International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume 4, Issue 1 (January-February, 2016), PP. 160-163

INTUITIONISTIC FUZZY QUASI RGA-OPEN AND INTUITIONISTIC FUZZY QUASI RGA -CLOSED MAPPINGS

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Abstract: **An intuitionistic fuzzy set A is said to be intuitionistic fuzzy rgα-closed [21] in intuitionistic fuzzy topological spaces if αcl(A) ⊆ U whenever A ⊆ U and U is intuitionistic fuzzy regular α- open in X. In this paper we introduce quasi rgα -open mapping from intuitionistic fuzzy topological space X to intuitionistic fuzzy topological Y as the image of every intuitionistic fuzzy rgα -open set is intuitionistic fuzzy open. Also we obtain its Characterization and basic properties.**

Keywords: **Intuitionistic fuzzy rgα -closed set, intuitionistic fuzzy rgα -open sets, intuitionistic fuzzy rgα -continuous mappings, intuitionistic fuzzy quasi rgα -open mappings, intuitionistic fuzzy quasi rgα -closed mappings.**

I. INTRODUCTION

Mapping plays an important role in study of modern mathematics, especially in Topology and Functional Analysis. Closed and open mapping are one such mapping which are studied for different type of closed sets by various mathematicians for the past many years. . The concept of intuitionistic fuzzy sets was introduced by Atanassov [1] as a generalization of fuzzy sets. In 1997 Coker [5] introduced the concept of intuitionistic fuzzy topological spaces. In 2008, Thakur and Chaturvedi [14] introduced the notion of intuitionistic fuzzy generalized closed set in intuitionistic fuzzy topological space. Since then different mathematicians worked and studied in different forms of intuitionistic fuzzy g-closed set and related topological properties. The authors of the paper introduced the concepts of intuitionistic fuzzy sg-closed sets [7] , intuitionistic fuzzy sg-continuous mappings[17], intuitionistic fuzzy sg-irresolute mappings[18], intuitionistic fuzzy rw-closed sets[20], intuitionistic fuzzy w-closed sets[19], intuitionistic fuzzy rgα-closed sets[21], intuitionistic fuzzy rgα continuity [8] , intuitionistic fuzzy gpr-closed sets[22], intuitionistic fuzzy gpr open and gpr-closed mappings [9] , intuitionistic fuzzy g-open and g-closed mappings [16] , intuitionistic fuzzy sg-open and sg-closed mappings [11] in intuitionistic fuzzy topology. In this paper we will continue the study of related concepts by involving intuitionistic fuzzy rgα-open sets. We introduce and characterize the concepts of intuitionistic fuzz*y* quasi rgα- -open and intuitionistic fuzzy quasi rgα--closed mappings.

II. PRELIMINARIES

Definition 2.1: An intuitionistic fuzzy set A of an intuitionistic fuzzy topological space (X,ℑ) is called:

(a) Intuitionistic fuzzy g-closed if cl (A) ⊆ O whenever A ⊆ O and O is intuitionistic fuzzy open.[14]
(b) Intuitionistic fuzzy g-open if its complement A^c is intuitionistic fuzzy g-closed.[14]
(c) Intuitionistic fuzzy sg-closed if cl (A) ⊆ O whenever A ⊆ O and O is intuitionistic fuzzy regular open.[7]
(d) Intuitionistic fuzzy sg-open if its complement A^c is intuitionistic fuzzy rg-closed.[7]
(e) Intuitionistic fuzzy w-closed if cl (A) ⊆ O whenever A ⊆ O and O is intuitionistic fuzzy semi open.[19]
(f) Intuitionistic fuzzy w -open if its complement A^c is intuitionistic fuzzy w-closed.[19]
(g) Intuitionistic fuzzy rw-closed if cl (A) ⊆ O whenever A ⊆ O and O is intuitionistic fuzzy regular semi open.[20]
(h) Intuitionistic fuzzy rw -open if its complement A^c is intuitionistic fuzzy rw-closed.[20]
(i) Intuitionistic fuzzy gpr-closed if pcl (A) ⊆ O whenever A ⊆ O and O is intuitionistic fuzzy regular open.[22]
(j) Intuitionistic fuzzy gpr -open if its complement A^c is intuitionistic fuzzy gpr-closed.[22]
(k) Intuitionistic fuzzy rgα -closed if αcl (A) ⊆ O whenever A ⊆ O and O is intuitionistic fuzzy regular alpha open.[21]
(l) Intuitionistic fuzzy rgα-open if its complement A^c is intuitionistic fuzzy rgα-closed.[21]

Definition 2.2 [21] The rgα - interior and rgα - closure of an intuitionistic fuzzy set A of an intuitionistic fuzzy topological space (X,ℑ) respectively denoted by rgαint(A) and rgαcl(A) are defined as follows:

rgα int(A) = ∪ { V : V⊆ A , V is intuitionistic fuzzy rgα - open}

rgα cl (A) = ∩ { F: A⊆ F, F is intuitionistic fuzzy rgα - closed **}**

Definition 2.3 [6]: Let (X, ℑ) and (Y, σ) be two intuitionistic fuzzy topological spaces and let *f* : X→Y be a function. Then *f* is said to be

(a) Intuitionistic fuzzy continuous if the pre image of each intuitionistic fuzzy open set of Y is an intuitionistic fuzzy open set in X.
(b) Intuitionistic fuzzy closed if the image of each intuitionisic fuzzy closed set in X is an intuitionistic fuzzy closed set in Y.
(c) Intuitionistic fuzzy open if the image of each intuitionisic fuzzy open set in X is an intuitionistic fuzzy open set in Y.

Definition 2.4: Let (X,ℑ) and (Y, σ) be two intuitionistic fuzzy topological spaces and let *f:* X→Y be a function. Then *f* is said to be

(a) Intutionistic fuzzy g-continuous if the pre image of every intuitionistic fuzzy closed set in Y is intuitionistic fuzzy g –closed in X.[15]
(b) Intuitionistic fuzzy g-open if image of every open set of X is intuitionistic fuzzy g-open in Y.[16]
(c) Intuitionistic fuzzy g-closed if image of every closed set of X is intuitionistic fuzzy g-closed in Y.[16]
(d) Intutionistic fuzzy sg-continuous if the pre image of every intuitionistic fuzzy closed set in Y is intuitionistic fuzzy sg –closed in X.[17]
(e) Intuitionistic fuzzy sg-open if image of every open set of X is intuitionistic fuzzy sg-open in Y.[10]
(f) Intuitionistic fuzzy sg-closed if image of every closed set of X is intuitionistic fuzzy sg-closed in Y.[10]
(g) Intutionistic fuzzy sg- irresolute if the pre image of every intuitionistic fuzzy sg- closed set in Y is intuitionistic fuzzy sg –closed in X.[18]
(h) Intutionistic fuzzy w-continuous if the pre image of every intuitionistic fuzzy closed set in Y is intuitionistic fuzzy w –closed in X.[19]
(i) Intuitionistic fuzzy w-open if image of every open set of X is intuitionistic fuzzy w-open in Y.[19]
(j) Intuitionistic fuzzy w-closed if image of every closed set of X is intuitionistic fuzzy w-closed in Y.[19]
(k) Intutionistic fuzzy gpr-continuous if the pre image of every intuitionistic fuzzy closed set in Y is intuitionistic fuzzy gpr –closed in X.[22]
(l) Intuitionistic fuzzy gpr-open if image of every open set of X is intuitionistic fuzzy gpr-open in Y.[9]
(m) Intuitionistic fuzzy gpr-closed if image of every closed set of X is intuitionistic fuzzy gpr-closed in Y.[9]
(n) Intutionistic fuzzy rgα-continuous if the pre image of every intuitionistic fuzzy closed set in Y is intuitionistic fuzzy rgα –closed in X.[8]
(o) Intuitionistic fuzzy rgα-open if image of every open set of X is intuitionistic fuzzy rgα- open in Y.[8]
(p) Intuitionistic fuzzy rgα-closed if image of every closed set of X is intuitionistic fuzzy rgα-closed in Y.[8]

Definition 2.5: [10] A mapping *f* :(X, ℑ) →(Y, σ) is intuitionistic fuzzy quasi rw-open if the image of every intuitionistic fuzzy rw-open set of X is intuitionistic fuzzy open set in Y.

Definition 2.6: [10] A mapping *f* :(X, ℑ) →(Y, σ) is intuitionistic fuzzy quasi rw-closed if image of every intuitionistic fuzzy rw-closed set of X is intuitionistic fuzzy closed set in Y.

III. INTUITIONISTIC FUZZY QUASI RGA -OPEN MAPPINGS.

Definition 3.1: A mapping *f* :(X, ℑ) →(Y, σ) is intuitionistic fuzzy quasi rgα -open if the image of every intuitionistic fuzzy rgα -open set of X is intuitionistic fuzzy open set in Y.

Theorem 3.1: A mapping *f*: (X, ℑ)→ (Y, σ) is intuitionistic fuzzy quasi rgα -open if and only if for every intuitionistic fuzzy set U of X *f* (rgα int(U)) ⊆ int(*f*(u)).

Proof: **Necessity** Let *f* be an intuitionistic fuzzy quasi rgα - open mapping and U is an intuitionistic fuzzy open set in X. Now int(U) ⊆ U which implies that *f* (int(U) ⊆ *f*(U). Since *f* is an intuitionistic fuzzy quasi rgα -open mapping, *f*(rgα int(U)) is intuitionistic fuzzy open set in Y such that *f*(rgα int(U) ⊆ *f*(U) therefore *f*(rgα int(U) ⊆ int *f* (U).

Sufficiency: For the converse suppose that U is an intuitionistic fuzzy rgα -open set of X. Then *f* (U) = *f* (rgα int (U)) ⊆ int (*f* (U)). But int(*f*(U)) ⊆ *f* (U).Consequently *f*(U) = int *f*(U) which implies that *f*(U) is an intuitionistic fuzzy open set of Y and hence *f* is an intuitionistic fuzzy quasi rgα - open mapping.

Theorem 3.2: If *f* : (X, ℑ) →(Y, σ) is an intuitionistic fuzzy quasi rgα -open mapping then rgα int (f^{-1}(G)) ⊆ f^{-1}(int (G)) for every intuitionistic fuzzy set G of Y.

Proof: Let G is an intuitionistic fuzzy set of Y. Then rgαint (f^{-1}(G))is an intuitionistic fuzzy rgα -open set in X. Since *f* is intuitionistic fuzzy quasi rgα -open *f*(rgα int f^{-1}(G)) is intuitionistic fuzzy open in Y and hence by theorem 3.1 *f*(rgα int(f^{-1}(G)) ⊆ int(*f*(f^{-1}(G)) ⊆ int(G) Thus rgα int f^{-1}(G) ⊆ f^{-1}(int (G)).

Theorem 3.3: A mapping *f* : (X, ℑ) →(Y, σ) is intuitionistic fuzzy quasi rgα -open if and only if for each intuitionistic fuzzy set S of Y and for each intuitionistic fuzzy rgα -closed set U of X containing f^{-1}(S) there is an intuitionistic fuzzy closed V of Y such that S ⊆ V and f^{-1}(V) ⊆ U .

Proof: Necessity: Suppose that *f* is an intuitionistic fuzzy quasi rgα - open mapping. Let S be the intuitionistic fuzzy set of Y and U is an intuitionistic fuzzy rgα -closed set of X such that $f^{-1}(S) \subseteq U$. Then $V = (f^{-1}(U^c))^c$ is intuitionistic fuzzy closed set of Y such that $f^{-1}(V) \subseteq U$.

Sufficiency: Suppose that F is an intuitionistic fuzzy rgα -open set of X. Then $f^{-1}((f(F))^c \subseteq F^c$ and F^c is intuitionistic fuzzy rgα -closed set in X. By hypothesis there is an intuitionistic fuzzy closed set V of Y such that $(f(F))^c \subseteq V$ and $f^{-1}(V) \subseteq F^c$ .Therefore $F \subseteq (f^{-1}(V))^c$. Hence $V^c \subseteq f(F) \subseteq f((f^{-1}(V))^c) \subseteq V^c$ which implies $f(F) = V^c$. Since V^c is intuitionistic fuzzy open set of Y. Hence f (F) is intuitionistic fuzzy open in Y and thus f is intuitionistic fuzzy quasi rgα -open mapping.

Theorem 3.4: An intuitionistic fuzzy mapping $f :(X, \Im) \to (Y, \sigma)$ is an intuitionistic fuzzy quasi rgα -open mapping if and only if $f^{-1}((\text{cl}(B)) \subseteq$ rgα cl $(f^{-1}(B))$ for every intuitionistic fuzzy set B of intuitionistic fuzzy topological space Y.

Proof: Necessity: Suppose that f is intuitionistic fuzzy quasi rgα -open for any intuitionistic fuzzy set B of intuitionistic fuzzy topological space Y Now rgα cl$(f^{-1}(B))$ is intuitionistic fuzzy rgα -closed set in X such that $f^{-1}((\text{cl}(B)) \subseteq$ rgα cl$(f^{-1}(B))$. Therefore by theorem 3.3 there exists an intuitionistic fuzzy closed set F in Y such that $B \subseteq F$ and $f^{-1}(F) \subseteq$ rgαcl$(f^{-1}(B))$. Therefore we obtain $f^{-1}(\text{cl}(B)) \subseteq f^{-1}(F) \subseteq$ rgαcl$(f^{-1}(B)$.

Sufficiency: Let $B \subseteq Y$ and F is intuitionistic fuzzy rgα -closed set of X containing $f^{-1}(B)$. Put W = cl(B) then we have $B \subseteq W$ and W is intuitionistic fuzzy closed set in Y such that $f^{-1}(W) \subseteq$ rgα cl$(f^{-1}(B) \subseteq F$. Then by theorem 3.3 f is intuitionistic fuzzy quasi rgα -open.

Theorem 3.5: If $f: (X, \Im) \to (Y, \sigma)$ and $g :(Y, \sigma) \to (Z, \mu)$ be two intuitionistic fuzzy mappings and $gof : (X,\Im) \to (Z, \mu)$ is intuitionistic fuzzy quasi rgα - open. If g is intuitionistic fuzzy continuous then f is intuitionistic fuzzy quasi rgα -open.

Proof: Let U be an intuitionistic fuzzy rgα -open set in X then gof (U) is open in Z. Since $gof: (X,\Im) \to (Z,\mu)$ is intuitionistic fuzzy quasi rgα - open mapping. Again $g :(Y, \sigma) \to (Z, \mu)$ is intuitionistic fuzzy continuous and gof (U) is intuitionistic fuzzy open in Z. Therefore $g^{-1}(gof(U)) = f(U)$ is intuitionistic fuzzy open in X. This shows that f is intuitionistic fuzzy quasi rgα-open mapping.

IV. INTUITIONISTIC FUZZY QUASI RGA -CLOSED MAPPINGS.

Definition 4.1: A mapping $f :(X, \Im) \to (Y, \sigma)$ is intuitionistic fuzzy quasi rgα-closed if image of every intuitionistic fuzzy rgα -closed set of X is intuitionistic fuzzy closed set in Y.

Theorem 4.1: A mapping $f : (X, \Im) \to (Y, \sigma)$ is intuitionistic fuzzy quasi rgα -closed if and only if for each intuitionistic fuzzy set S of Y and for each intuitionistic fuzzy rgα -open set U of X containing $f^{-1}(S)$ there is an intuitionistic fuzzy open set V of Y such that $S \subseteq V$ and $f^{-1}(V) \subseteq U$.

Proof Necessity: Suppose that f is an intuitionistic fuzzy quasi rgα - closed mapping. Let S be the intuitionistic fuzzy closed set of Y and U is an intuitionistic fuzzy rgα - open set of X such that $f^{-1}(S) \subseteq U$. Then $V = Y - f^{-1}(U^c)$ is intuitionistic fuzzy open set of Y such that $f^{-1}(V) \subseteq U$.

Sufficiency: For the converse suppose that F is an intuitionistic fuzzy rgα -closed set of X. Then $(f(F))^c$ is an intuitionistic fuzzy set of Y and F^c is intuitionistic fuzzy rgα -open set in X such that $f^{-1}((f(F))^c) \subseteq F^c$. By hypothesis there is an intuitionistic fuzzy open set V of Y such that $(f(F))^c \subseteq V$ and $f^{-1}(V) \subseteq F^c$ .Therefore $F \subseteq (f^{-1}(V))^c$. Hence $V^c \subseteq f(F) \subseteq f((f^{-1}(V))^c) \subseteq V^c$ which implies $f(F) = V^c$. Since V^c is intuitionistic fuzzy closed set of Y. Hence f (F) is intuitionistic fuzzy closed in Y and thus f is fintuitionistic fuzzy quasi rgα-closed mapping.

Theorem 4.2: If $f: (X, \Im) \to (Y, \sigma)$ is intuitionistic fuzzy quasi rgα -closed mapping and $g :(Y, \sigma) \to (Z, \mu)$ are intuitionistic fuzzy closed map. Then $gof : (X, \Im) \to (Z,\mu)$ is intuitionistic fuzzy quasi rgα -closed mapping.

Proof: Let H be an intuitionistic fuzzy rgα -closed set of intuitionistic fuzzy topological space $(X, \Im)$. Then f (H) is intuitionistic fuzzy closed set of (Y, σ) because f is intuitionistic fuzzy quasi rgα -closed mapping. Now(gof) (H) = $g(f(H))$ is intuitionistic fuzzy closed set in intuitionistic fuzzy topological space Z because g is intuitionistic fuzzy closed map. Thus $gof : (X,\Im) \to (Z,\mu)$ is intuitionistic fuzzy quasi rgα -closed mapping.

Theorem 4.3: If $f: (X, \Im) \to (Y, \sigma)$ is intuitionistic fuzzy rgα - closed mapping and $g :(Y, \sigma) \to (Z, \mu)$ is intuitionistic fuzzy quasi rgα -closed map. Then $gof : (X,\Im) \to (Z,\mu)$ is intuitionistic fuzzy quasi rgα -closed.

Proof: Let H be an intuitionistic fuzzy rgα -closed set of intuitionistic fuzzy topological space$(X, \Im)$. Then f (H) is intuitionistic fuzzy rgα -closed set of (Y, σ) because f is intuitionistic fuzzy rgα -closed mapping. Now (gof) (H) = $g(f(H))$ is intuitionistic fuzzy closed set in intuitionistic fuzzy topological space Z because g is intuitionistic fuzzy quasi rgα -closed mapping. Thus $gof : (X, \Im) \to (Z,\mu)$ is intuitionistic fuzzy quasi rgα - closed.

Definition 4.2: A mapping $f : (X, \Im) \to (Y, \sigma)$ is intuitionistic fuzzy rgα*-closed if image of every intuitionistic fuzzy rgα -closed set of X is intuitionistic fuzzy rgα -closed set in Y.

Theorem 4.4 : Let $f: (X, \Im) \to (Y, \sigma)$ and $g : (Y, \sigma) \to (Z, \mu)$ are intuitionistic fuzzy mapping . Then

(a) If f is intuitionistic fuzzy quasi rgα -closed and g is intuitionistic fuzzy rgα -closed , then gof : $(X,\Im) \to (Z,\mu)$ is intuitionistic fuzzy rgα* closed.

(b) If f is intuitionistic fuzzy rgα* -closed and g is intuitionistic fuzzy quasi rgα closed , then gof : $(X,\Im) \to (Z,\mu)$ is intuitionistic fuzzy quasi rgα -closed.

Proof: (a) Let H be an intuitionistic fuzzy rgα-closed set of intuitionistic fuzzy topological space$(X,\Im)$. Then f (H) is intuitionistic fuzzy closed set of (Y, σ) because f is intuitionistic fuzzy quasi rgα--closed mapping. Now (gof) (H) = $g(f(H))$ is intuitionistic fuzzy rgα--closed set in intuitionistic fuzzy topological space Z because g is intuitionistic fuzzy rgα--closed mapping. Thus $gof: (X, \Im) \to (Z, \mu)$ is intuitionistic fuzzy rgα-* -closed.

(**b)** Let H be an intuitionistic fuzzy rgα--closed set of intuitionistic fuzzy topological space(X,ℑ). Then *f* (H) is intuitionistic fuzzy rgα--closed set of (Y, σ) because *f* is intuitionistic fuzzy rgα-*-closed map. Now (*gof*) (H) = *g(f*(H)) is intuitionistic fuzzy closed set in intuitionistic fuzzy topological space Z because *g* is intuitionistic fuzzy quasi rgα--closed mapping. Thus *gof* : (X,ℑ) →(Z,μ) is intuitionistic fuzzy quasi rgα--closed.

Theorem 4.5 : Let *f*: (X, ℑ) →(Y, σ) and *g* : (Y, σ) →(Z, μ) are intuitionistic fuzzy mapping such that *gof* : (X, ℑ) →(Z, μ) is intuitionistic fuzzy quasi rgα--closed . If g is intuitionistic fuzzy rgα--continuous then *f* is intuitionistic fuzzy rgα-* -closed.

Proof : Suppose H is intuitionistic fuzzy rgα--closed set in X. Since *gof* is intuitionistic fuzzy quasi rgα--closed *gof*(H) is intuitionistic fuzzy closed in Z. Since g is intuitionistic fuzzy rgα--continuous g^{-1}((*gof*)H) = *f*(H) is intuitionistic fuzzy rgα--closed in Y. Hence *f* is intuitionistic fuzzy rgα-*-closed.

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