kappa)) \Rightarrow f(G\mathcal{Z}C_{\rho_1,\rho_1^*}(\gamma,r,\kappa)) = G\mathcal{Z}\ C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa)$.

$(iv) \Rightarrow (i)$: Let $\gamma \in I^X$, by hypothesis of (iv), $f(G\mathcal{Z}C_{\rho_1,\rho_1^*}(\gamma),r,\kappa) = G\mathcal{Z}C_{\rho_2,\rho_2^*}$ $(f(\gamma),r,\kappa)$. Therefore, $f(G\mathcal{Z}C_{\rho_1,\rho_1^*}(f(\gamma),r,\kappa) \leq G\mathcal{Z}C_{\rho_2,\rho_2^*}(f(\gamma),r,\kappa)$. Then, f is a $gDF\mathcal{Z}Cl\ Irr$ function. Now, suppose $\nu \in I^Y$ is (r,κ)-$gf\mathcal{Z}c$. Then $G\mathcal{Z}C_{\rho_2,\rho_2^*}(\nu,r,\kappa) = \nu \Rightarrow f(G\mathcal{Z}C_{\rho_2,\rho_2^*}(\nu,r,\kappa)) = f(\nu)$.

But, by (iv), $G\mathcal{Z}C_{\rho_1,\rho_1^*}(f(\nu),r,\kappa) = f(G\mathcal{Z}C_{\rho_2,\rho_2^*}(\nu,r,\kappa))$. Therefore, $G\mathcal{Z}C_{\rho_1,\rho_1^*}$ $(f(\nu),r,\kappa) = f(\nu)$, then $f(\nu) \in I^Y$ is an (r,κ)-$gf\mathcal{Z}c$ set. Therefore, f^{-1} is a $gDF\mathcal{Z}Cl\ Irr$. □

Proposition 2.4. *For any two $dfts$'s (X,ρ_1,ρ_1^*) and (Y,ρ_2,ρ_2^*) and any map f : $(X,\rho_1,\rho_1^*) \to (Y,\rho_2,\rho_2^*)$.*

(i) *If f is any function, then $G\mathcal{Z}\mathcal{E}_{\rho_1,\rho_1^*}(f^{-1}(\delta),r,\kappa) \leq G\mathcal{Z}C_{\rho_1,\rho_1^*}(1-f^{-1}(\delta),r,\kappa,$ $\forall$ fuzzy set $\delta \in I^Y$.*

(ii) *If f is a $gDF\mathcal{Z}Cts$ function, then for every (r,κ)-$f\mathcal{Z}c$ $\delta \in I^Y$, we have $G\mathcal{Z}\mathcal{B}_{\rho_1,\rho_1^*}(f^{-1}(\delta),r,\kappa)$=$G\mathcal{Z}\mathcal{F}_{\rho_1,\rho_1^*}$ $(f^{-1}(\delta),r,\kappa)$.*

Proposition 2.5. *Let (X,ρ_1,ρ_1^*) & (Y,ρ_2,ρ_2^*) be $dfts$'s and let $f:(X,\rho_1,\rho_1^*) \to (Y,\rho_2,\rho_2^*)$ be $gDF\mathcal{Z}Cl\ Irr$ function $\ni (X,\rho_1,\rho_1^*)$ is $g^*DF\mathcal{Z}$-$(\rho,\rho^*)_{1/2}$ space. Then, for every (r,κ)-$gf\mathcal{Z}c$ set $\delta \in I^Y$, the following statements hold:*

(i) $G\mathcal{B}_{\rho_1,\rho_1^*}(f^{-1}(\delta)\ ,r,\kappa) = G\mathcal{F}_{\rho_1,\rho_1^*}(f^{-1}(\delta),r,\kappa)$.

(ii) $G\mathcal{E}_{\rho_1,\rho_1^*}(f^{-1}(\delta),r,\kappa) = 1 - f^{-1}(\delta)$.

Proposition 2.6. *Let $f:(X,\rho_1,\rho_1^*) \to (Y,\rho_2,\rho_2^*)$ be $gDF\mathcal{Z}$-closed map such that (Y,ρ_2,ρ_2^*) is $g^*DF\mathcal{Z}$-$(\rho,\rho^*)_{1/2}$ space. Then, $\forall(r,\kappa)$-$gf\mathcal{Z}c$ set δ in I^X, the following statements hold:*

(i) $G\mathcal{B}_{\rho_2,\rho_2^*}(f(\delta),r,\kappa) = G\mathcal{F}_{\rho_2,\rho_2^*}(f(\delta),r,\kappa)$.

(ii) $G\mathcal{E}_{\rho_2,\rho_2^*}(f(\delta),r,\kappa) = 1 - f(\delta)$.

Proposition 2.7. *Let (X,ρ_1,ρ_1^*), (Y,ρ_2,ρ_2^*) & (Z,ρ_3,ρ_3^*) be $dfts$'s, $f:(X,\rho_1,\rho_1^*) \to (Y,\rho_2,\rho_2^*)$ and $g:(Y,\rho_2,\rho_2^*) \to (Z,\rho_3,\rho_3^*)$ be $gDF\mathcal{Z}Cl\ Irr$ functions $\ni (X,\rho_1,\rho_1^*)$ is $g^*DF\mathcal{Z}$-$(\rho,\rho^*)_{1/2}$ space. Then, $\forall(r,\kappa)$-$gf\mathcal{Z}c$ set in Z, the following statements hold:*

(i) $G\mathcal{B}_{\rho_1,\rho_1^*}((g\circ f)^{-1}(\delta),r,\kappa) = G\mathcal{F}_{\rho_1,\rho_1^*}((g\circ f)^{-1}(\delta),r,\kappa)$.

(ii) $G\mathcal{E}_{\rho_1,\rho_1^*}((g \circ f)^{-1}(\delta), r, \kappa) = \underline{1} - (g \circ f)^{-1}(\delta)$.

3. CONCLUSION

We have introduced and investigated some new class of mappings called double fuzzy generalized $\mathcal{Z}$-open irresolute map, double fuzzy generalized $\mathcal{Z}$-closed irresolute map, double fuzzy generalized $\mathcal{Z}$-continuous map, double fuzzy generalized $\mathcal{Z}$-irresolute map and double fuzzy generalized $\mathcal{Z}$-closure irresolute map in dfts. Also, some of their fundamental properties are studied.

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