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On Λ^γ-sets in Fuzzy Bitopological Spaces

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abstract: The aim of this paper is to introduce the concept of Λ operator of a fuzzy set in a fuzzy bitopological space.Then we study (i, j)-fuzzy Λ^γ-set and its properties. Moreover, we define (i, j)-fuzzy Λ-closed set, (i, j)-fuzzy Λ^γ-closed set and (i, j)-fuzzy generalized closed set in fuzzy bitopological space. The concepts of (i, j)-fuzzy Λ-closed set and (i, j)-fuzzy generalized closed set are independent to each other but jointly they give the τ_i-fuzzy closed set. To this end, as the application of (i, j)-fuzzy Λ^γ-closed set we shall study (i, j)-fuzzy Λ^γ-continuity and (i, j)-fuzzy Λ^γ-generalized continuity and their properties.

Key Words: (i, j)-fuzzy Λ -set, (i, j)-fuzzy Λ^γ-set, (i, j)-fuzzy Λ^γ-closed set and (i, j)-fuzzy Λ^γ-continuous function.

Contents

1. Introduction

In 1986 Maki [18] introduced a very nice concept in topological space, so called Λ-set. After that, several authors have studied this notion in different directions in topological space such as Λ_s-sets (2000), pre Λ-sets (2002), Λsp-sets (2004), Λ_m-sets (2005), Λ_b-sets (2006), (Λ, α)-sets (2007) , Λ_δ-sets (2009) and Λ_r-sets (2011) respectively [5,12,14,11,7,6,8,15]. Then using the concept of Λ-set in 1997, Arenas et al. [2] introduced a generalized concept of the Makis idea and investigated the various characterizations in terms of different notions in topological space. In 2006, M. E.El- Shafei [17] has introduced the Λ-fuzzy set in fuzzy topological space in the sense of Maki. Fuzzy Λ_b-sets are studied by G. Aslim and G. Gunel [1] in fuzzy topological space.
Kandil [16], in 1989 introduced the concepts of fuzzy bitopological space. After that several authors were interested to do their work in that field. In 2013 B.C. Tripathy et al. [22] have introduced the concepts of (i, j)-fuzzy γ-open sets in

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fuzzy bitopological space. In 2008, M. Caldas et al. [10] introduced Λ_g-closed set in a topological space which is a weaker form of closed sets and stronger form of generalized-closed sets in the given space. K .Balasubramanian et al. [4] introduce the above concept in fuzzy environment in 2014. Moreover Mukherjee and Halder [20] studied the notion of δ-V-continuity in fuzzy topological space in the year 2008.

The purpose of our paper is to continue the research work in the similar direction but in different approach. In literature we have seen that every closed set is a Λ-closed set but the converse may not be true. In this paper we shall try to investigate that relationship under which the converse is true. In this paper we shall introduce a generalized idea of (i, j)-fuzzy γ-open sets namely (i, j)-fuzzy Λ^γ-sets in fuzzy bitopological space.We study the concept of (i, j)-fuzzy Λ^γ- closed set in fuzzy bitopological space and try to establish one equivalent form of τ_i- closed set in section 3.

Section 4 is devoted to study (i, j)-fuzzyΛ^γ-generalized closed set. In [10], M. Caldas et al. have shown one equivalent condition using the locally closed set but we formulate the same equivalent condition with the help of a weaker form of fuzzy locally closed set.

In section 5 we study the application part of (i, j)-fuzzy Λ^γ-closed set i.e (i, j)-fuzzy Λ^γ-generalized continuity and discover some related results.

A system (X,τ_i,τ_j) consisting of a set X with two fuzzy topologies τ_i and τ_j on X is called a fuzzy bitopological space [16]. For a fuzzy set λ of X the closure of λ and the interior of λ with respect to τ_i are denoted by τ_i-cl(λ) and τ_i-int(λ) respectively , for i = 1, 2. First we recall some definitions from topology, fuzzy topology and fuzzy bitopological spaces.

Definition 1.1. *A fuzzy subset λ of X is called (i, j)-fuzzy γ-open [22] , if $\lambda \wedge \mu$ is (i, j)-fuzzy-pre open for every (i, j)-fuzzy pre-open set μ in X.*

Definition 1.2. *[3] (i) A fuzzy subset λ of a fuzzy topological space (X,τ) is called a generalized closed (g-closed, for short) fuzzy set if $\lambda \leq \eta$ and $\eta \in \tau$ implies that cl(λ)$\leq \eta$.*
(ii) [3] A fuzzy topological space (X,τ) is called $T_{1/2}$-space iff every fuzzy generalized closed set is closed.

Definition 1.3. *A fuzzy subset λ of a fuzzy topological space (X, τ) is called a Λ-fuzzy set [17] if $\lambda = \lambda^\Lambda$, where $\lambda^\Lambda = \wedge\{\eta : \lambda \leq \eta,\ \eta \in \tau\}$.*

Definition 1.4. *A subset B of a topological space (X,τ) is called a λ-closed [9] if $B = C \wedge D$ where C is a Λ-set and D is a closed set.*

Definition 1.5. *A fuzzy topological space (X,τ)is called a fuzzy submaximal space [19] if cl(λ)=1 for any non-zero fuzzy set λ in (X,τ), then $\lambda \in \tau$.*

Definition 1.6. *A fuzzy set λ in a fuzzy topological space (X,τ) is called fuzzy dense [21] if there exists no fuzzy closed set μ in (X,τ) such that $\lambda < \mu <$1.*

Definition 1.7. *A subset S of a topological space (X,τ) is said to be locally closed if [13] $S = U \wedge F$, here U is open and F is closed.*

Definition 1.8. *A fuzzy set μ of a fuzzy topological space (X,τ) is called Λ-generalized fuzzy closed (briefly Λ-gf-closed) [4] if cl(μ)$\leq \beta$ whenever $\mu \leq \beta$ and β is λf-open.*

Definition 1.9. *Fuzzy pairwise continuous [16] if the induced functions f:(X,τ_1)$\rightarrow$ (Y,σ_1) and f:(X,τ_2)$\rightarrow$(Y,σ_2) are both fuzzy continuous.*

Definition 1.10. *[3] A map f:(X,τ)$\rightarrow$(Y,σ) is called generalized fuzzy continuous (in short gf-continuous) if the inverse image of every fuzzy closed set in Y is gf-closed in X.*

Definition 1.11. *[6] A function f from a topological space X to another topological space Y is called (λ, α)-continuous if f^{-1}(V) is a (λ, α)-open subset of X for every open subset V of Y.*

2. (i, j)-Fuzzy Λ^γ-Sets

As a particular case using τ_i-fuzzy open set we can define (i, j)-fuzzy Λ-set and (i, j)-fuzzy V-set in fuzzy bitopological space as follows:

Definition 2.1. *Let μ is any fuzzy subset in a fuzzy bitopological space (X,τ_i,τ_j). Then*
(i) Kernel of μ is denoted by (i, j)-$\Lambda(\mu)$ and is defined by

(i, j)-$\Lambda(\mu)$=$\wedge\{\eta$:$\mu \leq \eta$, where η is a $\tau_i\tau_j$-fuzzy open set in $(X,\tau_i,\tau_j)\}$ and
(ii)(i, j)-$V(\mu)$of a fuzzy set μ is defined by
(i, j)-$V(\mu)$= $\vee\{\eta$:$\eta \leq \mu$, where η is a $\tau_i\tau_j$ -fuzzy closed set in $(X,\tau_i,\tau_j)\}$.

Based on this definition we define (i, j)-fuzzy Λ^γ-set and (i, j)-fuzzy V^γ-set in a fuzzy bitopological space as follows:

Definition 2.2. *Let λ be any fuzzy subset in a fuzzy bitopological space (X,τ_i,τ_j). Then*
(i) γ-Kernel of λ is denoted by (i, j)-$\Lambda^\gamma(\lambda)$=$\wedge\{\eta$:$\lambda \leq \eta$,where η is a (i, j)-fuzzy γ-open set in $(X,\tau_i,\tau_j)\}$ and
(ii)(i, j)-$V^\gamma(\lambda)$ of a fuzzy set λ is defined by (i, j)-$V^\gamma(\lambda)$= $\vee\{\eta$:$\eta \leq \lambda$, where η is a (i, j)-fuzzy γ-closed set in $(X,\tau_i,\tau_j)\}$.

Lemma 2.3. *Let η, μ and μ_k be fuzzy subsets of a fuzzy bitopological space (X,τ_i,τ_j) for every k$\in \Gamma$ (an index set) and x_p be any point of X, then the following properties holds:*
(i) $\eta \leq$ (i, j)-$\Lambda^\gamma(\eta)$,
(ii) if $\eta \leq \mu$ then, (i, j)-$\Lambda^\gamma(\eta) \leq$(i, j)-$\Lambda^\gamma(\mu)$,
(iii)(i, j)-Λ^γ((i, j)-$\Lambda^\gamma(\eta)$)) =(i, j)-$\Lambda^\gamma(\eta)$,
(iv)if $\eta \in$(i, j)$F\gamma O(X)$then η = (i, j)-$\Lambda^\gamma(\eta)$,
(v) (i, j)-$\Lambda^\gamma(\vee\mu_k$:k$\in \Gamma$)= $\vee\{$(i, j)-$\Lambda^\gamma(\mu_k$:k$\in \Gamma)\}$,
(vi) (i, j)-$\Lambda^\gamma(\wedge\mu_k$:k$\in \Gamma$)$\leq \wedge\{$(i, j)-$\Lambda^\gamma(\mu_k$:k$\in \Gamma)\}$ and
(vii)(i, j)-$\Lambda^\gamma(1_X - \eta)$=$1_X -$(i, j)-$V^\gamma(\eta)$.

Proof: Here (i), (ii), (iii) and (iv) can be proved easily from the definition.
To prove (v)
Let $\mu = \vee\{\mu_k$:k$\in \Gamma\} \geq \mu_k$ for all k$\in \Gamma$.
Hence from (ii), (i, j)-$\Lambda^\gamma(\mu_k) \leq$(i, j)-$\Lambda^\gamma(\mu)$ for all k$\in \Gamma$ i.e.
$\vee\{$(i, j)-$\Lambda^\gamma(\mu_k)$:k$\in \Gamma\} \leq$(i, j)-$\Lambda^\gamma\{\vee\mu_k$: k$\in \Gamma\}$.
On the other hand let $x_p \notin \vee\{$(i, j)-$\Lambda^\gamma(\vee\mu_k)$:k$\in \Gamma\}$
then $x_p \notin \{$(i, j)-$\Lambda^\gamma(\vee\mu_k)$:k$\in \Gamma\}$
so $x_p \notin \mu_k$.
Now for each k$\in \Gamma$ there exists $\eta_k \in$(i, j)FγO(X) such that $\mu_k \leq \eta_k$ and $x_p \notin \eta_k$ for all k$\in \Gamma$. Then for $\underset{k\in\Gamma}{\vee}\mu_k \leq \underset{k\in\Gamma}{\vee}\eta_k$ and $\underset{k\in\Gamma}{\vee}\eta_k$ is an (i, j)-fuzzy γ-open set not containing fuzzy point x_p.
Thus $x_p \notin \vee\{$(i, j)-$\Lambda^\gamma(\vee\mu_k)$:k$\in \Gamma\}$.
Thus we have (i, j)-$\Lambda^\gamma(\vee\mu_k)$:k$\in \Gamma \leq \vee\{$(i, j)-$\Lambda^\gamma(\vee\mu_k)$:k$\in \Gamma\}$.
Therefore $\vee\{$(i, j)-$\Lambda^\gamma(\vee\mu_k)$:k$\in \Gamma\}$ = (i, j)-$\Lambda^\gamma\{\vee\mu_k$:k$\in \Gamma$.
To prove (vi)
Let $\mu = \wedge\{\mu_k$:k$\in \Gamma\}$.
So $\mu \leq \mu_k$ for k$\in \Gamma$.
Then from (ii) (i, j)-$\Lambda^\gamma(\mu)\leq \vee\{$(i, j)-$\Lambda^\gamma(\vee\mu_k)$:k$\in \Gamma\}$.
Hence (i, j)-$\Lambda^\gamma(\wedge\mu_k$:k$\in \Gamma)\leq \wedge\{$(i, j)-$\Lambda^\gamma(\mu_k)$:k$\in \Gamma\}$.
To prove (vii)

1_X-(i, j)- $V^\gamma(\eta)=1_X - \vee\{\beta:\beta \leq \eta,\ \beta^c \in$(i, j)F$\gamma$O$(X\}$
$= \wedge\{\mu:1_X - \eta \leq \mu,\ \mu$ is a (i, j)-fuzzy γ-open subset of $X\}$.
$=$ (i, j)-$\Lambda^\gamma(1_X - \eta)$(here $\mu = 1_X - \beta$).
By using the above lemma we can easily prove the following results. □

Lemma 2.4. *(i)(i, j)$V^\gamma(\eta) \leq \eta$,*
(ii)if $\eta \leq \mu$ then, (i, j)-$V^\gamma(\eta) \leq$(i, j)-$V^\gamma(\mu)$,
(iii)if $\eta \in$(i, j)FγC(X)then $\eta =$ (i, j)-$V^\gamma(\eta)$,
(iv)(i, j)-V^γ((i, j)-$V^\gamma(\eta)$) =(i, j)-$V^\gamma(\eta)$,
(v)(i, j)-$V^\gamma(\wedge\mu_k$:k$\in \Gamma$)= $\wedge\{$(i, j)-$V^\gamma(\mu_k$:k$\in \Gamma$)$\}$ and
(vi) (i, j)-$V^\gamma(\vee\mu_k$:k$\in \Gamma$)$\geq \vee\{$(i, j)-$V^\gamma(\mu_k$:k$\in \Gamma$)$\}$.

Definition 2.5. *In a fuzzy bitopological space (X,τ_i,τ_j), a fuzzy subset μ is said to be (i, j)-fuzzy Λ^γ(resp.(i, j)-fuzzy V^γ set if μ =(i, j)-$\Lambda^\gamma(\mu)$(resp.μ =(i, j)-$V^\gamma(\mu)$). The collection of all (i, j)-fuzzy Λ^γ(resp. (i, j)-fuzzy V^γ-set is denoted by(i, j)FΛ^γ(X)(resp.(i, j)FV^γ(X)).*

Theorem 2.6. *In a fuzzy bitopological space (X,τ_i,τ_j) the following properties are satisfied*
(i) 0_X and 1_X are (i, j)-fuzzy Λ^γ-set.
(ii) Arbitrary intersection of (i, j)-fuzzy Λ^γ-sets is a (i, j)-fuzzy Λ^γ-set.
(iii) Arbitrary union of (i, j)-fuzzy Λ^γ- sets is a (i, j)-fuzzy Λ^γ-set.

Proof: (i) It is obvious.
(ii) Let $\mu = \wedge\{\mu_k$:k$\in \Gamma\}$,where μ_k is a (i, j)-fuzzy Λ^γ-set i.e. $\mu_k =$ (i, j)-$\Lambda^\gamma(\mu_k)$
From lemma 2.3 (vi)
(i, j)-$\Lambda^\gamma(\wedge\mu_k$:k$\in \Gamma$)$\leq \wedge\{$(i, j)-$\Lambda^\gamma(\mu_k)$:k$\in \Gamma\}=\wedge\{$(i, j)-$\Lambda^\gamma(\mu_k)$:k$\in \Gamma\}$.
Hence (i, j)-$\Lambda^\gamma(\wedge\mu_k$:k$\in \Gamma$)$\leq \wedge\{$(i, j)-$\Lambda^\gamma(\mu_k)$:k$\in \Gamma\}$.
But from 2.3(i) $\{\wedge\mu_k$:k$\in \Gamma$)$\leq \wedge\{$(i, j)-$\Lambda^\gamma(\mu_k)$:k$\in \Gamma\}$.
Hence $\wedge\{\mu_k$:k$\in \Gamma\} =$ (i, j)-$\Lambda^\gamma\{\wedge(\mu_k$:k$\in \Gamma)\}$.
Thus arbitrary intersection of (i, j)-fuzzy Λ^γ-sets is a (i, j)-fuzzy Λ^γ-set.
In a similar way using the lemma 2.3(v) we can show that arbitrary union of (i, j)-fuzzy Λ^γ-sets is a (i, j)-fuzzy Λ^γ-set.
Thus from the above proposition we can say that the collection of (i, j)-fuzzy Λ^γ-sets forms an Alexandroff space in a fuzzy bitopological space (X,τ_i,τ_j).

□

Remark 2.7. *Since in a fuzzy bitopological space (X,τ_i,τ_j), the (i, j)-fuzzy γ-open set and $\tau_i\tau_j$-fuzzy open sets are independent of each other, thus we can conclude that the concept of (i, j)-fuzzy Λ^γ-set and (i, j)-fuzzy Λ -set are also independent* *of each other.*

Definition 2.8. *A fuzzy subset μ in a fuzzy bitopological space (X,τ_i,τ_j) is called (i, j)-fuzzy generalized closed set if τ_j-cl(μ)$\leq \eta$ whenever $\mu \leq \eta$ and $\eta \in \tau_i FO(X)$.*

Proposition 2.9. *If μ is a (i, j)-fuzzy generalized closed set and $\mu \leq$(i, j)-$\Lambda^\gamma(\mu)$$\leq \tau_j$-cl($\mu$) then (i, j)-$\Lambda^\gamma(\mu)$ is (i, j)-fuzzy generalized closed set.*

Proof: Since μ is a (i, j)-fuzzy generalized closed set and $\mu \leq$(i, j)-$\Lambda^\gamma(\mu)$$\leq \tau_j$-cl($\mu$) then (i, j)-$\Lambda^\gamma(\mu)$ it implies that
τ_j-cl(μ)$\leq \tau_j$-cl((i, j)-$\Lambda^\gamma(\mu)$)$\leq \tau_j$-cl(μ).
Therefore, we get τ_j-cl((i, j)-$\Lambda^\gamma(\mu)$)$= \tau_j$-cl(μ).
Hence (i, j)-$\Lambda^\gamma(\mu)$ is (i, j)-fuzzy generalized closed set as μ is (i, j)-fuzzy generalized closed set.

□

Proposition 2.10. *If λ is a τ_i-fuzzy open set in a fuzzy bitopological space X then there exist a (i, j)-fuzzy set μ and (i, j)-fuzzy regular open set η such that $\lambda \leq \mu \wedge \eta$.*

Proof: Since $\lambda \leq \tau_j$-cl(λ)$\Rightarrow \tau_i$-int(λ)$\wedge\mu \leq \tau_i$-int(τ_j-cl(λ))$\wedge\mu$
$\Rightarrow \lambda \leq \eta \wedge \eta$, where η is a (i, j)-fuzzy regular open set. □

3. (i, j)-Fuzzy Λ^γ-Closed Sets

In general (i, j)-fuzzy Λ^γ-closed set is not τ_i-fuzzy closed set. The objective of this section to find the condition under which every (i, j)-fuzzy Λ^γ -closed set is τ_i -fuzzy closed set .

Definition 3.1. *A fuzzy subset λ of a fuzzy bitopological space (X,τ_i,τ_j) is called (i, j)-fuzzy Λ-closed set if $\lambda = \mu \wedge \delta$, where μ is (i, j)-fuzzy-Λ set and δ is an τ_i -fuzzy closed set. The family of all (i, j) fuzzy Λ-closed set is denoted by (i, j)FΛC(X).*
A fuzzy subset of a fuzzy bitopological space (X,τ_i,τ_j) is called (i, j)- fuzzy Λ-open if its complement is (i, j)- fuzzy Λ-closed set.

Lemma 3.2. *For a fuzzy subset λ of a fuzzy bitopological space (X,τ_i,τ_j) the following conditions are equivalent.*
(i)$\lambda \in$(i, j)$F\Lambda C(X)$ and
(ii)$\lambda = \mu \wedge \tau_i$-cl($\lambda$), for some (i, j) fuzzy Λ-set μ.

Proof: (i)$\Rightarrow$(ii) Let λ be any (i, j)-fuzzy Λ-closed set in X. Then
$\lambda = \mu \wedge \delta$, where μ is (i, j) -fuzzy Λ- set and δ is τ_i-fuzzy- closed set in X.
Now $\lambda \leq \delta$
$\Rightarrow \tau_i$-cl(λ)$\leq \tau_i$-cl(δ)$= \delta$
$\Rightarrow \tau_i$-cl(λ)$\wedge\ \mu \leq \delta \wedge \mu = \lambda$
Again τ_i-cl(λ)$\geq \lambda$
$\Rightarrow \tau_i$-cl(λ)$\wedge\ \mu \geq \lambda$.
From the above two relation we get $\lambda = \mu \wedge \tau_i$-cl($\lambda$).
(ii)$\Rightarrow$ (i) It is obvious.

□

Theorem 3.3. *A (i, j)-fuzzy generalized closed set is τ_i-fuzzy closed set iff it is (i, j)-fuzzy Λ-closed set.*

Proof: Let λ be (i, j)-fuzzy generalized closed set. Thus τ_i-cl(λ)$\leq \mu$ whenever $\lambda \leq \mu$, where $\mu \in \tau_i$ FO(X).
But since λ is (i, j)- fuzzy Λ-closed set, then $\lambda =$ (i, j)-Λ(λ)$\wedge\ \tau_i$-cl(λ) $= \tau_i$-cl(λ) [since (i, j)-Λ($\lambda \geq \tau_i$-cl(λ)]. Therefore λ is τ_i-fuzzy closed set.
Converse part follows from the fact that every τ_i -fuzzy closed set is (i, j)-fuzzy Λ-closed set.

□

Definition 3.4. *A fuzzy set η in fuzzy bitopological space (X,τ_i,τ_j) is said to be (i, j)-fuzzy locally closed set if $\eta = \mu \wedge \beta$ where β is a τ_i -fuzzy closed set and μ is a τ_j- fuzzy open set in X.*

Remark 3.5. *Every (i, j)-fuzzy locally closed set is (i, j)-fuzzy Λ-closed set which follows from the definition.*

Definition 3.6. *A fuzzy subset λ of a fuzzy bitopological space (X,τ_i,τ_j) is called (i, j)-fuzzy dense set if λ is τ_i-fuzzy dense set or τ_j-fuzzy dense set .*

Definition 3.7. *A fuzzy bitopological space (X,τ_i,τ_j) is said to be (i, j)-fuzzy submaximal space if each (i, j)-fuzzy dense set is a τ_i-fuzzy open set.*

Proposition 3.8. *Every fuzzy subset of a (i, j)-fuzzy submaximal space* (X,τ_i,τ_j) *is (i, j)-fuzzy* Λ*-closed set.*

Proof: Let (X,τ_i,τ_j) be a (i, j)-fuzzy submaximal space and we know that every fuzzy subset λ of a (i, j)-fuzzy submaximal space can be expressed as an intersection of τ_j-fuzzy open set μ and τ_i-fuzzy closed set δ. It means that μ is a (i, j)-fuzzy Λ-set and therefore $\lambda = \mu \wedge \delta$. Thus λ is (i, j)-fuzzy Λ-closed set.

□

Proposition 3.9. *In a (i, j)-fuzzy submaximal space* (X,τ_i,τ_j) *every (i, j)-fuzzy* Λ*-open set is* τ_i *-fuzzy open if there does not exist (i, j)-fuzzy regular closed set other than* 1_X*.*

Proof: Let λ be any (i, j)-fuzzy Λ -open set then λ can be expressed as
$\lambda = \mu \vee \delta$, μ be any (i,j)-fuzzy V -set and δ be τ_i-fuzzy open set .
Now τ_i-cl(λ) = τ_i-cl ($\mu \vee \delta$) $\geq \tau_i$-cl(μ)$\vee$ τ_i-cl(τ_i-int(δ)) $\geq \tau_i$-cl(μ) $\vee$ 1_X.
Therefore λ is τ_i-fuzzy open since (X,τ_i,τ_j) is (i, j)-fuzzy submaximal space . □

Definition 3.10. *A fuzzy subset* λ *of a fuzzy bitopological space* (X,τ_i,τ_j) *is called (i, j)-fuzzy* Λ^γ *-closed set if* $\lambda = \mu \wedge \delta$ *, where* μ *is (i, j)-fuzzy* Λ^γ *-set and* δ *is an* τ_i *-fuzzy closed set. The family of all (i, j)-fuzzy* Λ^γ*-closed sets is denoted by (i, j)F*Λ^γ *C(X).*
A fuzzy subset λ *of a fuzzy bitopological space* (X,τ_i,τ_j) *is called (i, j)-fuzzy* Λ^γ *-open if its complement is (i, j)-fuzzy* Λ^γ*- closed set.*

Lemma 3.11. *For a fuzzy subset* λ *of a fuzzy bitopological space*(X,τ_i,τ_j) *the following conditions are equivalent:*
(i)λ *is (i, j)-fuzzy* Λ^γ *-closed set.*
(ii)$\lambda = \mu \wedge \tau_i$ *-cl(*λ*) , where* μ *is a (i, j)-fuzzy* Λ^γ *-set.*
(iii)λ *=(i, j)-*$\Lambda^\gamma(\lambda) \wedge \tau_i$*-cl(*$\lambda$*).*

Proof: (i)⇒ (ii) Let λ be a (i, j)-fuzzy Λ^γ -closed set. Therefore $\lambda = \mu \wedge \delta$ where μ is a (i, j)-fuzzy Λ^γ-set and δ is τ_i-fuzzy closed set. Since $\lambda \leq \delta$ implies τ_i-cl(λ)$\leq \delta$ and $\lambda = \mu \wedge \delta \geq \mu \wedge \tau_i$ -cl(λ) $\geq \lambda$. Therefore we have $\lambda = \mu \wedge \tau_i$ -cl(λ).
(ii)⇒(iii) Let $\lambda = \mu \wedge \tau_i$-cl($\lambda$), where μ is a (i, j)-fuzzy Λ^γ -set. Since $\lambda \leq \mu$ implies (i, j)-$\Lambda^\gamma(\lambda) \leq (\mu)$ and $\lambda = \mu \wedge \delta \geq$ (i, j)-$\Lambda^\gamma(\lambda)$ $\wedge\tau_i$-cl(λ)$\geq \lambda$.
Therefore we have λ =(i, j)-$\Lambda^\gamma(\lambda)$ $\wedge\tau_i$-cl(λ).
(iii)⇒(i) It is obvious. □

Remark 3.12. *Every (i, j)-fuzzy* Λ^γ*-closed set and (i, j)-fuzzy* Λ *-closed set are independent of each other , since every (i, j)-fuzzy* Λ^γ*-set and (i, j)-fuzzy* Λ*-set are independent.*

Proposition 3.13. *If λ be any (i, j)-fuzzy dense set and (i, j)-fuzzy Λ^γ-closed set then λ is(i,j)-fuzzy Λ^γ-set.*

Proof: Let λ be any (i, j)-fuzzy dense set and (i, j)-fuzzy Λ^γ-closed set then λ = (i, j)-$\Lambda^\gamma(\lambda)\wedge$ τ_i-cl(λ) = (i,j)-$\Lambda^\gamma(\lambda)\wedge$ 1_X = (i, j)-$\Lambda^\gamma(\lambda)$. Thus λ is a (i,j)-fuzzy Λ^γ -set. □

Definition 3.14. *A fuzzy bitopological space (X,τ_i,τ_j) is said to be fuzzy (i, j)-fuzzy $T_{1/2}$ space if every (i, j)-fuzzy generalized closed set is a τ_i -fuzzy closed set.*

Proposition 3.15. *In a fuzzy bitopological space (X,τ_i,τ_j) the following conditions are equivalent:*
(i) (X,τ_i,τ_j) is (i, j)-fuzzy $T_{1/2}$ space.
(ii)Every (i, j)-fuzzy generalized closed set is a (i, j)-fuzzy Λ-closed set.

Proof: (i)$\Rightarrow$(ii) Given(X,τ_i,τ_j) be a(i, j)-fuzzy $T_{1/2}$ space. Hence by the definition of(i, j)-fuzzy $T_{1/2}$ space every (i, j) -fuzzy generalized closed set is a τ_i -fuzzy closed set which is a (i, j)-fuzzy Λ -closed set.
(ii)$\Rightarrow$(i) Using theorem 3.3, it can be proved easily. □

Definition 3.16. *A fuzzy subset λ in a fuzzy bitopological space (X,τ_i,τ_j) is said to be (i, j)-fuzzy semi-γ-closed set if τ_i-int$_\gamma$(τ_j-cl(λ))$\leq \lambda$.*

Proposition 3.17. *A (i, j)-fuzzy Λ^γ-closed set is τ_i-fuzzy closed set if it is (i, j)-fuzzy semi-γ-closed set.*

Proof: Let λ be any (i, j)-fuzzy Λ^γ-closed set, so λ =(i, j)-$\Lambda^\gamma \wedge \tau_i$-cl($\lambda$). Given λ is a (i, j)-fuzzy semi γ-closed set. Thus τ_i-int$_\gamma$(τ_j-cl(λ))$\leq \lambda$. Let τ_i-int$_\gamma$(τ_j-cl(λ))$\leq \lambda \leq \delta_k$,k$\in I$, where δ_k are (i, j)-fuzzy γ-open set . Therefore τ_i-cl(λ)$\leq \wedge\delta_k$. This implies that τ_i-cl(λ)$\leq$ (i, j)$\Lambda^\gamma(\lambda)$. Therefore λ =τ_i-cl(λ), hence λ is a τ_i-fuzzy closed set. □

Remark 3.18. *A (i, j)-fuzzy Λ-closeed set is τ_i-fuzzy closed set if it is (i, j)-fuzzy semi-closed set.*

Definition 3.19. *A fuzzy point x_p is called a (i, j)-fuzzy Λ^γ-cluster point of λ if for every (i, j)-fuzzy Λ^γ-open set δ containing x_p such that $\lambda \wedge \delta \neq 0_X$.*

Definition 3.20. *We define (i, j)-Λ^γ(τ_i-cl) for any fuzzy set λ in a fuzzy bitopological space (X,τ_i,τ_j) as follows: (i, j)-Λ^γ(τ_i-cl(λ))= $\wedge\{\mu$:$\lambda \leq \mu\}$ and μ is (i, j)-fuzzy Λ^γ-closed set$\}$.*

Proposition 3.21. *If λ_i are (i, j)-fuzzy Λ^γ-closed set for each i$\in I$, then $\underset{i\in I}{\wedge}\lambda_i$ is (i, j)-fuzzy Λ^γ-closed set.*

Proof: Suppose $\lambda = \underset{i\in I}{\wedge}\lambda_i$ and $x_p \in$(i, j)-$\Lambda^\gamma(\tau_i$-cl(λ)). Then x_p is a (i, j)-fuzzy Λ^γ-cluster point of λ. Thus there exist a (i, j)-fuzzy Λ^γ-open set δ containing x_p such that $\lambda \wedge \delta \neq 0_X$ $\lambda \wedge \delta \neq 0_X$. This implies that $(\underset{i\in I}{\wedge}\lambda \wedge \delta \neq 0_X)$. Thus λ_i $\wedge\delta \neq 0_X$ for each i$\in I$. If $x_p \notin \lambda$ for each i$\in$ I then $x_p \notin \lambda_i$. Since λ_i is (i,j)-fuzzy Λ^γ-closed,λ_i =(i,j)-Λ^γ (τ_i-cl(λ_i)) and hence $x_p \notin$(i, j)-Λ^γ τ_i-cl(λ_i)). Therefore x_p is not a (i, j)-fuzzy Λ^γ-cluster point of λ_i . So there exist a (i, j)-fuzzy Λ^γ -open set μ containing x_p such that $\lambda_i \wedge \mu = 0_X$. Hence by the contradiction $x_p \in \lambda$. Therefore (i, j)- $\Lambda^\gamma(\tau_i$ -cl(λ_i))$\leq \lambda$ and hence λ =(i, j)Λ^γ(τ_i-cl(λ_i)). Therefore $\underset{i\in I}{\wedge}\lambda_i$ is (i, j)-fuzzy Λ^γ-closed set. □

4. (i, j)-Fuzzy Λ^γ-Generalized Closed Sets

Definition 4.1. *A fuzzy set λ of fuzzy bitopological space (X,τ_i,τ_j) is called (i, j)-fuzzy Λ-generalized closed set if τ_j-cl(λ)$\leq \mu$ whenever $\lambda \leq \mu$ and μ is (i, j)-fuzzy Λ-open set, where i$\neq$ j and i, j = 1, 2.*

Definition 4.2. *A fuzzy set λ of fuzzy bitopological space (X,τ_i,τ_j) is called (i, j)-fuzzy Λ^γ -generalized closed set if τ_j-cl(λ)$\leq$ μ whenever $\lambda \leq \mu$ and μ is a (i, j)-fuzzy Λ^γ -open set, where i$\neq$j and i, j = 1, 2.*

Proposition 4.3. *(i) Every τ_i-fuzzy closed set is (i, j)-fuzzy Λ-generalized closed set.*
(ii) Every (i, j)-fuzzy Λ-generalized closed set (i, j)-fuzzy generalized closed set.

Proof: (i) Let λ be any τ_i-fuzzy closed set and μ be any (i, j)-fuzzy Λ-open set such that $\Lambda \leq \mu$, τ_i-cl(λ)= λ. Thus λ is a (i, j)-fuzzy Λ-generalized closed set.
(ii) Since every τ_i -fuzzy open set is (i, j)-fuzzy Λ-open set, so every (i, j)-fuzzy Λ-generalized closed set is (i, j)-fuzzy generalized closed set follows from the definition. □

Remark 4.4. *Every (i, j)-fuzzy Λ^γ-generalized closed set need not be τ_i-fuzzy closed set as seen in the following example.*

Example 4.5. *Let X ={ x, y}, τ_i = {{(x, 0.1) ,(y, 0.1)},0_X, 1_X} and τ_j = {{(x, 0.2) ,(y, 0.2)},0_X, 1_X}. Here (i, j) F γO(X)= {{(x, p) ,(y, q)},0_X, 1_X where 0$\leq$p$\leq$0.2 ,0$\leq$q$\leq$0.2 and p>0.8, q>0.8 } . Let us suppose λ ={(x, 0.3) ,(y, 0.3)} , here (i, j)-$\Lambda^\gamma(\lambda)$> {(x, 0.8) ,(y, 0.8)} which also contains the τ_j-cl(λ). Thus λ is a (i, j)-fuzzy Λ^γ-generalized closed set, but not a τ_i-fuzzy closed set.*

Remark 4.6. *Every (i, j)-fuzzy generalized closed set need not be (i, j)-fuzzy Λ^γ-generalized closed set.*

Example 4.7. *In the above example-4.5, if we consider $\lambda = \{(x, 0.2), (y, 0.2)\}$, then λ is a (i, j)-fuzzy generalized closed set but it is not a (i, j)-fuzzy Λ^γ-generalized closed set .*

Remark 4.8. *Every (i, j)-fuzzy Λ^γ-closed set need not be (i, j)-fuzzy Λ^γ-generalized closed set as shown in the following example.*

Example 4.9. *Let $X = \{x, y\}$, $\tau_i = \{\{(x, 0.1), (y, 0.1)\}, 0_X, 1_X\}$ and $\tau_j = \{\{(x, 0.2), (y, 0.2)\}, 0_X, 1_X\}$. Here (i, j) $F\gamma O(X) = \{\{(x, p), (y, q)\}, 0_X, 1_X$ where $0 \leq p \leq 0.2$, $0 \leq q \leq 0.2$ and $p > 0.8$, $q > 0.8\}$. Let us suppose that $\lambda = \{(x, 0.85), (y, 0.85)\}$, here (i, j)-$\Lambda^\gamma(\lambda) = \lambda$, which implies that λ is (i, j)-fuzzy Λ^γ-closed set. Again $\lambda \leq \lambda$ and τ_j-$cl(\lambda) = 1_X$. Therefore, λ is not (i, j)-fuzzy Λ^γ-generalized closed set.*

Remark 4.10. *Every (i, j)-fuzzy Λ^γ-generalized closed set need not be a (i, j)-fuzzy Λ^γ-closed.*

Example 4.11. *From the above example 4.5, we see that λ is a (i, j)-fuzzy Λ^γ -generalized closed set. But here (i, j)-$\Lambda^\gamma(\lambda) \wedge \tau_i$-$cl(\lambda) \neq \lambda$. It implies that λ is not (i, j)-fuzzy Λ^γ-closed set.*

Theorem 4.12. *[10] Let A be a locally closed subset of a topological space (X, τ). For the set A, the following properties are equivalent:*
(i)A is closed.
(ii)A is Λ_g-closed.
(iii)A is generalized-closed.

From the above equivalent conditions we can easily say that the collection of all generalized-open sets forms a topology in (X, τ).
In this paper we originate the above equivalent condition in fuzzy bitopological space (X, τ_i, τ_j) with the help of (i, j)-fuzzy Λ-closed which is a weaker form of (i, j)-fuzzy locally closed set.

Theorem 4.13. *Let λ be any (i, j)-fuzzy Λ-closed set in a fuzzy bitopological space(X, τ_i, τ_j). For the fuzzy set λ the following properties are equivalent:*
(i)λ is τ_i-fuzzy closed set.
(ii)λ is (i, j)-fuzzy Λ-generalized closed.
(iii) λ is (i, j)-fuzzy generalized closed set.

Proof: (i)$\Rightarrow$(ii)Using proposition 4.3(i),the proof can be done easily.
(ii)$\Rightarrow$(iii)Using proposition 4.3(ii), it can be proved easily.
(iii)$\Rightarrow$ By using the proposition 3.3, one can easily establish the relation.
From the above result we can conclude that the family of all (i, j)-fuzzy generalized closed sets forms a fuzzy topology in the light of (i, j)-fuzzy Λ-closed set, though it is not true in general. □

5. (i, j)-Fuzzy Λ-Continuty and (i, j)-Fuzzy Λ^γ-Continuity

In this section, we define the idea of continuous function using (i, j)-fuzzy Λ-set and (i, j)-fuzzy Λ^γ-set. As an application we have shown that τ_i-fuzzy continuous and (i, j)-fuzzy Λ^γ-continuous functions are equivalent upto certain extent.

Definition 5.1. *Let f:$(X,\tau_i,\tau_j)\to(Y,\sigma_i,\sigma_j)$ be a function from a fuzzy bitopological space(X,τ_i,τ_j) into a another fuzzy bitopological space (Y,σ_i,σ_j), then f is called (i, j)-fuzzy Λ-continuous (resp.(i, j)-fuzzy Λ^γ-continuous, (i, j)-fuzzy generalized continuous,(i, j)-fuzzyΛ^γ -generalized continuous) if $f^{-1}(\mu)$ is (i, j)-fuzzy Λ -closed (resp. (i, j)-fuzzy Λ^γ-closed ,(i, j)-fuzzy generalized closed ,(i, j)-fuzzy Λ^γ-generalized closed set) in X for each σ_i-fuzzy closed set μ in Y.*

Proposition 5.2. *Every τ_i-fuzzy continuous function is (i, j)-fuzzy Λ-continuous function.*

Proof: It is straightforward from the definition. □

Remark 5.3. *Converse of the above proposition may not be true as seen in the following example.*

Example 5.4. *Let $X = \{ x, y\}$, $\tau_i = \{\{(x, 0.3) ,(y, 0.3)\},0_X, 1_X\}$ and $\tau_j = \{\{(x, 0.6) ,(y, 0.7)\},0_X, 1_X\}$, $\sigma_i = \{\{(x, 0.6) ,(y, 0.7)\},0_Y, 1_Y\}$ and $\sigma_j = \{\{(x, 0.2) ,(y, 0.5)\}, 0_Y, 1_Y\}$.*
Now we consider a function f:$(X,\tau_i,\tau_j)\to (Y,\sigma_i,\sigma_j)$ such that f(x)= x and f(y)= y. Thus f is a (i, j)-fuzzy Λ-continuous function but not a τ_i-fuzzy continuous. Since the inverse image of σ_i-fuzzy closed set in Y is (i, j)-fuzzy Λ-closed set in X, which is not a τ_i-fuzzy closed set.

In our next theorem we have shown that the converse part is true under some particular circumstances.

Theorem 5.5. *Let f:$(X,\tau_i,\tau_j)\to (Y,\sigma_i,\sigma_j)$ be a function , where X is a (i, j)-fuzzy submaximal space and the only (i, j) -fuzzy regular open set in X is 0_X then the following conditions are equivalent:*
(i) f is τ_i-fuzzy-continuous.
(ii) fis (i, j)-fuzzy Λ-continuous.

Proof: (i)⇒(ii) Let μ be any σ_i-fuzzy closed set in Y. Since f is τ_i-fuzzy-continuous, so $f^{-1}(\mu)$is τ_i-fuzzy closed set in X. Thus $f^{-1}(\mu)$ is (i, j)-fuzzy Λ-closed set in X since every τ_i-fuzzy closed set is (i, j)-fuzzy Λ-closed set. Therefore f is (i, j)-fuzzy Λ-continuous.
(ii)⇒(i) Let μ be any σ_i-fuzzy closed set in Y. Thus for any σ_i-fuzzy closed set we have $f^{-1}(\mu)$is (i, j)-fuzzy Λ-closed set. Hence $f^{-1}(\mu)$is a τ_i-fuzzy closed set in X, since in a (i, j)-fuzzy submaximal space every (i, j)-fuzzy Λ-closed set is a τ_i-fuzzy closed set. Therefore f is a τ_i-fuzzy continuous. □

Theorem 5.6. *For any function f:$(X,\tau_i,\tau_j)\rightarrow$ (Y,σ_i,σ_j) following conditions are equivalent:*
(i) f is (i, j)-fuzzy Λ^γ-continuity.
(ii) $f^{-1}(\sigma_i$-int$(\lambda))\leq$(i, j)-$\Lambda^\gamma(\tau_i$-int$(f^{-1}(\lambda))$, for any fuzzy subset λ of Y.
(iii) (i, j)-$\Lambda^\gamma(\tau_i$-cl$(f^{-1}(\lambda))\leq f^{-1}(\sigma_i$-cl$(\lambda))$, for any fuzzy subset λ of Y.

Proof: (i)$\Rightarrow$(ii)Let f be (i, j)-fuzzy Λ^γ-continuous and λ be any subset of Y. Since σ_i-int$(\lambda)\leq\lambda\Rightarrow f^{-1}(\sigma_i$-int$(\lambda))\leq f^{-1}(\lambda)$. Now since $f^{-1}(\sigma_i$-int$(\lambda))$ is (i, j)-fuzzy Λ^γ-open in X. Therefore $f^{-1}(\sigma_i$-int$(\lambda))\leq$(i, j)-$\Lambda^\gamma(\tau_i$-int$(f^{-1}(\lambda))$.
(ii)$\Rightarrow$(iii) Let λ be any subset of Y, then
j$f^{-1}(\sigma_i$-int$(1_Y-\lambda))\leq$(i,)-$\Lambda^\gamma(\tau_i$-int$(f^{-1}(\sigma_i$-int$(1_Y-\lambda))$
$\Rightarrow 1_X - f^{-1}(\sigma_i$-cl$(\lambda))\leq 1_X-$(i, j)-$\Lambda^\gamma$-$\tau_i$-cl$(f^{-1}(\lambda))$
$\Rightarrow$(i, j)-$\Lambda^\gamma(\tau_i$-cl$(f^{-1}(\lambda))\leq f^{-1}(\sigma_i$-cl$(\lambda))$.
(iii)$\Rightarrow$(i)Let λ be any σ_i-fuzzy closed set in Y.
Now $f^{-1}(\lambda)= f^{-1}(\sigma_i$-cl$(\lambda))\geq$(i, j)-$\Lambda^\gamma(\tau_i$-cl$(f^{-1}(\lambda)) = f^{-1}(\lambda)$.
Thus $f^{-1}(\lambda)$ is (i, j)-fuzzy Λ^γ-closed in X. □

Remark 5.7. *Every (i, j)-fuzzy Λ^γ-continuous function and (i, j)-fuzzy Λ-continuous function are independent of each other.*

Theorem 5.8. *A (i, j)-fuzzy Λ^γ-continuous function from a fuzzy bitopological space X to another fuzzy bitopological space Y is τ_i-fuzzy continuous if every (i, j)-fuzzy Λ^γ -closed set is (i, j)-fuzzy semi γ-closed set in X.*

Proof: Let f be (i, j) - fuzzy Λ^γ-continuous function from X to Y and let μ be any σ_i -fuzzy closed set in Y. Therefore $f^{-1}(\mu)$ is (i, j)-fuzzy Λ^γ-closed set in X. Since every (i, j)-fuzzy Λ^γ-closed set is (i, j)-fuzzy semi γ-closed set in X and hence by proposition-3.17, $f^{-1}(\mu)$ is τ_i-fuzzy closed set in X. Therefore f is τ_i-fuzzy continuous. □

Theorem 5.9. *Let f:$(X,\tau_i,\tau_j)\rightarrow$ (Y,σ_i,σ_j) be a function. Then the followings are equivalent.*
(i) f is τ_i-fuzzy continuous function.
(ii) f is (i, j)-fuzzy generalized continuous and (i, j)-fuzzy Λ^γ-continuous functions.

Proof: (i)$\Rightarrow$(ii)Proof is straightforward.
(ii)$\Rightarrow$(i) Let μ be any σ_i-fuzzy closed set in Y. Thus $f^{-1}(\mu)$ is (i, j)-fuzzy generalized closed and (i, j)-fuzzy Λ^γ-closed set by the given condition. Hence $f^{-1}(\mu)$ is τ_i-fuzzy closed set using theorem 4.3 . Therefore f is τ_i-fuzzy continuous.

The notion of (i, j)-fuzzy Λ-continuous and (i, j)-fuzzy Λ^γ-continuous functions are independent of each other. But in the light of Theorem 5.5 and 5.9 one can verify that they are sameness as an application. □

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