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ON RARELY FUZZY I_{rw}-CONTINUOUS FUNCTIONS

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ABSTRACT. In this paper, we introduce the concepts of rarely fuzzy I_{rw}-continuous functions in fuzzy topological spaces. Some interesting properties and characterizations of them are investigated. Also, some applications to fuzzy compact spaces are established.

1. INTRODUCTION

In 1945, Vaidyanathaswamy [16] introduced the concept of ideal topological spaces. Hayashi [6] defined the local function and studied some topological properties using local function in ideal topological spaces in 1964. Since then many mathematicians studied various topological concepts in ideal topological spaces. After the introduction of fuzzy sets by Zadeh [18] in 1965 and fuzzy topology by Chang [3] in 1968, several researches were conducted on the generalization of the notions of fuzzy sets and fuzzy topology. The hybridization of fuzzy topology and fuzzy ideal theory was initiated by Mahmoud [11] and Sarkar [14] independently in 1997. They ([11], [14]) introduced the concept of fuzzy ideal topological spaces as an extension of fuzzy topological spaces and ideal topological spaces. Popa [12] introduced the notion of rarely continuity as a generalization of weak continuity [9] which has been further investigated by Long and Herrington [10] and Jafari [7] and [8]. In the present paper we introduce and study the concept of rarely fuzzy I_{rw}-continuous functions in fuzzy ideal topological spaces which simultaneously generalizes the concepts of I_{rw}-closed sets due to Vadivel and Elavarasan [15].

2. PRELIMINARIES

Throughout this paper, (X, τ) always means fuzzy topological space in the sense of Chang [3]. For a fuzzy subset λ of X, the fuzzy interior of λ is denoted by $Int(\lambda)$ and is defined as $Int(\lambda) = \bigvee\{\mu|\mu \leq \lambda,\ \mu$ is a fuzzy open subset of $X\}$ and the fuzzy closure of λ is denoted by $Cl(\lambda)$ and is defined as $Cl(\lambda) = \bigwedge\{\mu|\mu \geq \lambda,\ \mu$ is a fuzzy closed subset of $X\}$. A fuzzy set λ in $(X,\ \tau)$ is said to be quasi-coincident with a fuzzy set μ, denoted by $\lambda q \mu$, if there exists a point $x \in X$ such that $\lambda(x) + \mu(x) > 1$ [5]. A fuzzy set μ in $(X,\ \tau)$ is called a Q-neighborhood of a fuzzy point x_β if there exists a fuzzy open set λ of X such that $x_\beta q \lambda \leq \mu$ [5].

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A nonempty collection of fuzzy sets I of a set X is called a fuzzy ideal [4, 5] if and only if (i) $\lambda \in I$ and $\mu \leq \lambda$, then $\mu \in I$, (ii) if $\lambda \in I$ and $\mu \in I$, then $\lambda \vee \mu \in I$. The triple (X, τ, I) means a fuzzy ideal topological space with a fuzzy ideal I and fuzzy topology τ. The local function for a fuzzy set λ of X with respect to τ and I denoted by $\lambda^*(\tau,\ I)$ (briefly λ^*) in a fuzzy ideal topological space $(X,\ \tau,\ I)$ is the union of all fuzzy points x_β such that if μ is a Q-neighborhood of x_β and $\delta \in I$ then for at least one point $y \in X$ for which $\mu(y) + \lambda(y) - 1 > \delta(y)$ [13]. The $*$-closure operator of a fuzzy set λ denoted by $Cl^*(\lambda)$ in $(X,\ \tau,\ I)$ defined as $Cl^*(\lambda) = \lambda \bigvee \lambda^*$ [13].

Lemma 2.1. [13] $\lambda_1 \leq \lambda_2 \Leftrightarrow \rceil(\lambda_1 q(1-\lambda_2))$, *for every pair of fuzzy sets* λ_1 *and* λ_2 *of* X.

Definition 2.1. A fuzzy set λ of fuzzy topological space $(X,\ \tau)$ is called fuzzy regular open [2] if $\lambda = int(cl(\lambda))$. The complement of a fuzzy regular open set is called fuzzy regular closed.

Definition 2.2. A fuzzy set λ of fuzzy topological space $(X,\ \tau)$ is said to be fuzzy regular semi-open [17] if there is a fuzzy regular open set μ such that $\mu \leq \lambda \leq cl(\mu)$. The complement of a fuzzy regular semi-open set is called fuzzy regular semi-closed.

Definition 2.3. A fuzzy set λ of fuzzy topological space $(X,\ \tau)$ is called fuzzy rw-closed [17]) if $cl(\lambda) \leq \mu$ whenever $\lambda \leq \mu$ and μ is fuzzy regular semi-open. Complement of a fuzzy rw-closed set is called fuzzy rw-open.

Definition 2.4. A fuzzy set λ of a fuzzy ideal topological space (X, τ, I) is called fuzzy I_{rw}-closed [15] if $\lambda^* \leq \mu$, whenever $\lambda \leq \mu$ and μ is fuzzy regular semi-open. The complement of a fuzzy I_{rw}-closed set is called fuzzy I_{rw}-open.

The family of all fuzzy I_{rw}-closed (resp. fuzzy I_{rw}-open) subsets of (X, τ, I) is denoted by FI_{rw}-$C(X)$ (resp. FI_{rw}-$O(X)$).

The fuzzy I_{rw}-closure and fuzzy I_{rw}-interior of a fuzzy set λ are respectively, denoted by I_{rw}-$Cl(\lambda)$ and I_{rw}-$Int(\lambda)$ and is defined as
I_{rw}-$Cl(\lambda) = \wedge\{\mu \mid \lambda \leq \mu, \mu \in FI_{rw}$-$C(X)\}$ and
I_{rw}-$Int(\lambda) = \vee\{\mu \mid \lambda \geq \mu, \mu \in FI_{rw}$-$O(X)\}$.

A fuzzy set λ is said to be fuzzy I_{rw}-closed (resp. fuzzy I_{rw}-open) if and only if I_{rw}-$Cl(\lambda) = \lambda$(resp. I_{rw}-$Int(\lambda) = \lambda$). Clearly, I_{rw}-$Cl(1-\lambda) = 1 - I_{rw}$-$Int(\lambda)$ and I_{rw}-$Int(1-\lambda) = I_{rw}$-$Cl(\lambda)$.

Definition 2.5. [3] A function $f : (X, \tau, I) \to (Y, \sigma)$ is called fuzzy continuous if $f^{-1}(\mu)$ is fuzzy open in X for every fuzzy open set $\mu \in Y$.

Definition 2.6. [3] A function $f : (X, \tau) \to (Y, \sigma)$ is called fuzzy open if and only if for any fuzzy open subset λ of X, $f(\lambda) \in \sigma$.

Definition 2.7. [15] A function $f : (X, \tau, I) \to (Y, \sigma)$ is called fuzzy I_{rw}-continuous if $f^{-1}(\mu)$ is fuzzy I_{rw}-open in X for every fuzzy open set $\mu \in Y$.

Definition 2.8. [15] A function $f : (X, \tau, I) \to (Y, \sigma)$ is called fuzzy I_{rw}-irresolute if $f^{-1}(\mu)$ is fuzzy I_{rw}-open in X for every fuzzy I_{rw}-open set $\mu \in Y$.

Definition 2.9. [1] Let (X, τ) be a fts. For $\lambda \in I^X$, λ is called an r-fuzzy rare set if $Int(\lambda) = 0_X$.

Example 2.10. Let $X = \{a,\ b\}$ and a fuzzy set $\lambda \in I^X$ defined as follows: $\lambda(a) = 0.7,\ \lambda(b) = 0.6$. Let $\tau = \{0,\ 1,\ \lambda\}$, be the fuzzy topology on X, a fuzzy set $\mu(= \mu(a) = 0.6, \mu(b) = 0.7)$ of X is fuzzy rare set.

Definition 2.11. Let $(X,\ \tau)$ and $(Y,\ \eta)$ be a fts's. Let $f:(X,\ \tau)\to(Y,\ \eta)$ be a function. Then f is called

(1) weakly continuous [2] if for each fuzzy open set μ of Y, $f^{-1}(\mu)\leq Int(f^{-1}(Cl(\mu)))$.
(2) rarely continuous if for each fuzzy open set μ of Y, there exists an fuzzy rare set λ of Y with $\mu+Cl(\lambda)\geq 1$ and a fuzzy open set ρ of X such that $f(\rho)\leq\mu\vee\lambda$.

Proposition 2.2. [1] *Let $(X,\ \tau)$ and $(Y,\ \sigma)$ be any two fts's, and $f:(X,\ \tau)\to(Y,\ \sigma)$ is fuzzy open and one-to-one, then f preserves fuzzy rare sets.*

3. RARELY FUZZY I_{rw}-CONTINUOUS FUNCTIONS

Definition 3.1. Let $(X,\ \tau)$ and $(Y,\ \sigma)$ be a fts's, and $f:(X,\ \tau)\to(Y,\ \eta)$ be a function. Then f is called

(1) rarely fuzzy rw-continuous if for each fuzzy open set μ of Y, there exists an fuzzy rare set λ of Y with $\mu+Cl(\lambda)$ and a fuzzy rw-open set ρ in X such that $f(\rho)\leq\mu\vee\lambda$.
(2) rarely fuzzy I_{rw}-continuous if for each fuzzy open set μ of Y, there exists an fuzzy rare set λ of Y with $\mu+Cl(\lambda)$ and an I_{rw}-open set ρ of X, such that $f(\rho)\leq\mu\vee\lambda$.

Remark. *Every rarely fuzzy rw-continuous function is rarely fuzzy I_{rw}-continuous but converse need not be true.*

Example 3.2. Let $X=\{a,\ b,\ c,\ d\}$, and $Y=\{p,\ q,\ r,\ s\}$ and the fuzzy sets $\alpha,\ \beta,\ \gamma,\ \delta,\ \lambda$ are defined as follows:

$\alpha(a)=0.5,\ \alpha(b)=0.4,\ \alpha(c)=0.6,\ \alpha(d)=0.4$
$\beta(a)=0.4,\ \beta(b)=0.6,\ \beta(c)=0.4,\ \beta(d)=0.5$
$\gamma(a)=0.5,\ \gamma(b)=0.6,\ \gamma(c)=0.6,\ \gamma(d)=0.5$
$\delta(a)=0.4,\ \delta(b)=0.4,\ \delta(c)=0.4,\ \delta(d)=0.4$
$\lambda(p)=0.5,\ \lambda(q)=0.6,\ \lambda(r)=0.4,\ \lambda(r)=0.5$

Let $\tau=\{0_X,\ 1_X,\ \alpha,\ \beta,\ \gamma,\ \delta\}$ and $\sigma=\{0,\ 1,\ \lambda\}$ be fuzzy topologies on X and Y respectively and $I=\mathcal{P}(X)$ be the fuzzy ideal on X. Then the mapping $f:(X,\ \tau,\ I)\to(Y,\ \sigma)$ defined by $f(a)=p,\ f(b)=q,\ f(c)=r$ and $f(d)=s$ is rarely fuzzy I_{rw}-continuous but not rarely fuzzy rw-continuous, since λ be fuzzy open set in Y and μ be a fuzzy rare set defined by $\mu(p)=0.5,\mu(q)=0.4,\mu(r)=0.6,\mu(s)=0.5$ with $\lambda+Cl(\mu)\geq 1$ and a fuzzy I_{rw}-closed set $\rho(=\lambda)$ of X such that $f(0.5,0.6,0.4,0.5)\leq(0.5,0.6,0.6,0.5)$ but ρ is not fuzzy rw-closed set.

Definition 3.3. Let $(X,\ \tau)$ and $(Y,\ \sigma)$ be a fts's, and $f:(X,\ \tau)\to(Y,\ \eta)$ be a function. Then f is called weakly fuzzy I_{rw}-continuous if for each fuzzy I_{rw}-open set μ of Y, $f^{-1}(\mu)\leq Int_{\tau}(f^{-1}(Cl(\mu)))$.

Definition 3.4. [15] A fts (X,τ) is said to be fuzzy I_{rw}-$T_{1/2}$-space if every I_{rw}-open set λ is fuzzy open set.

Proposition 3.1. *Let $(X,\ \tau)$ and $(Y,\ \sigma)$ be any two fuzzy topological spaces. If $f:(X,\ \tau)\to(Y,\ \sigma)$ is both fuzzy I_{rw}-open, fuzzy I_{rw}-irresolute and $(X,\ \tau)$ is I_{rw}-$T_{1/2}$ space, then it is weakly I_{rw}-continuous.*

Proof. Let λ be a fuzzy open set in X. Since f is fuzzy I_{rw}-open $f(\lambda)$ of Y is I_{rw}-open. Also, since f is fuzzy I_{rw}-irresolute, $f^{-1}(f(\lambda))$ in X is fuzzy I_{rw}-open set. Since $(X,\ \tau)$ is fuzzy I_{rw}-$T_{1/2}$ space, every fuzzy I_{rw}-open set is fuzzy open set, now, $f^{-1}(f(\lambda))$ is fuzzy open. Consider $f^{-1}(f(\lambda))\leq f^{-1}(Cl(f(\lambda)))$ from which $Int(f^{-1}(f(\lambda)))\leq$

$Int(f^{-1}(Cl(f(\lambda))))$. Since $f^{-1}(f(\lambda))$ is fuzzy open in X, $f^{-1}(f(\lambda)) \leq Int(f^{-1}(Cl(f(\lambda))))$. Thus f is weakly fuzzy I_{rw}-continuous. □

Definition 3.5. [15] A collection $\{\lambda_i : i \in \wedge\}$ of fuzzy I_{rw}-open sets in a fuzzy ideal topological space $(X,\ \tau,\ I)$ is called a fuzzy I_{rw}-open cover of a fuzzy set μ of X if $\mu \leq \bigcup\{\lambda_i : i \in \wedge\}$.

Definition 3.6. [15] A fuzzy ideal topological space $(X,\ \tau,\ I)$ is said to be fuzzy I_{rw}-compact if every fuzzy I_{rw}-open cover of X has a finite subcover.

Definition 3.7. [15] A fuzzy set μ of a fuzzy ideal topological space $(X,\ \tau,\ I)$ is said to be fuzzy I_{rw}-compact if for every collection $\{\lambda_i : i \in \wedge\}$ of fuzzy I_{rw}-open subsets of X such that $\mu \leq \bigcup\{\lambda_i : i \in \wedge\}$ there exists a finite subset $\wedge_0$ and $\wedge$ such that $\mu \leq \{\lambda_i : i \in \wedge_0\}$.

Definition 3.8. [15] A crisp subset μ of a fuzzy ideal topological space $(X,\ \tau,\ I)$ is said to be fuzzy I_{rw}-compact if μ is fuzzy I_{rw}-compact as a fuzzy ideal subspace of X.

Definition 3.9. A fts (X, τ) is said to be rarely fuzzy I_{rw}-almost compact if every fuzzy I_{rw}-open cover $\{\lambda_i \in X,\ \lambda_i$ is fuzzy I_{rw}-open, $i \in J\}$ of (X, τ), there exists a finite subset J_0 of J such that $\bigvee_{i\in J} \lambda_i \vee \rho_i = 1$ where $\rho_i \in X$ are fuzzy rare sets.

Proposition 3.2. *Let $(X,\ \tau, I)$ and $(Y,\ \sigma)$ be any two fts's, and $f : (X,\ \tau, I) \to (Y,\ \sigma)$ be rarely fuzzy I_{rw}-continuous. If $(X,\ \tau)$ is fuzzy I_{rw}-compact then $(Y,\ \sigma)$ is rarely fuzzy I_{rw}-almost compact.*

Proof. Let $\{\lambda_i \in Y,\ i \in J\}$ be fuzzy I_{rw}-open cover of (Y, σ). Then $1 = \vee_{i\in J}\lambda_i$. Since f is rarely fuzzy I_{rw}-continuous, there exists an fuzzy rare sets ρ_i of Y such that $\lambda_i + Cl(\rho_i) \geq 1$ and an fuzzy I_{rw}-open set μ_i of X such that $f(\mu_i) \leq \lambda_i \vee \rho_i$. Since (X, τ) is fuzzy I_{rw}-compact, every fuzzy I_{rw}-open cover of (X, τ) has a finite sub cover. Thus $1 \leq \vee_{i\in J_0}\mu_i$. Hence $1 = f(1) = f(\vee_{i\in J_0}\mu_i) = \vee_{i\in J_0} f(\mu_i) \leq \vee_{i\in J_0}\lambda_i \vee \rho_i$. Therefore (Y, σ) is rarely fuzzy I_{rw}-almost compact. □

Proposition 3.3. *Let $(X,\ \tau.I)$ and $(Y,\ \sigma)$ be any two fts's, and $f : (X,\ \tau, I) \to (Y,\ \sigma)$ be rarely fuzzy rw-continuous. If $(X,\ \tau)$ is fuzzy I_{rw}-compact then $(Y,\ \sigma)$ is rarely fuzzy I_{rw}-almost compact.*

Proof. Since every rarely fuzzy rw-continuous function is rarely fuzzy I_{rw}-continuous, then proof follows immediately from the Proposition 3.2. □

Proposition 3.4. *Let $(X,\ \tau, I)$, $(Y,\ \sigma, J)$ and $(Z,\ \eta)$ be any fts's. If $f : (X,\ \tau, I) \to (Y,\ \sigma, J)$ be rarely fuzzy I_{rw}-continuous, fuzzy I_{rw}-open and $g : (Y,\ \sigma, J) \to (Z,\ \eta)$ is fuzzy open and one-to-one, then $g \circ f : (X,\ \tau, I) \to (Z,\ \eta)$ is rarely fuzzy I_{rw}-continuous.*

Proof. Let λ be a fuzzy open set in X. Since f is fuzzy I_{rw}-open $f(\lambda)$ in Y with $f(\lambda)$ is fuzzy open. Since f is rarely fuzzy I_{rw}-continuous, there exists an fuzzy rare set ρ in Y with $f(\lambda) + Cl(\rho) \geq 1$ and an fuzzy I_{rw}-open set μ in X such that $f(\mu) \leq f(\lambda) \vee \rho$. By the proposition 2.2, $g(\rho)$ in Z is also an fuzzy rare set. Since $\rho$of Y is such that $\rho < \gamma$ for all γ of Y with γ is fuzzy open in Y, and g is injective, it follows that $(g \circ f)(\lambda) + Cl(g(\rho)) \geq 1$. Then $(g \circ f)(\mu) = g(f(\mu)) \leq g(f(\lambda) \vee \rho) \leq g(f(\lambda)) \vee g(\rho) \leq (g \circ f)(\lambda) \vee g(\rho)$. Hence the result. □

Proposition 3.5. *Let $(X,\ \tau, I)$, $(Y,\ \sigma, J)$ and $(Z,\ \eta)$ be any fts's. If $f : (X,\ \tau, I) \to (Y,\ \sigma, J)$ be fuzzy I_{rw}-open, onto and $g : (Y,\ \sigma, J) \to (Z,\ \eta)$ be a function such that $g \circ f : (X,\ \tau, I) \to (Z,\ \eta)$ is rarely fuzzy I_{rw}-continuous, then g is rarely fuzzy I_{rw}-continuous.*

Proof. Let λ be fuzzy set in X and μ be a fuzzy set in Y be such that $f(\lambda) = \mu$. Let $(g \circ f)(\lambda) = \gamma$ in Z with γ is fuzzy open. Since $(g \circ f)$ is fuzzy I_{rw}-continuous, there exists a rare set ρ in Z with $\gamma + Cl(\rho) \geq 1$ and an fuzzy I_{rw}-open set δ in X such that $(g \circ f)(\delta) \leq \gamma \vee \rho$. Since f is fuzzy I_{rw}-open, $f(\delta)$ is an fuzzy I_{rw}-open set in Y. Thus there exists a fuzzy rare set ρ of Z with $\gamma + Cl(\rho) \geq 1$ and an fuzzy I_{rw}-open set $f(\delta)$ in Y such that $g(f(\delta)) \leq \gamma \vee \rho$. Hence g is rarely fuzzy I_{rw}-continuous. □

Proposition 3.6. *Let $(X,\ \tau, I)$ and $(Y,\ \sigma)$ be any two fuzzy topological spaces. If $f : (X,\ \tau, I) \to (Y,\ \sigma)$ is rarely fuzzy I_{rw}-continuous and $(X,\ \tau, I)$ is fuzzy I_{rw}-$T_{1/2}$-space, then f is rarely continuous.*

Proof. The proof is trivial. □

Definition 3.10. A fts (X, τ) is said to be rarely fuzzy I_{rw}-T_2-space if for each pair $\lambda,\ \mu$ of X with $\lambda \neq \mu$ there exist fuzzy I_{rw}-open sets $\rho_1,\ \rho_2$ in X with $\rho_1 \neq \rho_2$ and a fuzzy rare set γ of X with $\rho_1 + Cl(\gamma) \geq 1$ and $\rho_2 + Cl(\gamma) \geq 1$ such that $\lambda \leq \rho_1 \vee \gamma$ and $\mu \leq \rho_2 \vee \gamma$.

Proposition 3.7. *Let $(X,\ \tau, I)$ and $(Y,\ \sigma, J)$ be any two fuzzy topological spaces. If $f : (X,\ \tau, I) \to (Y,\ \sigma)$ is fuzzy I_{rw}-open and injective and $(X,\ \tau, I)$ is rarely fuzzy I_{rw}-T_2 space, then $(Y,\ \sigma)$ is also a rarely fuzzy I_{rw}-T_2 space.*

Proof. Let λ and μ be a fuzzy set of X with $\lambda \neq \mu$. Since f is injective, $f(\lambda) \neq f(\mu)$. Since $(X,\ \tau, I)$ is rarely fuzzy I_{rw}-T_2-space, there exist fuzzy I_{rw}-open sets $\rho_1,\ \rho_2$ in X with $\rho_1 \neq \rho_2$ and a fuzzy rare set γ in X with $\rho_1 + Cl(\gamma) \geq 1$ and $\rho_2 + Cl(\gamma) \geq 1$ such that $\lambda \leq \rho_1 \vee \gamma$ and $\mu \leq \rho_2 \vee \gamma$. Since f is fuzzy I_{rw}-open, $f(\rho_1),\ f(\rho_2)$ in Y are fuzzy I_{rw}-open sets with $f(\rho_1) \neq f(\rho_2)$. Since f is fuzzy I_{rw}-open and one-to-one, $f(\gamma)$ is also an fuzzy rare set with $f(\rho_1) + Cl(\gamma) \geq 1$ and $f(\rho_2) + Cl(\gamma) \geq 1$ such that $f(\lambda) \leq f(\rho_1 \vee \gamma)$ and $f(\mu) \leq f(\rho_1 \vee \gamma)$. Thus $(Y,\ \sigma, J)$ is rarely fuzzy I_{rw}-T_2-space. □

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