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FUZZY IRRESOLUTE FUNCTIONS VIA FUZZY $\mathscr{C}$-OPEN SETS

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ABSTRACT. The fuzzy continuity of $f : X \to Y$ is defined as the pre image of a fuzzy open subset of Y is fuzzy open in X. The fuzzy irresolute function of $f : X \to Y$ is defined as the pre image of a fuzzy nearly open subset of Y is fuzzy nearly open in X. In this paper a new class of fuzzy irresoluteness is introduced using fuzzy $\mathscr{C}$-open sets and their properties are investigated.

1. INTRODUCTION

The notions fuzzy irresoluteness are studied by Yalvac [1], Mukherjee and Sinha [2], Malakar [3], Caldas [4], [5], and Seenivasan [6], [7]. In 2016 [8], Xavier and Thangavelu introduced fuzzy $\mathscr{C}$-open sets using arbitrary complement function $\mathscr{C} : [0,1] \to [0,1]$. In 2017 [9], the fuzzy $\mathscr{C}$-interior operator are defined by fuzzy $\mathscr{C}$-open sets. Further fuzzy nearly $\mathscr{C}$-open sets are investigated using fuzzy $\mathscr{C}$-interior operator and fuzzy closure operator. Later fuzzy $\mathscr{C}$-continuity are defined using fuzzy nearly $\mathscr{C}$-open sets. In this paper the fuzzy irresolute functions are defined using fuzzy nearly $\mathscr{C}$-open sets and their properties are studied.

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2. Preliminaries

Definition 2.1. *[10]*

(i) λ *is fuzzy regular* $\mathscr{C}$*-open*$(RO_{\mathscr{C}})$*, if* $int_{\mathscr{C}}(cl(\lambda)) = \lambda$;

(ii) λ *is fuzzy* α*-*$\mathscr{C}$*-*$open(\alpha O_{\mathscr{C}})$*, if* $\lambda \leq int_{\mathscr{C}}(cl(int_{\mathscr{C}}(\lambda)))$;

(iii) λ *is fuzzy semi* $\mathscr{C}$*-open*$(SO_{\mathscr{C}})$*, if* $\lambda \leq cl(int_{\mathscr{C}}(\lambda))$;

(iv) λ *is fuzzy pre* $\mathscr{C}$*-open*$(PO_{\mathscr{C}})$*, if* $\lambda \leq int_{\mathscr{C}}(cl(\lambda))$;

(v) λ *is fuzzy semi pre* $\mathscr{C}$*-open*$(\beta O_{\mathscr{C}})$*, if* $\lambda \leq cl(int_{\mathscr{C}}(cl(\lambda)))$;

(vi) λ *is fuzzy b-*$\mathscr{C}$*-open*$(BO_{\mathscr{C}})$*, if* $\lambda \leq cl(int_{\mathscr{C}}(\lambda)) \vee int_{\mathscr{C}}(cl(\lambda))$;

(vii) λ *is fuzzy* $b^{\#}$*-*$\mathscr{C}$*-open*$(b^{\#}O_{\mathscr{C}})$*, if* $\lambda = cl(int_{\mathscr{C}}(\lambda)) \vee int_{\mathscr{C}}(cl(\lambda))$.

The standard complement of fuzzy regular open (fuzzy α-open, fuzzy semi open, fuzzy pre open, fuzzy semi pre open, fuzzy b-open, fuzzy $b^{\#}$-open) is fuzzy regular closed (fuzzy α-closed, fuzzy semi closed, fuzzy pre closed, fuzzy semi pre closed, fuzzy b-closed, fuzzy $b^{\#}$-closed). The analogues result is not true for the above said fuzzy nearly $\mathscr{C}$-open sets.

Definition 2.2. *[10]*

(i) λ *is fuzzy regular* $\mathscr{C}$*-closed, if* $cl(int_{\mathscr{C}}(\lambda)) = \lambda$;

(ii) λ *is fuzzy* α*-*$\mathscr{C}$*-*$closed$*, if* $cl(int_{\mathscr{C}}(cl(\lambda))) \leq \lambda$;

(iii) λ *is fuzzy semi* $\mathscr{C}$*-closed, if* $int_{\mathscr{C}}(cl(\lambda)) \leq \lambda$;

(iv) λ *is fuzzy pre* $\mathscr{C}$*-closed, if* $cl(int_{\mathscr{C}}(\lambda)) \leq \lambda$;

(v) λ *is fuzzy semi pre* $\mathscr{C}$*-closed, if* $int_{\mathscr{C}}(cl(int_{\mathscr{C}}(\lambda))) \leq \lambda$;

(vi) λ *is fuzzy b-*$\mathscr{C}$*-closed, if* $\lambda \geq cl(int_{\mathscr{C}}(\lambda)) \wedge int_{\mathscr{C}}(cl(\lambda))$;

(vii) λ *is fuzzy* $b^{\#}$*-*$\mathscr{C}$*-closed, if* $int_{\mathscr{C}}(cl(\lambda)) \wedge cl(int_{\mathscr{C}}(\lambda)) = \lambda$.

Definition 2.3. *[10] A function* $f : (X, \tau) \to (Y, \sigma)$ *be a function and* $\mathscr{C}$ *be a complement function. Then* f *is said to be*

(i) *fuzzy* $\mathscr{C}$*-continuous if* $f^{-1}(\mu)$ *is fuzzy* $\mathscr{C}$*-open for each fuzzy open subset* μ *of* Y.

(ii) *fuzzy regular* $\mathscr{C}$*-continuous if* $f^{-1}(\mu)$ *is fuzzy regular* $\mathscr{C}$*-open for each fuzzy open subset* μ *of* Y.

(iii) *fuzzy* α*-*$\mathscr{C}$*-continuous if* $f^{-1}(\mu)$ *is fuzzy* α*-*$\mathscr{C}$*-open for each fuzzy open subset* μ *of* Y.

(iv) *fuzzy semi* $\mathscr{C}$*-continuous if* $f^{-1}(\mu)$ *is fuzzy semi* $\mathscr{C}$*-open for each fuzzy open subset* μ *of* Y.

(v) *fuzzy pre $\mathscr{C}$-continuous if $f^{-1}(\mu)$ is fuzzy pre $\mathscr{C}$-open for each fuzzy open subset μ of Y.*

(vi) *fuzzy semi pre $\mathscr{C}$-continuous if $f^{-1}(\mu)$ is fuzzy semi pre $\mathscr{C}$-open for each fuzzy open subset μ of Y.*

(vii) *fuzzy b-$\mathscr{C}$-continuous if $f^{-1}(\mu)$ is fuzzy b-$\mathscr{C}$-open for each fuzzy open subset μ of Y.*

(viii) *fuzzy $b^{\#}$-$\mathscr{C}$-continuous if $f^{-1}(\mu)$ is fuzzy $b^{\#}$-$\mathscr{C}$-open for each fuzzy open subset μ of Y.*

Lemma 2.1. *[8] A function of $f:(X,\tau)\to(Y,\sigma)$ is fuzzy continuous if and only if $f^{-1}(\lambda)$ is a fuzzy $\mathscr{C}$-open subset of X for each fuzzy $\mathscr{C}$-open set λ of Y, where $\mathscr{C}$ satisfies the monotonic and involutive conditions.*

3. Fuzzy $\mathscr{C}$-IRRESOLUTENESS

Definition 3.1. *Let $f:(X,\tau)\to(Y,\sigma)$ be a function and $\mathscr{C}$ be a complement function. Then f is*

(i) *fuzzy regular $\mathscr{C}$-irresolute if it induces a function $f^{-1}: RO_{\mathscr{C}}(Y,\sigma)\to RO_{\mathscr{C}}(X,\tau)$.*

(ii) *fuzzy α-$\mathscr{C}$-irresolute if it induces a function $f^{-1}:\alpha O_{\mathscr{C}}(Y,\sigma)\to\alpha O_{\mathscr{C}}(X,\tau)$.*

(iii) *fuzzy semi $\mathscr{C}$-irresolute if it induces a function $f^{-1}: SO_{\mathscr{C}}(Y,\sigma)\to SO_{\mathscr{C}}(X,\tau)$.*

(iv) *fuzzy pre $\mathscr{C}$-irresolute if it induces a function $f^{-1}: PO_{\mathscr{C}}(Y,\sigma)\to PO_{\mathscr{C}}(X,\tau)$.*

(v) *fuzzy semi pre $\mathscr{C}$-irresolute if it induces a function $f^{-1}:\beta O_{\mathscr{C}}(Y,\sigma)\to\beta O_{\mathscr{C}}(X,\tau)$.*

(vi) *fuzzy b-$\mathscr{C}$-irresolute if it induces a function $f^{-1}: BO_{\mathscr{C}}(Y,\sigma)\to BO_{\mathscr{C}}(X,\tau)$.*

(vii) *fuzzy $b^{\#}$-$\mathscr{C}$-irresolute if it induces a function $f^{-1}: b^{\#}O_{\mathscr{C}}(Y,\sigma)\to b^{\#}O_{\mathscr{C}}(X,\tau)$.*

Theorem 3.1. *Suppose $f:(X,\tau)\to(Y,\sigma)$ be a function and $\mathscr{C}$ be a complement function that satisfies monotonic and involutive conditions. Then f is fuzzy regular $\mathscr{C}$-irresolute if and only if $f^{-1}(\lambda)$ is fuzzy regular $\mathscr{C}$-closed in X, for every fuzzy regular $\mathscr{C}$-closed in Y .*

Proof. Suppose f is fuzzy regular-$\mathscr{C}$-irresolute. Let λ be fuzzy regular-$\mathscr{C}$-closed in Y. Since $\mathscr{C}$ satisfies monotonic and involutive conditions, $\mathscr{C}\lambda$ is fuzzy regular-$\mathscr{C}$-open in Y. Then $f^{-1}(\mathscr{C}\lambda)$ is fuzzy regular $\mathscr{C}$-open in $X \Rightarrow \mathscr{C}(f^{-1}(\lambda))$ is fuzzy regular $\mathscr{C}$-open in $X \Rightarrow f^{-1}(\lambda)$ is fuzzy regular $\mathscr{C}$-closed in X.

Conversely, assume that $f^{-1}(\lambda)$ is fuzzy regular $\mathscr{C}$-closed in X. Let λ be fuzzy regular $\mathscr{C}$-open in Y. Since $\mathscr{C}$ satisfies involutive condition, $\mathscr{C}(\mathscr{C}\lambda)$ is fuzzy regular $\mathscr{C}$-open. Then $\mathscr{C}\lambda$ is fuzzy regular $\mathscr{C}$-closed in Y. By assumption $f^{-1}(\mathscr{C}\lambda)$ is fuzzy regular $\mathscr{C}$-closed in X. Then $\mathscr{C}(f^{-1}(\lambda))$ is fuzzy regular-$\mathscr{C}$-closed in $X \Rightarrow \mathscr{C}(\mathscr{C}(f^{-1}(\lambda)))$ is fuzzy regular $\mathscr{C}$-open in X. Since $\mathscr{C}$ satisfies involutive condition,$f^{-1}(\lambda)$ is fuzzy regular $\mathscr{C}$-open in X. Thus f is fuzzy regular $\mathscr{C}$-irresolute. □

Theorem 3.2. *Suppose $f : (X,\tau) \to (Y,\sigma)$ be a function and $\mathscr{C}$ be a complement function that satisfies monotonic and involutive conditions. Then f is fuzzy α-$\mathscr{C}$-irresolute if and only if $f^{-1}(\lambda)$ is fuzzy α-$\mathscr{C}$-closed in X, for every fuzzy α-$\mathscr{C}$-closed in Y .*

Proof. Suppose f is fuzzy α-$\mathscr{C}$-irresolute. Let λ be fuzzy α-$\mathscr{C}$-closed in Y. Since $\mathscr{C}$ satisfies monotonic and involutive conditions, $\mathscr{C}\lambda$ is fuzzy α-$\mathscr{C}$-open in Y. Then $f^{-1}(\mathscr{C}\lambda)$ is fuzzy α-$\mathscr{C}$-open in $X \Rightarrow \mathscr{C}(f^{-1}(\lambda))$ is fuzzy α-$\mathscr{C}$-open in X $\Rightarrow f^{-1}(\lambda)$ is fuzzy α-$\mathscr{C}$-closed in X.

Conversely, assume that $f^{-1}(\lambda)$ is fuzzy α-$\mathscr{C}$-closed in X. Let λ be fuzzy α-$\mathscr{C}$-open in Y. Since $\mathscr{C}$ satisfies involutive condition, $\mathscr{C}(\mathscr{C}\lambda)$ is fuzzy α-$\mathscr{C}$-open. Then $\mathscr{C}\lambda$ is fuzzy α-$\mathscr{C}$-closed in Y. By assumption $f^{-1}(\mathscr{C}\lambda)$ is fuzzy α-$\mathscr{C}$-closed in X. Then $\mathscr{C}(f^{-1}(\lambda))$ is fuzzy α-$\mathscr{C}$-closed in $X \Rightarrow \mathscr{C}(\mathscr{C}(f^{-1}(\lambda)))$ is fuzzy α-$\mathscr{C}$-open in X. Since $\mathscr{C}$ satisfies involutive condition,$f^{-1}(\lambda)$ is fuzzy α-$\mathscr{C}$-open in X. Thus f is fuzzy α-$\mathscr{C}$-irresolute. □

Theorem 3.3. *Suppose $f : (X,\tau) \to (Y,\sigma)$ be a function and $\mathscr{C}$ be a complement function that satisfies monotonic and involutive conditions. Then f is fuzzy semi $\mathscr{C}$-irresolute if and only if $f^{-1}(\lambda)$ is fuzzy semi $\mathscr{C}$-closed in X, for every fuzzy semi $\mathscr{C}$-closed in Y .*

Proof. Suppose f is fuzzy semi $\mathscr{C}$-irresolute. Let λ be fuzzy semi $\mathscr{C}$-closed in Y. Since $\mathscr{C}$ satisfies monotonic and involutive conditions, $\mathscr{C}\lambda$ is fuzzy semi $\mathscr{C}$-open in Y. Then $f^{-1}(\mathscr{C}\lambda)$ is fuzzy semi $\mathscr{C}$-open in $X \Rightarrow \mathscr{C}(f^{-1}(\lambda))$ is fuzzy semi $\mathscr{C}$-open in $X \Rightarrow f^{-1}(\lambda)$ is fuzzy semi $\mathscr{C}$-closed in X.

Conversely, assume that $f^{-1}(\lambda)$ is fuzzy semi $\mathscr{C}$-closed in X. Let λ be fuzzy semi $\mathscr{C}$-open in Y. Since $\mathscr{C}$ satisfies involutive condition, $\mathscr{C}(\mathscr{C}\lambda)$ is fuzzy semi $\mathscr{C}$-open. Then $\mathscr{C}\lambda$ is fuzzy semi $\mathscr{C}$-closed in Y. By assumption $f^{-1}(\mathscr{C}\lambda)$ is fuzzy semi $\mathscr{C}$-closed in X. Then $\mathscr{C}(f^{-1}(\lambda))$ is fuzzy semi $\mathscr{C}$-closed in X

$\Rightarrow \mathscr{C}(\mathscr{C}(f^{-1}(\lambda)))$ is fuzzy semi $\mathscr{C}$-open in X. Since $\mathscr{C}$ satisfies involutive condition,$f^{-1}(\lambda)$ is fuzzy semi $\mathscr{C}$-open in X. Thus f is fuzzy semi $\mathscr{C}$-irresolute. □

Theorem 3.4. *Suppose $f : (X, \tau) \to (Y, \sigma)$ be a function and $\mathscr{C}$ be a complement function that satisfies monotonic and involutive conditions. Then f is fuzzy pre $\mathscr{C}$-irresolute if and only if $f^{-1}(\lambda)$ is fuzzy pre $\mathscr{C}$-closed in X, for every fuzzy pre $\mathscr{C}$-closed in Y .*

Proof. Suppose f is fuzzy pre $\mathscr{C}$-irresolute. Let λ be fuzzy pre $\mathscr{C}$-closed in Y. Since $\mathscr{C}$ satisfies monotonic and involutive conditions, $\mathscr{C}\lambda$ is fuzzy pre $\mathscr{C}$-open in Y. Then $f^{-1}(\mathscr{C}\lambda)$ is fuzzy pre $\mathscr{C}$-open in $X \Rightarrow \mathscr{C}(f^{-1}(\lambda))$ is fuzzy pre $\mathscr{C}$-open in $X \Rightarrow f^{-1}(\lambda)$ is fuzzy pre $\mathscr{C}$-closed in X.

Conversely, assume that $f^{-1}(\lambda)$ is fuzzy pre $\mathscr{C}$-closed in X. Let λ be fuzzy pre $\mathscr{C}$-open in Y. Since $\mathscr{C}$ satisfies involutive condition, $\mathscr{C}(\mathscr{C}\lambda)$ is fuzzy pre $\mathscr{C}$-open. Then $\mathscr{C}\lambda$ is fuzzy pre $\mathscr{C}$-closed in Y. By assumption $f^{-1}(\mathscr{C}\lambda)$ is fuzzy pre $\mathscr{C}$-closed in X. Then $\mathscr{C}(f^{-1}(\lambda))$ is fuzzy pre $\mathscr{C}$-closed in $X \Rightarrow \mathscr{C}(\mathscr{C}(f^{-1}(\lambda)))$ is fuzzy pre $\mathscr{C}$-open in X. Since $\mathscr{C}$ satisfies involutive condition,$f^{-1}(\lambda)$ is fuzzy pre $\mathscr{C}$-open in X. Thus f is fuzzy pre $\mathscr{C}$-irresolute. □

Theorem 3.5. *Suppose $f : (X, \tau) \to (Y, \sigma)$ be a function and $\mathscr{C}$ be a complement function that satisfies monotonic and involutive conditions. Then f is fuzzy semi pre $\mathscr{C}$-irresolute if and only if $f^{-1}(\lambda)$ is fuzzy semi pre $\mathscr{C}$-closed in X, for every fuzzy semi pre $\mathscr{C}$-closed in Y .*

Proof. Suppose f is fuzzy semi pre $\mathscr{C}$-irresolute. Let λ be fuzzy semi pre $\mathscr{C}$-closed in Y. Since $\mathscr{C}$ satisfies monotonic and involutive conditions, $\mathscr{C}\lambda$ is fuzzy semi pre $\mathscr{C}$-open in Y. Then $f^{-1}(\mathscr{C}\lambda)$ is fuzzy semi pre $\mathscr{C}$-open in X $\Rightarrow \mathscr{C}(f^{-1}(\lambda))$ is fuzzy semi pre $\mathscr{C}$-open in $X \Rightarrow f^{-1}(\lambda)$ is fuzzy semi pre $\mathscr{C}$-closed in X.

Conversely, assume that $f^{-1}(\lambda)$ is fuzzy semi pre $\mathscr{C}$-closed in X. Let λ be fuzzy semi pre $\mathscr{C}$-open in Y. Since $\mathscr{C}$ satisfies involutive condition, $\mathscr{C}(\mathscr{C}\lambda)$ is fuzzy semi pre $\mathscr{C}$-open. Then $\mathscr{C}\lambda$ is fuzzy semi pre $\mathscr{C}$-closed in Y. By assumption $f^{-1}(\mathscr{C}\lambda)$ is fuzzy semi pre $\mathscr{C}$-closed in X. Then $\mathscr{C}(f^{-1}(\lambda))$ is fuzzy semi pre $\mathscr{C}$-closed in $X \Rightarrow \mathscr{C}(\mathscr{C}(f^{-1}(\lambda)))$ is fuzzy semi pre $\mathscr{C}$-open in X. Since $\mathscr{C}$ satisfies involutive condition,$f^{-1}(\lambda)$ is fuzzy semi pre $\mathscr{C}$-open in X. Thus f is fuzzy semi pre $\mathscr{C}$-irresolute. □

Theorem 3.6. *Suppose $f : (X, \tau) \to (Y, \sigma)$ be a function and $\mathscr{C}$ be a complement function that satisfies monotonic and involutive conditions. Then f is fuzzy b-$\mathscr{C}$-irresolute if and only if $f^{-1}(\lambda)$ is fuzzy b-$\mathscr{C}$-closed in X, for every fuzzy b-$\mathscr{C}$-closed in Y .*

Proof. Suppose f is fuzzy b-$\mathscr{C}$-irresolute. Let λ be fuzzy b-$\mathscr{C}$-closed in Y. Since $\mathscr{C}$ satisfies monotonic and involutive conditions, $\mathscr{C}\lambda$ is fuzzy b-$\mathscr{C}$-open in Y. Then $f^{-1}(\mathscr{C}\lambda)$ is fuzzy b-$\mathscr{C}$-open in $X \Rightarrow \mathscr{C}(f^{-1}(\lambda))$ is fuzzy b-$\mathscr{C}$-open in X $\Rightarrow f^{-1}(\lambda)$ is fuzzy b-$\mathscr{C}$-closed in X.

Conversely, assume that $f^{-1}(\lambda)$ is fuzzy b-$\mathscr{C}$-closed in X. Let λ be fuzzy b-$\mathscr{C}$-open in Y. Since $\mathscr{C}$ satisfies involutive condition, $\mathscr{C}(\mathscr{C}\lambda)$ is fuzzy b-$\mathscr{C}$-open. Then $\mathscr{C}\lambda$ is fuzzy b-$\mathscr{C}$-closed in Y. By assumption $f^{-1}(\mathscr{C}\lambda)$ is fuzzy b-$\mathscr{C}$-closed in X. Then $\mathscr{C}(f^{-1}(\lambda))$ is fuzzy b-$\mathscr{C}$-closed in $X \Rightarrow \mathscr{C}(\mathscr{C}(f^{-1}(\lambda)))$ is fuzzy b-$\mathscr{C}$-open in X. Since $\mathscr{C}$ satisfies involutive condition,$f^{-1}(\lambda)$ is fuzzy b-$\mathscr{C}$-open in X. Thus f is fuzzy b-$\mathscr{C}$-irresolute. □

Theorem 3.7. *Suppose $f : (X, \tau) \to (Y, \sigma)$ be a function and $\mathscr{C}$ be a complement function that satisfies monotonic and involutive conditions. Then f is fuzzy $b^{\#}$-$\mathscr{C}$-irresolute if and only if $f^{-1}(\lambda)$ is fuzzy $b^{\#}$-$\mathscr{C}$-closed in X, for every fuzzy $b^{\#}$-$\mathscr{C}$-closed in Y .*

Proof. Suppose f is fuzzy $b^{\#}$-$\mathscr{C}$-irresolute. Let λ be fuzzy $b^{\#}$-$\mathscr{C}$-closed in Y. Since $\mathscr{C}$ satisfies monotonic and involutive conditions, $\mathscr{C}\lambda$ is fuzzy $b^{\#}$-$\mathscr{C}$-open in Y. Then $f^{-1}(\mathscr{C}\lambda)$ is fuzzy $b^{\#}$-$\mathscr{C}$-open in $X \Rightarrow \mathscr{C}(f^{-1}(\lambda))$ is fuzzy $b^{\#}$-$\mathscr{C}$-open in $X \Rightarrow f^{-1}(\lambda)$ is fuzzy $b^{\#}$-$\mathscr{C}$-closed in X.

Conversely, assume that $f^{-1}(\lambda)$ is fuzzy $b^{\#}$-$\mathscr{C}$-closed in X. Let λ be fuzzy $b^{\#}$-$\mathscr{C}$-open in Y. Since $\mathscr{C}$ satisfies involutive condition, $\mathscr{C}(\mathscr{C}\lambda)$ is fuzzy $b^{\#}$-$\mathscr{C}$-open. Then $\mathscr{C}\lambda$ is fuzzy $b^{\#}$-$\mathscr{C}$-closed in Y. By assumption $f^{-1}(\mathscr{C}\lambda)$ is fuzzy $b^{\#}$-$\mathscr{C}$-closed in X. Then $\mathscr{C}(f^{-1}(\lambda))$ is fuzzy $b^{\#}$-$\mathscr{C}$-closed in $X \Rightarrow \mathscr{C}(\mathscr{C}(f^{-1}(\lambda)))$ is fuzzy $b^{\#}$-$\mathscr{C}$-open in X. Since $\mathscr{C}$ satisfies involutive condition,$f^{-1}(\lambda)$ is fuzzy $b^{\#}$-$\mathscr{C}$-open in X. Thus f is fuzzy $b^{\#}$-$\mathscr{C}$-irresolute. □

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