



INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

On $If_{\hat{g}} * \text{Closed Sets In Intuitionistic Fuzzy Topological Spaces}$

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ABSTRACT

In this paper, we introduce the new class of closed sets namely, *intuitionistic fuzzy $\hat{g}$ -closed sets* in intuitionistic fuzzy topological spaces using intuitionistic fuzzy generalized closed sets. Also we discuss some basic properties and investigate the relationship with other existing intuitionistic fuzzy closed sets in intuitionistic fuzzy topological space.

Keywords: Intuitionistic fuzzy topology, Intuitionistic fuzzy $\hat{g}$ -closed sets, Intuitionistic fuzzy generalized closed sets, Intuitionistic fuzzy generalized open sets.

AMS Classification: 54A40, 03F55

1. INTRODUCTION

The concept of fuzzy sets was introduced by Zadeh [11] in 1965 and later Atanassov [1] generalized this idea to intuitionistic fuzzy sets using the notion of fuzzy sets. On the other hand D. Coker [3] introduced intuitionistic fuzzy topological spaces using the notion of intuitionistic fuzzy sets. The concept of generalized closed sets in topological spaces was introduced by Levine[5]. In 2008, Thakur S.S. and Chaturvedi [10] introduced the concepts of intuitionistic fuzzy generalized closed sets in intuitionistic fuzzy topological spaces.

In this paper we have introduced the new class of closed sets namely, intuitionistic fuzzy $\hat{g}$ -closed sets in intuitionistic fuzzy topological spaces and discussed some of their properties.

2. PRELIMINARIES

Definition 2.1[1]: An *intuitionistic fuzzy set* (IFS for short) A is an object having the form $A = \{\langle x, \mu_A(x), \nu_A(x) \rangle \mid x \in X\}$, where the functions $\mu_A : X \rightarrow [0, 1]$ and $\nu_A : X \rightarrow [0, 1]$ denote the degree of membership (namely $\mu_A(x)$) and the degree of non-membership (namely $\nu_A(x)$) of each element $x \in X$ to the set A , respectively, and $0 \leq \mu_A(x) + \nu_A(x) \leq 1$ for each $x \in X$. Denote by $IFS(X)$, the set of all intuitionistic fuzzy sets in X .

An intuitionistic fuzzy set A in X is simply denoted by $A = \langle x, \mu_A, \nu_A \rangle$ instead of denoting $A = \{\langle x, \mu_A(x), \nu_A(x) \rangle \mid x \in X\}$.

Definition 2.2[1]: Let A and B be IFSs of the form $A = \{\langle x, \mu_A(x), \nu_A(x) \rangle \mid x \in X\}$ and

$B =$

$\{\langle x, \mu_B(x), \nu_B(x) \rangle \mid x \in X\}$.

Then,

- (a) $A \subseteq B$ if and only if $\mu_A(x) \leq \mu_B(x)$ and $\nu_A(x) \geq \nu_B(x)$ for all $x \in X$
- (b) $A = B$ if and only if $A \subseteq B$ and $B \subseteq A$
- (c) $A^c = \{\langle x, \nu_A(x), \mu_A(x) \rangle \mid x \in X\}$
- (d) $A \cap B = \{\langle x, \mu_A(x) \wedge \mu_B(x), \nu_A(x) \vee \nu_B(x) \rangle \mid x \in X\}$
- (e) $A \cup B = \{\langle x, \mu_A(x) \vee \mu_B(x), \nu_A(x) \wedge \nu_B(x) \rangle \mid x \in X\}$

Note: The intuitionistic fuzzy sets $0 \sim = \{\langle x, 0, 1 \rangle \mid x \in X\}$ and $1 \sim = \{\langle x, 1, 0 \rangle \mid x \in X\}$ are respectively the empty set and the whole set of X .

Definition 2.3[3]: An *intuitionistic fuzzy topology* (IFT in short) on X is a family τ of IFSs in X satisfying the following axioms :

- $0 \sim, 1 \sim \in \tau$
- $G_1 \cap G_2 \in \tau$, for any $G_1, G_2 \in \tau$
- $\cup G_i \in \tau$ for any family $\{G_i \mid i \in J\} \subseteq \tau$.

In this case the pair (X, τ) is called an *intuitionistic fuzzy topological space* (IFTS in short) and any IFS in τ is known as an intuitionistic fuzzy open set (IFOS in short) in X .

The complement A^c of an IFOS A in an IFTS (X, τ) is called an intuitionistic fuzzy closed set (IFCS in short) in X .

Definition 2.4[3]: Let (X, τ) be an IFTS and $A = \langle x, \mu_A, \nu_A \rangle$ be an IFS in X .

Then the *intuitionistic fuzzy interior* and an *intuitionistic fuzzy closure* are defined by

$$\text{int}(A) = \cup \{G \mid G \text{ is an IFOS in } X \text{ and } G \subseteq A\},$$

$$\text{cl}(A) = \cap \{K \mid K \text{ is an IFCS in } X \text{ and } A \subseteq K\}.$$

Note that for any IFS A in (X, τ) , we have

- (1) A is an intuitionistic fuzzy closed set in X iff $\text{cl}(A) = A$
- (2) A is an intuitionistic fuzzy open set in X iff $\text{int}(A) = A$
- (3) $\text{cl}(A^c) = (\text{int}(A))^c$
- (4) $\text{int}(A^c) = (\text{cl}(A))^c$

Definition 2.5: An IFS $A = \langle x, \mu_A, \nu_A \rangle$ in an IFTS (X, τ) is said to be an

- (a) intuitionistic fuzzy semi open set [7] (IFSOS in short) if $A \subseteq \text{cl}(\text{int}(A))$
- (b) intuitionistic fuzzy pre open set [6] (IFPOS in short) if $A \subseteq \text{int}(\text{cl}(A))$
- (c) intuitionistic fuzzy α -open set [8] (IF α OS in short) if $A \subseteq \text{int}(\text{cl}(\text{int}(A)))$

The complement of an IFSOS (resp. IFPOS, IF α OS) is called IFSCS (resp. IFPCS, IF α CS). The intersection of all IFSCS (resp. IFPCS, IF α CS) in X containing A is called the semiclosure (resp. pre closure and α -closure) of A and is denoted by $\text{scl}(A)$ (resp. $\text{pcl}(A)$ and $\alpha\text{cl}(A)$).

Definition 2.6: An IFS $A = \langle x, \mu_A, \nu_A \rangle$ in an IFTS (X, τ) is said to be an

- 1) intuitionistic fuzzy generalized closed set [10] (IFgCS in short) if $\text{cl}(A) \subseteq U$ whenever $A \subseteq U$ and U is an IFOS in X .
- 2) intuitionistic fuzzy generalized pre closed set [6] (IFgPCS in short) if $\text{pcl}(A) \subseteq U$ whenever $A \subseteq U$ and U is an IFOS in X .
- 3) intuitionistic fuzzy generalized semi closed set [7] (IFgSCS in short) if $\text{scl}(A) \subseteq U$ whenever $A \subseteq U$ and U is an IFOS in X .
- 4) intuitionistic fuzzy semi generalized closed set [7] (IFSgCS in short) if $\text{scl}(A) \subseteq U$ whenever $A \subseteq U$ and U is an IFSOS in X .

- 5) intuitionistic fuzzy α generalized closed set [8] (IF α GS in short) if $\alpha\text{cl}(A) \subseteq U$ whenever $A \subseteq U$ and U is an IFOS in X .
- 6) intuitionistic fuzzy g^* closed set [2] (IF g^* CS in short) if $\text{cl}(A) \subseteq U$ whenever $A \subseteq U$ and U is an IFgOS in X .
- 7) intuitionistic fuzzy strongly g^* closed set [4] (IF strongly g^* CS in short) if $\text{cl}(\text{int}(A)) \subseteq U$ whenever $A \subseteq U$ and U is an IFgOS in X .
- 8) intuitionistic fuzzy β^{**} generalized closed set [9] (IF β^{**} gCS in short) if $\text{cl}(\text{int}(\text{cl}(A))) \cap \text{int}(\text{cl}(\text{int}(A))) \subseteq U$ whenever $A \subseteq U$ and U is an IFOS in X .

The complement of an IFgCS (resp. IFgPCS, IFsgCS, IF α GS, IF g^* CS, IF strongly g^* CS and IF β^{**} CS) is called as IFgOS (resp. IFgPOS, IFsgOS, IF α OS, IF g^* CS, IF strongly g^* OS and IF β^{**} OS).

Definition 2.7: $\text{cl}^*(A)$ is defined as the intersection of all IFgCS containing A

3. INTUITIONISTIC FUZZY $\hat{g}^*$ CLOSED SET

We introduce the following definition.

Definition 3.1: An IFS A is said to be an *intuitionistic fuzzy generalized $\hat{g}^*$ closed set* (IF $\hat{g}^*$ CS in short) in (X, τ) if $\text{cl}^*(A) \subseteq U$ whenever $A \subseteq U$ and U is an IFgOS in X . The family of all IF $\hat{g}^*$ CS of an IFTS (X, τ) is denoted by IF $\hat{g}^*$ C(X).

Definition 3.2: The complement of an IF $\hat{g}^*$ CS is said to be an *intuitionistic fuzzy $\hat{g}^*$ open set* and it is denoted by IF $\hat{g}^*$ OS in (X, τ) . The family of all IF $\hat{g}^*$ OS of an IFTS (X, τ) is denoted by IF $\hat{g}^*$ O(X).

Example 3.3: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.6, 0.4 \rangle, \langle b, 0.7, 0.2 \rangle\}$. Then IF $\hat{g}^*$ CS = $\{\langle a, 0.3, 0.7 \rangle, \langle b, 0.1, 0.8 \rangle\}$ and IF $\hat{g}^*$ OS = $\{\langle a, 0.7, 0.3 \rangle, \langle b, 0.8, 0.1 \rangle\}$ in X .

Theorem 3.4: Every IFCS is an IF $\hat{g}^*$ CS but not conversely.

Proof: Let A be an IFCS in X and U be any IFgOS in (X, τ) such that $A \subseteq U$. Since, "Every IFCS is an IFgCS" and A is an IFCS in X , $\text{cl}^*(A) \subseteq \text{cl}(A) = A \subseteq U$. Therefore, A is an IF $\hat{g}^*$ CS in X .

Example 3.5: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.2, 0.6 \rangle\}$. Then the IFS $A = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.4, 0.5 \rangle\}$ is an IF $\hat{g}^*$ CS in X but not IFCS in X .

Theorem 3.6: Every IFSCS is an IF $\hat{g}^*$ CS but not conversely.

Proof: Let A be an IFSCS in X and U be any IFgOS in (X, τ) such that $A \subseteq U$. Since, "Every IFSCS is an IFgCS" and A is an IFSCS in X , $\text{cl}^*(A) \subseteq \text{scl}(A) = A \subseteq U$. Therefore, A is an IF $\hat{g}^*$ CS in X .

Example 3.7: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.6, 0.4 \rangle, \langle b, 0.7, 0.2 \rangle\}$. Then the IFS $A = \{\langle a, 0.7, 0.3 \rangle, \langle b, 0.8, 0.1 \rangle\}$ is an IF $\hat{g}^*$ CS in X but not IFSCS in X .

Theorem 3.8: Every IF α CS is an IF $\hat{g}^*$ CS but not conversely.

Proof: Let A be an IF α CS in X and U be an IFgOS in (X, τ) such that $A \subseteq U$. Since, "Every IF α CS is an IFgCS" and A is an IF α CS in X , $\text{cl}^*(A) \subseteq \alpha\text{cl}(A) = A \subseteq U$. Therefore, A is an IF $\hat{g}^*$ CS in X .

Example 3.9: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.4, 0.6 \rangle, \langle b, 0.2, 0.7 \rangle\}$. Then the IFS $A = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.3, 0.5 \rangle\}$ is an IF $\hat{g}^*$ CS in X but not IF α CS in X .

Theorem 3.10: Every IFgCS is an $IF\hat{g}^*$ CS but not conversely.

Proof: Let A be an IFgCS in X and U be any IFOS in (X, τ) such that $A \subseteq U$. Since, “Every IFOS is IFgOS” we have, $cl^*(A) \subseteq cl(A) \subseteq U$. Therefore, $cl^*(A) \subseteq U$ where U is an IFgOS in X . Hence, A is an $IF\hat{g}^*$ CS in X .

Example 3.11: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.4, 0.6 \rangle\}$. Then the IFS $A = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.4, 0.6 \rangle\}$ is an $IF\hat{g}^*$ CS in X but not an IFgCS in X .

Theorem 3.12: Every IFSgCS is an $IF\hat{g}^*$ CS but not conversely.

Proof: Let A be an IFSgCS in X and U be any IFSOS in (X, τ) such that $A \subseteq U$. Since, “Every IFSOS is IFgOS” we have, $cl^*(A) \subseteq scl(A) \subseteq U$. Therefore, $cl^*(A) \subseteq U$ where U is an IFgOS in X . Hence, A is an $IF\hat{g}^*$ CS in X .

Example 3.13: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.6, 0.4 \rangle, \langle b, 0.7, 0.2 \rangle\}$. Then the IFS $A = \{\langle a, 0.6, 0.4 \rangle, \langle b, 0.7, 0.2 \rangle\}$ is an $IF\hat{g}^*$ CS in X but not an IFSgCS in X .

Theorem 3.14: Every IF α gCS is an $IF\hat{g}^*$ CS but not conversely.

Proof: Let A be an IF α gCS in X and U be any IFOS in (X, τ) such that $A \subseteq U$. Since, “Every IFOS is IFgOS” and “Every IF α CS is IFgCS” we have, $cl^*(A) \subseteq \alpha cl(A) \subseteq U$. Therefore, $cl^*(A) \subseteq U$ where U is an IFgOS in X . Hence, A is an $IF\hat{g}^*$ CS in X .

Example 3.15: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.4, 0.6 \rangle\}$. Then the IFS $A = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.4, 0.6 \rangle\}$ is an $IF\hat{g}^*$ CS in X but not IF α gCS in X .

Theorem 3.16: Every IFg*CS is an $IF\hat{g}^*$ CS but not conversely.

Proof: Let A be an IFg*CS in X and U be any IFgOS in (X, τ) such that $A \subseteq U$. Since, “Every IFCS is IFgCS”. Therefore, $cl^*(A) \subseteq U$ where U is an IFgOS in X . Hence, A is an $IF\hat{g}^*$ CS in X .

Example 3.17: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.6, 0.4 \rangle, \langle b, 0.7, 0.2 \rangle\}$. Then the IFS $A = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.4, 0.5 \rangle\}$ is an $IF\hat{g}^*$ CS in X but not an IFg*CS in X .

Theorem 3.18: Every $IF\hat{g}^*$ CS is an IF β^{**} gCS but not conversely.

Proof: Let A be an $IF\hat{g}^*$ CS in X and U be an IFOS in (X, τ) such that $A \subseteq U$. Since, $cl(int(cl(A))) \cap int(cl(int(A))) \subseteq cl^*(A) \subseteq U$. Therefore, $cl(int(cl(A))) \cap int(cl(int(A))) \subseteq U$. Hence A is an IF β^{**} gCS in X .

Example 3.19: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.2, 0.6 \rangle\}$. Then the IFS $A = \{\langle a, 0.4, 0.6 \rangle, \langle b, 0.1, 0.7 \rangle\}$ is an IF β^{**} gCS in X but not $IF\hat{g}^*$ CS in X .

Remark 3.20: IFPCS and $IF\hat{g}^*$ CS are independent to each other.

Example 3.21: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.6, 0.3 \rangle\}$. Then the IFS $A = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.5, 0.4 \rangle\}$ is an IFPCS in X but not $IF\hat{g}^*$ CS in X since, $A \subseteq T$ and T is IFgOS in X but $cl^*(A) = 1 \notin T$.

Example 3.21: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.6, 0.3 \rangle\}$. Then the IFS $A = \{\langle a, 0.6, 0.4 \rangle, \langle b, 0.7, 0.2 \rangle\}$ is an $IF\hat{g}^*$ CS in X but not IFPCS in X . since $cl(int(A)) = 1 \notin T$.

Remark 3.22: IFgPCS and $IF\hat{g}^*$ CS are independent to each other.

Example 3.23: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.4, 0.5 \rangle, \langle b, 0.2, 0.6 \rangle\}$. Then the IFS $A = \{\langle a, 0.3, 0.6 \rangle, \langle b, 0.1, 0.7 \rangle\}$ is an IFgPCS in X but not $\text{IF}\hat{g}^*\text{CS}$ in X . since, $A \subseteq T$ and T is IFgOS in X , but $\text{cl}^*(A) = \{\langle a, 0.5, 0.4 \rangle, \langle b, 0.6, 0.2 \rangle\} \not\subseteq T$.

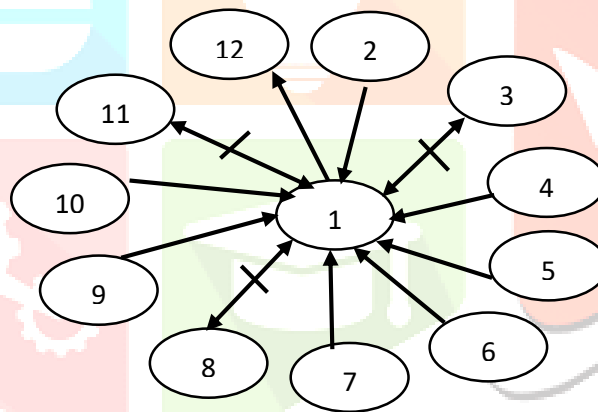
Example 3.23: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.4, 0.6 \rangle\}$. Then the IFS $A = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.4, 0.6 \rangle\}$ is an $\text{IF}\hat{g}^*\text{CS}$ in X but not IFgPCS in X since $A \subseteq T$ and T is IFOS in X but $\text{pcl}(A) = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.6, 0.4 \rangle\} \not\subseteq T$.

Remark 3.24: IF strongly $g^*\text{CS}$ and $\text{IF}\hat{g}^*\text{CS}$ are independent to each other.

Example 3.25: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.6, 0.2 \rangle\}$. Then the IFS $A = \{\langle a, 0.4, 0.6 \rangle, \langle b, 0.5, 0.3 \rangle\}$ is an IFstrongly $g^*\text{CS}$ in X , but not $\text{IF}\hat{g}^*\text{CS}$ in X , since $A \subseteq T$ and T is IFgOS in X , but $\text{cl}^*(A) = \{\langle a, 0.5, 0.5 \rangle, \langle b, 0.2, 0.6 \rangle\} \not\subseteq T$.

Example 3.25: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.2, 0.8 \rangle, \langle b, 0.3, 0.7 \rangle\}$. Then the IFS $A = \{\langle a, 0.4, 0.5 \rangle, \langle b, 0.5, 0.4 \rangle\}$ is an $\text{IF}\hat{g}^*\text{CS}$ in X but not IFstrongly $g^*\text{CS}$ in X since $A \subseteq T$ and T is IFgOS in X but $\text{cl}(\text{int}(A)) = \{\langle a, 0.8, 0.2 \rangle, \langle b, 0.7, 0.3 \rangle\} \not\subseteq T$.

The following diagram shows the relationship of $\text{IF}\hat{g}^*\text{CS}$ with other existing sets. $A \rightarrow B$ represents A implies B and $A \nrightarrow B$ represents A and B are independent to each other.



1. $\text{IF}\hat{g}^*\text{CS}$	2. IFCS	3. IFPCS	4. IFSCS
5. $\text{IF}\alpha\text{CS}$	6. IFgCS	7. IFSgCS	8. IFgPCS
9. $\text{IF}\alpha g\text{CS}$	10. $\text{IF}\hat{g}^*\text{CS}$	11. IF strongly $g^*\text{CS}$	12. $\text{IF}\beta^{**}g\text{CS}$

Theorem 3.26: If A and B are $\text{IF}\hat{g}^*\text{CS}$ s in an IFTS (X, τ) , then $A \cup B$ is also an $\text{IF}\hat{g}^*\text{CS}$ in (X, τ) .

Proof: Let $A \cup B \subseteq U$ and U is IFgOS then $A \subseteq U$ or $B \subseteq U$. Since, A and B are $\text{IF}\hat{g}^*\text{CS}$, $\text{cl}^*(A) \subseteq U$ or $\text{cl}^*(B) \subseteq U$ then, $\text{cl}^*(A) \cup \text{cl}^*(B) \subseteq U$. Now, $\text{cl}^*(A \cup B) = \text{cl}^*(A) \cup \text{cl}^*(B) \subseteq U$ Therefore, $A \cup B$ is an $\text{IF}\hat{g}^*\text{CS}$ in (X, τ) .

Remark 3.27: The intersection of two $\text{IF}\hat{g}^*\text{CS}$ s in an IFTS (X, τ) neednot be an $\text{IF}\hat{g}^*\text{CS}$ in (X, τ) .

Example 3.28: Let $X = \{a, b\}$ and $\tau = \{0 \sim, T, 1 \sim\}$ be an IFT on X where $T = \{\langle a, 0.1, 0.9 \rangle, \langle b, 0, 1 \rangle\}$. Consider the two IFS $A = \{\langle a, 0, 0.9 \rangle, \langle b, 0.1, 0.9 \rangle\}$ and $B = \{\langle a, 0.5, 0.4 \rangle, \langle b, 0, 1 \rangle\}$. Then A and B are $\text{IF}\hat{g}^*\text{CS}$ s but $A \cap B = \{\langle a, 0, 0.9 \rangle, \langle b, 0, 1 \rangle\}$ is not $\text{IF}\hat{g}^*\text{CS}$ in X . Since $A \cap B \subseteq T$ and T is IFgOS in X but $\text{cl}^*(A \cap B) = \{\langle a, 0.9, 0.1 \rangle, \langle b, 1, 0 \rangle\} \not\subseteq T$.

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