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Some Properties of Intuitionistic (T, S)-Fuzzy Filters on Lattice Implication Algebras

Jiabin Xu[1]

Abstract

Combining intuitionistic fuzzy sets and filter theory,we studied interval valued intuitionistic (T, S)-fuzzy filters on lattice implication algebras. some relation properties of it are obtained, the relation between intuitionistic (T, S)-fuzzy filters and intuitionistic fuzzy set are discussed.The investigation method and content of lattice implication algebras are extended.

Mathematics Subject Classification: 03E72
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1 Introduction

Intelligent information processing is one important research direction in artificial intelligence. non-classical logics, a great extension and development

[1] College of Mathematics and Information Sciences, Neijiang Normal University, Neijiang 641000, Sichuan, China.

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of classical logic,have become as a formal and useful tool for computer science to deal with uncertain information. In the field of non-classical logics, lattice-valued logic plays an important role for the following two aspects: One is that it extends the chain-type truth-valued field of some well known present logic to some relatively general lattice. The other is that the incompletely comparable property of truth value characterized by general lattice can more efficiently reflect the uncertainty of human being's thinking, judging and decision. Hence, lattice-valued logic is becoming an active research field which strongly influences the development of algebraic logic, computer science and artificial intelligent technology. V.Novak[1] and J.Pavelka[2] research on the lattice-valued logic formal systems.

In order to establish a logical system with truth value in a relatively general lattice, Xu [3]proposed the concept of lattice implication algebras(LIA for short). However, when a logic algebra is studied, filters and congruences are very important tools, they can give a foundation for logical systems from semantic viewpoint. On filter theory of lattice implication algebras have been extensively investigated, many useful structures are obtained [4, 5, 6, 8, 10, 12, 13, 14, 15, 16, 17]. The concept of fuzzy set was introduced by Zadeh(1965)[7]. Since then this idea has been applied to other algebraic structures such as groups, semigroups, rings, modules, vector spaces and topologies. The concept of intuitionistic fuzzy sets was first introduced by Atanassov[19] in 1986 which is a generalization of the fuzzy sets. Many authors applied the concept of intuitionistic fuzzy sets to other algebraic structure such as groups, fuzzy ideals of BCK-algebras, filter theory of lattice implication [15, 16, 17] and BL-algebras[18], etc.

This paper,combining the concept of intuitionistic fuzzy set, t-norm,s-norm and filter, the concept of intuitionistic (T, S)-fuzzy filters of lattice implication algebras is introduced, some relation properties and some equivalent results are obtained.

2 Preliminary Notes

Definition 2.1 ([3,6]). *Let $(L, \vee, \wedge, O, I)$ be a bounded lattice with an order-reversing involution $'$, the greatest element I and the smallest element*

O, and

$$\rightarrow: L \times L \longrightarrow L$$

be a mapping. $\mathcal{L} = (L, \vee, \wedge, ', \rightarrow, O, I)$ is called a lattice implication algebra if the following conditions hold for any $x, y, z \in L$:

(I_1) $x \rightarrow (y \rightarrow z) = y \rightarrow (x \rightarrow z)$;
(I_2) $x \rightarrow x = I$;
(I_3) $x \rightarrow y = y' \rightarrow x'$;
(I_4) $x \rightarrow y = y \rightarrow x = I$ implies $x = y$;
(I_5) $(x \rightarrow y) \rightarrow y = (y \rightarrow x) \rightarrow x$;
(l_1) $(x \vee y) \rightarrow z = (x \rightarrow z) \wedge (y \rightarrow z)$;
(l_2) $(x \wedge y) \rightarrow z = (x \rightarrow z) \vee (y \rightarrow z)$.

Theorem 2.2 ([6]**).** *In a lattice implication algebra $\mathcal{L}$. The following hold, for any $x, y, z \in L$*

(1) $I \rightarrow x = x$ and $x \rightarrow O = x'$;
(2)$(x \rightarrow y) \rightarrow ((y \rightarrow z) \rightarrow (x \rightarrow z)) = I$;
(3) $x \vee y = (x \rightarrow y) \rightarrow y$;
(4) $x \wedge y = (x' \vee y')'$;
(5) $(x \rightarrow y) \vee (y \rightarrow x) = I$;
(6) $x \rightarrow (y \vee z) = (y \rightarrow z) \rightarrow (x \rightarrow z)$.

In what follows, let $\mathcal{L}$ denoted a lattice implication algebra unless otherwise specified.

Definition 2.3 ([6]**).** *A non-empty subset F of a lattice implication algebra $\mathcal{L}$ is called a* **filter** *of $\mathcal{L}$ if it satisfies, for any $x, y \in L$,*

(F1)$1 \in F$;
(F2)$x \in F, x \rightarrow y \in F \Rightarrow y \in F$.

Proposition 2.4 ([6]**).** *A non-empty subset F of a lattice implication algebra $\mathcal{L}$ is called a* **filter** *of $\mathcal{L}$ if it satisfies, for any $x, y \in L$,*

(F3)$x, y \in F \Rightarrow x \otimes y \in F$;
(F4) $x \in F, x \leq y \Rightarrow y \in F$.

A fuzzy set A of a lattice implication algebra $\mathcal{L}$ is a mapping from $\mathcal{L}$ to $[0, 1]$, (see, [8]).

Definition 2.5 ([6])**.** (1) *A fuzzy set A of a lattice implication algebra $\mathcal{L}$ is called a* **fuzzy filter***, if it satisfies, for any $x, y \in L$,*

(FF1) $A(1) \geq A(x)$;

(FF2) $A(y) \geq min\{A(x), A(x \to y)\}$.

Definition 2.6 ([22])**.** *Let δ be a mapping from $[0, 1] \times [0, 1]$ to $[0, 1]$. δ is called a t-norm (resp. s-norm) on $[0, 1]$, if it satisfies the following conditions: for any $x, y, z \in [0, 1]$,*

(1) $\delta(x, 1) = x$ (resp. $\delta(x, 0) = x$),

(2) $\delta(x, y) = \delta(y, x)$,

(3) $\delta(\delta(x, y), z) = \delta(x, \delta(y, z))$,

(4) if $x \leq y$, then $\delta(x, z) \leq \delta(y, z)$.

The set of all δ-idempotent elements $D_\delta = \{x \in [0, 1] | \delta(x, x) = x\}$.

An intuitionistic fuzzy set on X is defined as an object of the form $A = \{(x, M_A(x), x, N_A(x)) | x \in X\}$, where M_A, N_A are fuzzy sets on X such that $[0, 0] \leq M_A(x) + N_A(x) \leq [1, 1]$. For the sake of simplicity, in the following, such intuitionistic fuzzy sets will be denoted by $A = (M_A, N_A)$.

3 Intuitionistic (T, S)-Fuzzy Filters

In this section, all theorems are discussed under the condition that t-norm, s-norm are all nilpotent.

Definition 3.1. *An intuitionistic fuzzy set A of $\mathcal{L}$ is called an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$, if for any $x, y, z \in L$:*

(V1) $M_A(I) \geq M_A(x)$ and $N_A(I) \leq N_A(x)$;

(V2) $M_A(y) \geq T(M_A(x \to y), M_A(x))$ and $N_A(y) \leq S(N_A(x \to y), N_A(x))$.

Remark 3.2. In definition 5, taking $T = min, S = max$, then intuitionistic (T, S)-fuzzy filter is intuitionistic fuzzy filter. So intuitionistic (T, S)-fuzzy filter is a generalization of intuitionistic fuzzy filter.

Example 3.3. Let $L = \{O, a, b, c, d, I\}$, Hasse graph of L and its operator see example 2.6 in[5]. Then $\mathcal{L} = (L, \vee, \wedge, \to, O, I)$ is a lattice implication algebra.

Define a vague set A of $\mathcal{L}$:

$$A = \{\langle I, [0.7, 0.2]\rangle, \langle a, [0.5, 0.3]\rangle, \langle b, [0.5, 0.3]\rangle, \langle c, [0.5, 0.3]\rangle, \langle d, [0.5, 0.3]\rangle, \langle O, [0.7, 0.2]\rangle\}$$

It is easy to verify A is a intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$.

Theorem 3.4. *Let A be an intuitionistic fuzzy set on $\mathcal{L}$. Then A is an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$, if and only if, for any $\alpha, \beta \in [0, 1]$ and $\alpha + \beta \leq 1$, the sets $U(M_A; \alpha)(\neq \emptyset)$ and $L(N_A; \beta)(\neq \emptyset)$ are filters of $\mathcal{L}$, where $U(M_A; \alpha) = \{x \in L | M_A(x) \geq \alpha\}$, $L(N_A; \beta) = \{x \in L | N_A(x) \leq \beta\}$.*

Proof. Assume A is an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$, then $M_A(I) \geq M_A(x)$. By the condition $U(M_A, \alpha) \neq \emptyset$, it follows that there exists $a \in L$ such that $M_A(a) \geq \alpha$, and so $M_A(I) \geq \alpha$, hence $I \in U(M_A; \alpha)$.

Let $x, x \to y \in U(M_A; \alpha)$, then $M_A(x) \geq \alpha, M_A(x \to y) \geq \alpha$. Since A is a v-filter of $\mathcal{L}$, then $M_A(y) \geq T(M_A(x), M_A(x \to y)) \geq T(\alpha, \alpha) = \alpha$. Hence $y \in U(M_A; \alpha)$.Therefore $U(M_A; \alpha)$ is a filter of $\mathcal{L}$.

We will show that $L(N_A; \beta)$ is a filter of $\mathcal{L}$.

Since A is an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$, then $N_A(I) \leq N_A(x)$. By the condition $L(N_A, \beta) \neq \emptyset$, it follows that there exists $a \in L$ such that $N_A(a) \leq \beta$, and so $N_A(a) \leq \beta$, we have $N_A(I) \leq N_A(a) \leq \beta$, hence $I \in L(N_A; \beta)$.

Let $x, x \to y \in L(N_A; \beta)$, then $N_A(x) \leq \beta; N_A(x \to y) \leq \beta$. Since A is an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$, then $N_A(y) \leq S(N_A(x), N_A(x \to y)\} \leq S(\beta, \beta) = \beta$. It follows that $N_A(y) \leq \beta$, hence $y \in L(N_A; \beta)$. Therefore $L(N_A; \beta)$ is a filter of $\mathcal{L}$.

Conversely, suppose that $U(M_A; \alpha)(\neq \emptyset)$ and $L(N_A; \beta)(\neq \emptyset)$ are filters of $\mathcal{L}$, then, for any $x \in L$, $x \in U(M_A; M_A(x))$ and $x \in L(N_A; N_A(x))$. By $U(M_A, M_A(x))(\neq \emptyset)$ and $L(N_A, N_A(x))(\neq \emptyset)$ are filters of $\mathcal{L}$, it follows that $I \in U(M_A, M_A(x))$ and $I \in L(N_A, \tilde{M}N_A(x))$, and so $M_A(I) \geq M_A(x)$ and $N_A(I) \leq N_A(x)$.

For any $x, y \in L$, let $\alpha = T(M_A(x), M_A(x \to y))$ and $\beta = S(N_A(x), N_A(x \to y)\}$, then $x, x \to y \in U(M_A; \alpha)$ and $x, x \to y \in L(N_A; \beta)$. And so $y \in U(M_A; \alpha)$ and $y \in L(N_A; \beta)$. Therefore $M_A(y) \geq \alpha = T(M_A(x), M_A(x \to y))$ and $N_A(y) \leq \beta = S(N_A(x), N_A(x \to y)\}$. From Definition 3.1, we have A is an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$. □

Let A, B be two intuitionistic fuzzy sets on $\mathcal{L}$, denote C by the intersection of A and B, i.e. $C = A \cap B$, where

$$\begin{aligned} M_C(x) &= T(M_A(x), M_B(x)), \\ N_C(x) &= S(N_A(x), N_B(x)) \end{aligned}$$

for any $x \in L$.

Theorem 3.5. *Let A, B be two intuitionistic (T, S)-fuzzy filters of $\mathcal{L}$, then $A \cap B$ is also an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$.*

Proof. Let $x, y, z \in L$ be such that $z \leq x \to y$, then $z \to (x \to y) = I$. Since A, B are two intuitionistic (T, S)-fuzzy filters of $\mathcal{L}$, we have that $M_A(y) \geq T(M_A(z), M_A(x))$, $N_A(y) \leq S(N_A(z), N_A(x))$ and $M_B(y) \geq T(M_B(z), M_B(x)\}$, $N_B(y) \leq S(N_B(z), N_B(x)\}$. Since

$$\begin{aligned} M_{A\cap B}(y) &= T(M_A(y), M_B(y)\} \geq T(T(M_A(z), M_A(x)), T(M_B(z), M_B(x))) \\ &= T(T(M_A(z), M_B(z)), T(M_A(x), M_B(x))) \\ &= T(M_{A\cap B}(z), M_{A\cap B}(x)) \end{aligned}$$

and

$$\begin{aligned} N_{A\cap B}(y) &= S(N_A(y), N_B(y)\} \leq S(S(N_A(z), N_A(x)), S(N_B(z), N_B(x))) \\ &= S(S(N_A(z), N_B(z)), S(N_A(x), N_B(x))) \\ &= S(N_{A\cap B}(z), N_{A\cap B}(x)) \end{aligned}$$

Since A, B be two intuitionistic (T, S)-fuzzy filters of $\mathcal{L}$, we have $M_A(I) \geq M_A(x)), N_A(I) \leq N_A(x))$ and $M_B(I) \geq M_B(x)$, $N_B(I) \leq N_B(x)$. Hence $M_{A\cap B}(I) = T(M_A(I), M_B(I)) \geq T(M_A(x), M_B(x)) = M_{A\cap B}(x)$. Similarly, we have $N_{A\cap B}(I) = S(N_A(I), N_B(I)) \leq S(N_A(x), N_B(x)) = N_{A\cap B}(x)$. Then $A \cap B$ is an intuitionistic (T, S)-fuzzy filters of $\mathcal{L}$. □

Let A_i be a family intuitionistic fuzzy sets on $\mathcal{L}$, where i is an index set. Denoting C by the intersection of A_i, i.e. $\cap_{i\in I}A_i$, where

$$\begin{aligned} M_C(x) &= T(M_{A_1}(x), M_{A_2}(x), \cdots), \\ N_C(x) &= S(N_{A_1}(x), N_{A_2}(x), \cdots) \end{aligned}$$

for any $x \in L$.

Corollary 3.6. *Let A_i be a family intuitionistic (T, S)-fuzzy filters of $\mathcal{L}$, where $i \in I$, I is an index set. then $\cap_{i\in I}A_i$ is also an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$.*

Suppose A is an intuitionistic fuzzy set on $\mathcal{L}$ and $\alpha, \beta \in [0, 1]$. Denoting $A_{(\alpha,\beta)}$ by the set $\{x \in L | M_A(x) \geq \alpha, N_A(x) \leq \beta\}$.

Theorem 3.7. *Let A be an intuitionistic fuzzy set on $\mathcal{L}$. Then*

(1) for any $\alpha, \beta \in [0, 1]$, if $A_{(\alpha,\beta)}$ is a filter of $\mathcal{L}$. Then, for any $x, y, z \in L$,

(V3) $M_A(z) \leq T(M_A(x \to y), M_A(x))$ and $N_A(z) \geq S(N_A(x \to y), N_A(x))$ imply $M_A(z) \leq M_A(y)$ and$N_A(z) \geq N_A(y)$.

(2) If A satisfy (V1)and (V3), then, for any $\alpha, \beta \in [0, 1]$, $A_{(\alpha,\beta)}$ is a filter of $\mathcal{L}$.

Proof. (1) Assume that $A_{(\alpha,\beta)}$ is a filter of $\mathcal{L}$ for any $\alpha, \beta \in [0, 1]$. Since $M_A(z) \leq T(M_A(x \to y), M_A(x))$ and $N_A(z) \geq S(N_A(x \to y), N_A(x))$, it follows that $M_A(z) \leq M_A(x \to y), M_A(z) \leq M_A(x$ and $N_A(z) \geq N_A(x \to y), N_A(z) \geq N_A(x)$. Therefore, $x \to y \in A_{(M_A(z),N_A(z))}, x \in A_{(M_A(z),N_A(z))}$. As $M_A(z), N_A(z) \in [0, 1]$, and $A_{(M_A(z),N_A(z))}$ is a filter of $\mathcal{L}$, so $y \in A_{(M_A(z),N_A(z))}$. Thus $M_A(z) \leq M_A(y)$ and$N_A(z) \geq N_A(y)$.

(2) Assume A satisfy (V1) and (V3). For any $x, y \in L$, $\alpha, \beta \in [0, 1]$, we have $x \to y \in A_{(\alpha,\beta)}, x \in A_{(\alpha,\beta)}$, therefore $M_A(x \to y) \geq \alpha$, $N_A(x \to y) \leq \beta$ and $M_A(x) \geq \alpha$, $N_A(x) \leq \beta$, and so $T(M_A(x \to y), M_A(x)) \geq T(\alpha, \alpha) = \alpha$, $S(N_A(x \to y), N_A(x)) \leq S(\beta, \beta) = \beta$. By (V3), we have $M_A(y) \geq \alpha$ and $N_A(y) \leq \beta$, that is, $y \in A_{(\alpha,\beta)}$.

Since $M_A(I) \geq M_A(x)$ and $N_A(I) \leq N_A(x)$ for any $x \in L$, it follows that $M_A(I) \geq \alpha$ and $N_A(I) \leq \beta$, that is, $I \in A_{(\alpha,\beta)}$. Then, for any $\alpha, \beta \in [0, 1]$, $A_{(\alpha,\beta)}$ is a filter of $\mathcal{L}$. □

Theorem 3.8. *Let A be an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$, then, for any $\alpha, \beta \in [0, 1]$, $A_{(\alpha,\beta)}(\neq \phi)$ is a filter of $\mathcal{L}$.*

Proof. Since $A_{(\alpha,\beta)} \neq \phi$, there exist $\alpha, \beta \in [0, 1]$ such that $M_A(x) \geq \alpha, N_A(x) \leq \beta$. And A is an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$, we have $M_A(I) \geq M_A(x) \geq \alpha, N_A(I) \leq N_A(x) \leq \beta$, therefore $I \in A_{(\alpha,\beta)}$.

Let $x, y \in L$ and $x \in A_{(\alpha,\beta)}, x \to y \in A_{(\alpha,\beta)}$, therefore $M_A(x) \geq \alpha, N_A(x) \leq \beta, M_A(x \to y) \geq \alpha, M_A(x \to y) \leq \beta$. Since A is an intuitionistic (T, S)-fuzzy filter $\mathcal{L}$, thus $M_A(y) \geq T(M_A(x \to y), M_A(x)) \geq \alpha$ and $N_A(y) \leq S(N_A(x \to y), N_A(x)) \leq \beta$, it follows that $y \in A_{(\alpha,\beta)}$. Therefore, $A_{(\alpha,\beta)}$ is a filter of $\mathcal{L}$. □

In the Theorem 3.8, the filter $A_{(\alpha,\beta)}$ is also called **intuitionistic-cut** filter of $\mathcal{L}$.

Theorem 3.9. *Any filter F of $\mathcal{L}$ is a intuitionistic-cut filter of some intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$.*

Proof. Consider the intuitionistic fuzzy set A:

$$\mathcal{L} : A = \{(x, M_A(x), x, N_A(x))|x \in L\},$$

where

If $x \in F$,

$$M_A(x) = \alpha, N_A(x) = 1 - \alpha. \tag{1}$$

If $x \notin F$,

$$M_A(x) = 0, N_A(x) = 1. \tag{2}$$

where $\alpha \in [0, 1]$. Since F is a filter of $\mathcal{L}$, we have $I \in F$. Therefore $M_A(I) = \alpha \geq M_A(x)$ and $N_A(I) = 1 - \alpha \leq N_A(x)$.

For any $x, y \in L$, if $y \in F$, then $M_A(y) = \alpha = T(\alpha, \alpha) \geq T(M_A(x \to y), M_A(x))$ and $N_A(y) = 1 - \alpha = S(1 - \alpha, 1 - \alpha) \leq S(N_A(x \to y), N_A(x))$.

If $y \notin F$, then $x \notin F$ or $x \to y \notin F$. And so $M_A(y) = 0 = T(0, 0) = T(M_A(x \to y), M_A(x))$ and $N_A(y) = 1 = S(1, 1) = S(N_A(x \to y), N_A(x))$. Therefore A is an intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$. □

Theorem 3.10. *Let A be intuitionistic (T, S)-fuzzy filter of $\mathcal{L}$. Then $F = \{x \in L|M_A(x) = M_A(I), N_A(x) = N_A(I)\}$ is a filter of $\mathcal{L}$.*

Proof. Since $F = \{x \in L | M_A(x) = M_A(I), N_A(x) = N_A(I)\}$, obviously $I \in F$. Let $x \to y \in F, x \in F$, so $M_A(x \to y) = M_A(x) = M_A(I)$ and $N_A(x \to y) = N_A(x) = N_A(I)$. Therefore

$$M_A(y) \geq T(M_A(x \to y),\ M_A(x)) = M_A(I) \text{ and } M_A(I) \geq M_A(y),$$

then

$$M_A(y) = M_A(I).$$

Similarly, we have $N_A(y) = N_A(I)$. Thus $y \in F$.

It follows that F is a filter of $\mathcal{L}$. □

4 Conclusion

Filter theory plays an very important role in studying logical systems and the related algebraic structures. In this paper, we develop the intuitionistic (T, S)-fuzzy filter theory of lattice implication algebras. Mainly, we give some new characterizations of intuitionistic (T, S)-fuzzy filters in lattice implication algebras. The theory can be used in MV-algebras, lattice implication algebras, BL-algebras, MTL-algebras, etc.

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