# On Some Closed Sets In Fuzzy Minimal Ideal Spaces

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**Abstract:** The purpose of this paper is to introduce fuzzy minimal ideal topological spaces and fuzzy minimal ideal generalized closed sets in fuzzy minimal topological spaces and to investigate the relationships between fuzzy minimal spaces and fuzzy minimal ideal spaces.

**Keywords:** Fuzzy ideal topological spaces, Fuzzy $I_g$- closed sets, Fuzzy minimal ideal space, Fuzzy minimal ideal generalized closed sets etc.

## Introduction

In 1945, R. Vaidyanathaswamy[7] introduced the concept of ideal topological spaces. Hayashi[4] 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[5] in 1965 and fuzzy topology by Chang[2] in 1968, several mathematicians[10, 3, 6] studied the generalization of fuzzy sets and fuzzy ideal topological spaces. In this sequence Noiri and Popa[11] have created and developed the theory of minimal structure in general topology. As a generalization of the fuzzy domain, Brescan[6] introduced the concept of fuzzy minimal structure. This paper explores the fuzzy minimal ideal topological spaces and its generalization in fuzzy ideal topological spaces.

## Preliminary

Let X be a nonempty set. A family $r$ of fuzzy sets of X is called a fuzzy topology on X if the null fuzzy set 0 and the whole fuzzy set 1 belongs to $r$ and $r$ is closed with respect to any union and finite intersection[5]. If $r$ is a fuzzy topology on X, then the pair $(X, r)$ is called a fuzzy topological space [5] and the members of $r$ are called fuzzy open sets and their complements are called fuzzy closed sets. The closure of a fuzzy set $A$ of X denoted by $(A)$ , is the intersection of all fuzzy closed sets which contains $A$ . The interior of a fuzzy set $A$ of X denoted by $Ikt(A)$ is the union of all fuzzy sets of X contained in $A$ . A fuzzy set $A$ in fuzzy topological space $(X, r)$ is said to be quasi-coincident with a fuzzy set $B$ denoted by $AqB$ , if there exists a point $x \in X$ such that $A(x) + B(x) > 1$ [9] . A fuzzy set $V$ in a fuzzy topological space $(X, r)$ is called a Q- neighborhood of a fuzzy point $x_\beta$ if there exists a fuzzy open set $U$ of X such that $x_\beta\, qU \leq V$ [3] .

**Definition 2.1:** A nonempty collection of fuzzy sets $I$ of a set X satisfying the conditions

(i) if $A \in I$ and $B \leq A$ , then $B \in I$ (heredity) ,

(ii) if $A \in I$ and $B \in I$ then $A \cup B \in I$ (finite additivity) is called a fuzzy ideal on X. The triplex (X, $r$, $I$) denotes a fuzzy ideal topological space with a fuzzy ideal $I$ and fuzzy topology $r$ [5, 9].

**Definition 2.2:** The local function for a fuzzy set $A$ of X with respect to $r$ and $I$ denoted by $A^*(r, I)$ ( $briefly\ A^*$) in a fuzzy ideal topological space $(\mathrm{X}, r, I)$ is the union of all fuzzy points $x_\beta$ such that if $U$ is a Q-neighbourhood of $x_\beta$ and $E \in I$ then for at least one point $y \in \mathrm{X}$ for which $U(y) + A(y) - 1 > E(y)$ [ 9 ].

**Definition 2.3:** The Closure of a fuzzy set A denoted by $Cl^*(A)$ in $(\mathrm{X}, r, I)$ defined as $Cl^*(A) = A \cup A^*$ [ 9 ].

In a fuzzy ideal topological space (X, $r$, $I$) , the collection $r^*(I)$ means an extension of fuzzy topological space than $r$ via fuzzy ideal which is constructed by considering the Class $\beta = \{U - E : U \in r, E \in I\}$ as a base [ 9 ].

**Definition 2.4:** A fuzzy set $A$ of a fuzzy ideal topological space (X, $r$, $I$) is called fuzzy $I_g$-closed if $A^* \leq U$, whenever $A \leq U$ and $U$ is fuzzy open. And A is called called fuzzy $I_g$–open if its complement is fuzzy $I_g$–closed [10].

**Remark 2.5:** Every fuzzy $g$-closed (resp. fuzzy $*$-closed) set is fuzzy $I_g$–closed and every fuzzy $g$-open (resp. fuzzy $*$-open) set is fuzzy $I_g$–open. Examples can be easily constructed to show that the converse may not be true [10].

**Remark 2.6:** In a fuzzy ideal topological space $(\mathrm{X}, r, I)$, I is fuzzy $I_g$-closed for every I ∈ I [10].

**Lemma2.7:** $A \leq B \Leftrightarrow \rceil(Aq1 - B)$, for every pair of fuzzy sets $A$ and $B$ of X [11].

**Definition 2.8:** Let $F$(X) be a class of fuzzy subsets of a non empty set X. A subclass $F_m$ of $F$(X) is called fuzzy minimal structure on X (or a $F_m$-structure) if $0 \in F_m$, $1 \in F_m$. The pair (X, $F_m$) is called fuzzy minimal space or a $F_m$-space. A fuzzy set $A$ is called $F_m$-open set if $A \in F_m$, if $A^c \in F_m$ then $A$ is called $F_m$-closed set[6].

**Remark 2.9:** Fuzzy minimal structure on X maintains only the first condition of the definition of fuzzy topology[6].

**Remark 2.10:** Let $(\mathrm{X}, r)$ be a fuzzy topological space. Then the subfamilies $r$, $FSO$(X), $FPO$(X), $F\eth PO$(X), $FSPO$(X), $FS\eth PO$(X), of $F$(X) are all fuzzy minimal structures on X[6].

**Definition 2.11:** Let X be a nonempty set and $F_m$ be a fuzzy minimal structure on X.Then the $F_m$-closure and the $F_m$ -interior of a fuzzy set of X are defined in as follows[6]:

(i) $F_m\ Cl(A) = \cap \{\sigma : A \subseteq \sigma, \sigma^c \in F_m\}$,

(ii) $F_m\ Ikt(A) = \cup \{\delta : \delta \subset A, \delta \in F_m\}$.

**Lemma 2.12:** Let (X, $F_m$) be a $F_m$-space on X and $A \in F_m$ and $x_\alpha$ be a fuzzy point in X. Then $x_\alpha \in F_m$ $Cl(A)$ if and only if $\mu q A$ for any fuzzy set $\mu \in F_m$ satisfying the condition $x_\alpha q \mu$.[6].

## 3.1 Fuzzy Minimal Ideal space

**Definition 3.1:** Let $F$(X) be a class of fuzzy subsets of a non empty set X. A subclass $F_m$ of $F$(X) is called fuzzy minimal ideal structure on X (or a $F_m I$-structure) (i) if $A \in I$ and $B \leq A$ , then $B \in I$

(heredity) , (ii) if $A \in I$ and $B \in I$ then $A \cup B \in I$ (finite additivity) is called a fuzzy ideal on X . The triplex $(X, F_m, I)$ denotes a fuzzy minimal ideal topological space .

The local function for a fuzzy set $A$ of X with respect to $F_m$ and $I$ denoted by $A*(F_m, I)$ ( briefly A*) in a fuzzy minimal ideal topological space $(X, F_m, I)$ is the union of all fuzzy points $x_\beta$ such that if $U$ is a fuzzy Q-neighbourhood of $x_\beta$ and $E \in I$ then for at least one point $y \in X$ for which $U(y) + A(y) - 1 > E(y)$ .

**Remark 3.2:** Let $(X, F_m, I)$ be a fuzzy minimal structure. Then
(i) If $I = \{\emptyset\}$, then $A^*{}_m(\emptyset) = mCl\,(A)$,
(ii) If $I = \wp(X)$, then $A^*_m(\wp(X)) = \emptyset$

**Definition 3.3:** Let $(X, F_m, I)$ be a fuzzy minimal space with an ideal $I$ on X. For $A \subset X$ the set operator $mCl^*$ is called a fuzzy minimal $*$-closure ideal and is defined as $mCl^*(A) = A \cup A^*_m$. It is denoted as $m^*_S(X, F_m, I)$ the fuzzy minimal structure generated by $mCl^*$ , that is, $m^*_S(X, F_m, I) = \{U \subset X : mCl^*(X - U) = X - U\}$ ; $m^*_S(X, F_m)$ is called fuzzy $*$-minimal ideal structure which is finer than $F_m$ .

**Remark 3.4:** The elements of $m^*_S(X, F_m, I)$ are called fuzzy minimal $*$-open (briefly, fuzzy $m$ $*$-open) and the complement of a fuzzy $m$ $*$-open set is called fuzzy minimal $*$-closed (briefly,fuzzy $m$ $*$-closed).

**Theorem 3.5:** Let $(X, F_m)$ be a fuzzy minimal-space with an fuzzy ideal $I$ on X and $A, B$ be fuzzy subsets of X. Then the following properties hold:

(i) $A \subset B \Rightarrow A^*_m \subset B^*_m$,
(ii) $I \subset I' \Rightarrow A^*_m(I') \subset A^*_m(I)$,
(iii) $A^*_m = mCl(A^*_m) \subset mCl(A)$,
(iv) $A^*_m \cup B^*_m \subset (A \cup B)^*_m$,
(v) $(A^*_m)^*_m \subset A^*_m$.

**Proof: (i)** Since $A \subset B \Rightarrow A^*_m \subset B^*_m$, for every $x \in A^*_m$ .Then by the definition $x \in A^*_m$ implies $x \in B^*_m$. Which completes the proof.

(ii) The proof is obvious
(iii) The proof is obvious
(iv) Let $x_\beta \notin A^*_m \cup B^*_m$ therefore $x_\beta$ is not contained in both $A^*_m$ and $B^*_m$. Then there is one Q-neighbourhoof $u_1$ of $x_\beta$ such that for every $y \in X$, $u_1 + A(y) - 1 \le E_1$, for some $E_1 \in I$.Similarly there is one Q-neighborhood of $u_2$ of $x_\beta$ such that for every $y \in X$, $u_2 + A(y) - 1 \le E_2$, for some $E_2 \in I$. Let $u = u_1 \cup u_2$, u is also Q-neighbourhood of $x_\beta$ such that $u(y) + A \cup B(y) - 1 \le E_1 \cup E_1$ for every $y \in X$. Therfore by fininte additivity of fuzzy ideal $E_1 \cup E_1 \in I$ and $x_\beta \notin (A \cup B)^*$. Hence $A^*_m \cup B^*_m \subset (A \cup B)^*_m$.
(v) The proof is obvious.

**Remark 3.6:** Let $(X, F_m, I)$ be a fuzzy minimal ideal space with an ideal $I$ on X, then $A^*_m \cup B^*_m = (A \cup B)^*_m$.

**Corollary 3.7:** Let $(X, F_m, I)$ be a fuzzy minimal space and $A \subset X$ .Then the set operator fuzzy $mCl^*(A)$ satisfies the following conditions:

(i) $A \subset mCl^*(A)$,
(ii) $mCl(\emptyset) = \emptyset\ akd\ mCl^*(X) = X$,
(iii) $If\ A \subset B, thek\ mCl^*(A) \subset mCl^*(B)$,
(iv) $mCl^*(A) \cup mCl^*(B) \subset mCl^*(A \cup B)$.

## 4.1 Fuzzy minimal $I_g$ -closed

**Definition 4.1:** A subset $A$ of fuzzy minimal ideal space $(X, F_m, I)$ is fuzzy minimal$-I$-generalized closed (in brief, fuzzy minimal $I_g$-closed) if $A_m^* \subset U$ whenever $U$ is fuzzy minimal-open and denoted as $(X, F_m, I_g)$.

**Proposition 4.2:** Let $(X, m_S)$ be a fuzzy minimal space. Every fuzzy minimal-closed set is fuzzy minimal $I_g$-closed.

**Remark 4.3:** Every fuzzy minimal $*$-closed set is fuzzy minimal $I_g$-closed. But the converse may not be true. Examples can be easily constructed to show that the converse may not be true.

**Example 4.4 :** Let X={a, b} and A and U be defined as follows:

A(a)=0.3 , A(b)=0.2

U(a)=0.5 , U(b)=0.7

Let $r$ = {0, U, 1} be the fuzzy minimal topology on X and I = {0} be a fuzzy minimal ideal on X. Then A is fuzzy minimal $I_g$-closed in $(X, F_m, I)$, but not fuzzy minimal $*$-closed.

**Remark 4.5:** Let $(X, F_m, I)$ be a fuzzy minimal ideal space then every fuzzy $g$-closed set (resp. fuzzy $*$-closed) set is fuzzy minimal $I_g$ -closed.

**Theorem 4.7:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space. Then $A^*$ is fuzzy minimal $I_g$-closed for every fuzzy set $A$ of X.

**Proof:** Let $A$ be a fuzzy set of X and $U$ be any fuzzy minimal open set of X such that $A^* \leq U$. Since $(A^*)^* \leq A^*$ it follows that $(A^*)^* \leq U$. Hence $A^*$ is fuzzy minimal $I_g$ -closed.

**Theorem 4.8:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space and $A$ be a fuzzy minimal $I_g$-closed and fuzzy open set in X. Then $A$ is fuzzy minimal $*$-closed.

**Proof:** Since $A$ is fuzzy open and fuzzy minimal $I_g$ -closed and $A \leq A$. It follows that $A^* \leq A$ because $A$ is fuzzy minimal $I_g$ -closed .Hence $Cl^*(A) = A \cup A^* \leq A$ and $A$ is fuzzy minimal $*$-closed.

**Theorem 4.9:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space and $A$ be a fuzzy minimal set of X. Then the following are equivalent:

(i) $A$ is fuzzy minimal $I_g$ -closed.

(ii) $Cl^*(A) \leq U$ whenever $A \leq U$ and $U$ is fuzzy minimal open in X.

(iii) $\rceil(AqF) \Longrightarrow \rceil(Cl^*(A)qF)$ for every fuzzy minmal closed set $F$ of X.

(iv) $\rceil(AqF) \Longrightarrow \rceil(A^*qF)$ for every fuzzy minimal closed set $F$ of X.

**Proof:** (i) $\Longrightarrow$(ii). Let $A$ be a fuzzy minimal $I_g$ -closed set in X. Let $A \leq U$ where $U$ is fuzzy minimal open set in X. Then $A^* \leq U$. Hence $Cl^*(A) = A \cup A^* \leq U$. Which implies that $Cl^*(A) \leq U$.

(ii) ⟹(i). Let $A$ be a fuzzy set of X. By hypothesis $Cl^*(A) \leq U$ .Which implies that $A^* \leq U$. Hence $A$ is fuzzy minimal $I_g$ -closed.

(ii) ⟹(iii). Let $F$ be a fuzzy minimal closed set of X and $\rceil(AqF)$. Then $1 - F$ is fuzzy minimal open in X and by Lemma 2.7, $\leq 1 - F$ . Therefore, $Cl^*(A) \leq 1 - F$, because $A$ is fuzzy minimal $I_g$ -closed. Hence by Lemma 2.7, , $\rceil(Cl^*(A)qF)$.

(iii) ⟹(ii). Let $U$ be a fuzzy minimal open set of X such that $A \leq U$.Then by Lemma 2.7, , $\rceil(Aq(1 - U))$ and $1 - U$ is fuzzy minimal closed in X. Therefore by hypothesis $\rceil(Cl^*(A)q(1 - U))$. Hence, $Cl^*(A) \leq U$.

(i)⟹(iv). Let $F$ be a fuzzy minimal closed set in X such that $\rceil(AqF)$. Then $A \leq 1 - F$ where $1 - F$ is fuzzy minimal open. Therefore by (i) $A^* \leq 1 - F$. Hence $\rceil(A^*qF)$.

(iv) ⟹(i). Let $U$ be a fuzzy minimal closed set in X such that $A \leq U$.Then by Lemma 2.7, , $\rceil(Aq(1 - U))$ and $1 - U$ is fuzzy minimal closed in X. Therefore by hypothesis $\rceil(A^*q(1 - U))$. Hence $A^* \leq U$ and $A$ is fuzzy minimal $I_g$ -closed set in X.

**Theorem 4.10:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space and $A$ be a fuzzy minimal $I_g$ -closed set. Then $x\ qCl^*(A) \implies Cl(x\ )qA$ for any fuzzy point $x$ of X.

**Proof:** Let $x\ qCl^*(A)$ . If $\rceil(Cl(x\ )qA)$. Then by Lemma 2.7, , $A \leq (1 - Cl(x\ ))$. And so by Theorem 3.3(ii), $Cl^*(A) \leq (1 - Cl(x\ ))$ because $(1 - Cl(x\ ))$ is fuzzy minimal open set in X. Which implies that $Cl^*(A) \leq (1 - x\ )$. Hence by Theorem 3.3(ii), $\rceil(x\ qCl^*(A))$,which is a contradiction.

**Theorem 4.11:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space and $A$ be a fuzzy minimal $I_g$-closed set in X. Then $A$ is fuzzy minimal $*$ -closed.
**Proof:** The proof is obvious.

**Theorem 4.12:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space and $A$ be fuzzy $*$-dense in itself fuzzy minimal $I_g$-closed set of X. Then $A$ is fuzzy $g$-closed.
**Proof:** Let $U$ be a fuzzy minimal open set of X such that $A \leq U$. Since $A$ is fuzzy minimal $I_g$-closed, by Theorem 4.9 (ii), $Cl^*(A) \leq U$. Therefore, $Cl(A) \leq U$, because $A$ is fuzzy $*$-dense in itself. Hence $A$ is fuzzy $g$-closed.

**Theorem 4.13:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space where $I = \{0\}$ and $A$ be a fuzzy minimal set of X. Then $A$ is fuzzy minimal $I_g$-closed if and only if $A$ is fuzzy $g$-closed.
**Proof:** Since $I = \{0\}$, $A^* = Cl(A)$ for each subset $A$ of . Now the result can be easily proved.

**Theorem 4.14:** Let $(X, F_m, I)$be a fuzzy minimal ideal topological space and $A$, $B$ are fuzzy minimal $I_g$ -closed sets of X. Then $A \cup B$ is fuzzy minimal $I_g$ -closed.
**Proof:** Let $U$ be a fuzzy minimal open set of X such that $A \cup B \leq U$. Then $A \leq U$ and $B \leq U$ .Therefore $A^* \leq U$ and $B^* \leq U$ because $A$ and $B$ are fuzzy minimal $I_g$-closed sets of X. Hence $(A \cup B)^* \leq U$ and $A \cup B$ is fuzzy minimal $I_g$-closed.

**Remark 4.15:** The intersection of two fuzzy minimal $I_g$-closed sets in a fuzzy minimal ideal topological space $(X, F_m, I)$ may not be fuzzy minimal $I_g$ -closed .

**Example 4.16 :** Let X ={a, b} and A,B be two fuzzy minimal sets defined as follows :

A (a) = 0.9 , A (b) = 0.7
B (a) = 0.8 , B (b) = 0.7
U (a) = 0.3 , U (b) = 0.4

Let τ = { 0, U, 1} and I = {0} . Then A and B are fuzzy minimal $I_g$-closed sets in $(X, F_m, I)$ but A ∩ B is not fuzzy minimal $I_g$ -closed.

**Theorem 4.17:** Let $(X, F_m, I)$ be a fuzzy ideal topological space and A, B are fuzzy minimal sets of X such that A ≤ B ≤ Cl*(A). If A is fuzzy minimal $I_g$-closed set in X, then B is fuzzy minimal $I_g$ -closed.
**Proof:** Let U be a fuzzy minimal open set such that B ≤ U. Since A ≤ B we have A ≤ U. Hence, Cl*(A) ≤ U because A is fuzzy minimal $I_g$ -closed. Now B ≤ Cl*(A) implies that Cl*(B) ≤ Cl*(A) ≤ U . Consequenly B is fuzzy minimal $I_g$ -closed.

**Theorem 4.18:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space and $A, B$ are fuzzy minimal sets of X such that $A \leq B \leq A^*$. Then $A$ and $B$ are fuzzy $I_g$-closed.
**Proof:** The proof is obvious.

**Theorem 4.19:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space .If $A$ and $B$ are fuzzy subsets of X such that $A \leq B \leq A^*$ and $A$ is fuzzy minimal $I_g$-closed . Then $A^* = B^*$ and $B$ is fuzzy minimal $*$ -open in itself .

**Proof:** Obvious.

**Theorem 4.20:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space and $\mathcal{F}$ be the family of all fuzzy minimal $*$- closed sets of X . Then $\tau \subset \mathcal{F}$ if and only if every fuzzy set of X is fuzzy minimal $I_g$-closed .

**Proof: Necessity.** Let $\tau \subset \mathcal{F}$ and $U$ be a fuzzy minimal open set in X such that $A \leq U$ .Now $U \in r \Longrightarrow U \in \mathcal{F}$ . And so $Cl^*(A) \leq Cl^*(U) = U$ and $A$ is fuzzy minimal $I_g$ -closed set in X.
**Sufficiency.** Suppose that every fuzzy minimal set of X is fuzzy minimal $I_g$-closed . Let $U \in r$. Since $U$ is fuzzy minimal $I_g$ -closed and U≤ U , $Cl^*(U) \leq U$ . Hence $Cl^*(U) = U$ and $U \in \mathcal{F}$ . Therefore $\tau \subset \mathcal{F}$ .

**Definition 4.21:** A fuzzy set $A$ of a fuzzy minimal ideal topological space $(X, F_m, I)$ is called fuzzy minimal $I_g$ -open if its complement $1 - A$ is fuzzy minimal $I_g$-closed.

**Remark 4.22:** Every fuzzy $g$-open set is fuzzy minimal $I_g$ -open . But the converse may not be true.

**Remark 4.23:** Every fuzzy $*$-open set in a fuzzy minimal ideal topological space $(X, F_m, I)$ is fuzzy minimal $I_g$ -open. But the converse may not be true.

**Theorem 4.24:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space and $A$ is fuzzy set of X. Then $A$ is fuzzy minimal $I_g$ -open if and only if $F \leq Ikt^*(A)$ whenever $F$ is fuzzy minimal closed and $F \leq A$.

**Proof: Necessity.** Let $A$ be fuzzy minimal $I_g$ -open and $F$ is fuzzy minimal closed set such that $F \leq A$. Then $1 - A$ is fuzzy minimal $I_g$ -closed, $1 - A \leq 1 - F$ and $1 - F$ is fuzzy minimal open in X. Hence $Cl^*(1 - A) \leq (1 - F)$. Which implies that $F \leq Ikt^*(A)$.

**Sufficiency.** Let $U$ be a fuzzy minimal open set such that $1 - A \leq U$. Then $1 - U$ is fuzzy minimal closed set of X such that $1 - U \leq A$ . And so by hypothesis, $1 - U \leq Ikt^*(A)$.Which implies that $Cl^*(1 - A) \leq U$ and $1 - A$ is fuzzy minimal $I_g$ -closed. Hence $A$ is fuzzy minimal $I_g$-open.

**Theorem 4.25:** Let $(X, F_m, I)$ be a fuzzy minimal ideal topological space and $A$ be a fuzzy set of X. If $A$ is fuzzy minimal $I_g$ -open and $Ikt^*(A) \leq B \leq A$, then $B$ is fuzzy minimal $I_g$ -open.
**Proof:** Follows from Definition 4.21 and Theorem 4.18.

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