퍼지 및 지능시스템학회 논문지 2007, Vol. 17, No. 1, pp. 118-122

Intuitionistic fuzzy interior ideals in ordered semigroup

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Abstract

In this paper, we consider the intuitionistic fuzzification of the notion of a interior ideal in ordered semigroup S, and investigate some properties of such ideals. In terms of intuitionistic fuzzy set, characterizations of intuitionistic fuzzy interior ideals in ordered semigroups are discussed. Using a collection of interior ideals with additional conditions, an intuitionistic fuzzy interiror ideal is constructed. Natural equivalence relations on the set of all intuitionistic fuzzy interior ideals of an ordered semigroup are investigated. We also give a characterization of a intuitionistic fuzzy simple semigroup in terms of intuitionistic fuzzy interior ideals.

Key words : Intuitionistic fuzzy left(right,bi,quasi) ideals

1. Introduction

The concept of fuzzy sets was intrduced by Zadeh [19]. Later,several researchs were conduced on the generalization of fuzzy set. The concept of intuitionistic fuzzy sets introduced by Atanassov [1,2,3] is one among them.

In [5], De et al. studied the Sanchez's approach for medical diagnosis and extended this concept with the notion of intuitionistic fuzzy set theory. Dengfeng and Chuntian [6] introduced the concept of the degree of similarity between intuitionistic fuzzy sets, presented several new similarity measures for measuring the degree of similarity between intuitionistic fuzzy sets, which may be finite or continuous, and gave corresponding proofs of these similariry measure and discussed applications of the similarity measure between intuitionistic fuzzy sets to pattern recofnition problems. Sevarl researchers[8,17,18] have applied the notion of intuitionistic fuzzy sets to semigroup theory. In particular ,Kehayopulu and Tsingelis [15] first considered the fuzzy sets in ordered groupoids. They discussed fuzzy analogous for several notions that have been proved to be useful in the theory of ordered groupoids/semigroups. In 2005,Y.B.Jun [10] introduced the notion of intuitionistic fuzzy bi-ideal in ordered semigroup and investigated some properties of such ideals. In this paper, we consider the intuitionistic fuzzification of the notion of a interior ideal in ordered semigroup S, and investigate some properties of such ideals. In terms of intuitionistic fuzzy set, characterizations of intuitionistic fuzzy interior ideals in ordered semigroups are discussed. Using a collection of interior ideals with additional conditions, an intuitionistic fuzzy interiror ideal is constructed. Natural equivalence relations on the set of all intuitionistic fuzzy interior ideals of an ordered semigroup are investigated. We also give a characterization of a intuitionistic fuzzy simple semigroup in terms of intuitionistic fuzzy interior ideals.

접수일자 : 2006년 10월 27일
완료일자 : 2006년 11월 27일

2. Preliminaries

In this section, we introduce some definitions and lemmas which will be used in this paper. For more details we refer to [8],[10],[17] and [18]. By an *ordered semigroup* we mean an ordered set S at same time a semigroup satisfying the following conditin:

$$(\forall a, b, x \in S)(a \leq b \Rightarrow xa \leq xb \ \ and \ \ ax \leq bx)$$

Definition 2.1. ([12]) A nonempty subset A in ordered semigroup $(S, \cdot, \leq)$ is called an *left*(resp.*right) ideal* of S if it satisfies:

(1) $SA \subseteq A$ (resp.$AS \subseteq A$),

(2) If $a \in A$ and $S \ni b \leq a$,then $b \in A$.

A is called an ideal of an ordered semigroup if and only if A is both of left and right ideal of S.

Definition 2.2. ([12]) A nonemty subset A in $(S, \cdot, \leq)$ is called *interiror ideal* of S if it satisfies:

(1) $SAS \subseteq A$,

(2) If $a \in A$ and $S \ni b \leq a$,then $b \in A$.

For a subset A of a semigroup S, we denoted by $(A]$ the set of S defined as follows: $(A] = \{t \in S | t \leq a$ for some $a \in A\}$. It is well known that condition (2) is equivalent to the condition $(A]$.

Given a set S,a mapping $\mu : S \to [0, 1]$ is called a *fuzzy set* in S. The *complement* of μ,denoted by $\overline{\mu}$, is the fuzzy set in S given by $\overline{\mu}(x) = 1 - \mu(x)$ for all $x \in S$.

As an important generalization of the notion of fuzzy sets in M, Atanassov [1,2,3] introduced the concept of an *intuitionistic fuzzy set* defined on a non-empty set M as objects having the form

$$A = \{\langle x, \mu_A(x), \gamma_A(x)\rangle \mid x \in M\},$$

where the functions $\mu_A : M \to [0, 1]$ and $\gamma_A : M \to [0, 1]$ denote the *degree of membership* (namely $\mu_A(x)$) and the *degree of nonmembership* (namely $\gamma_A(x)$) of each element $x \in M$ to A respectively, and $0 \leq \mu_A(x) + \gamma_A(x) \leq 1$ for all $x \in M$. For the sake of simplicity, we shall use the symbol $A = (\mu_A, \gamma_A)$ for the intuitionistic fuzzy set $A = \{\langle x, \mu_A(x), \gamma_A(x)\rangle \mid x \in M\}$.

Definition 2.3. ([1])Let $A = (\mu_A, \gamma_A)$ and $B = (\mu_B, \gamma_B)$ be intuitionistic fuzzy sets in a set M.

(1). $A \subseteq B \Leftrightarrow (\forall x \in M)\,(\mu_A(x) \leq \mu_B(x),\ \gamma_A(x) \geq \gamma_B(x))$.

(2) $A = B \Leftrightarrow A \subseteq B$ and $B \subseteq A$.

(3) $A \cap B = (\mu_A \wedge \mu_B, \gamma_A \vee \gamma_B)$.

(4) $A \cup B = (\mu_A \vee \mu_B, \gamma_A \wedge \gamma_B)$.

(5) $\Box A = (\mu_A, \overline{\mu}_A)$

(6) $\Diamond A = (\overline{\gamma}_A, \gamma_A)$

(7) $0_\sim = (0, 1)$ and $1_\sim = (1, 0)$.

Definition 2.4. An intuitionistic fuzzy set $A = (\mu_A, \gamma_A)$ in an ordered semigroup $(S, \cdot, \leq)$ is called an *intuitionistic fuzzy subsemigroup* of S if it satisfies:

(1) $(\forall x, y \in R)\ (\mu_A(xy) \geq \min\{\mu_A(x), \mu_A(y)\})$.

(2) $(\forall x, y \in R)\ (\gamma_A(xy) \leq \max\{\gamma_A(x), \gamma_A(y)\})$.

Definition 2.5. An intuitionistic fuzzy set $A = (\mu_A, \gamma_A)$ in an ordered semigroup $(S, \cdot, \leq)$ is called an *intuitionistic fuzzy left ideal* of S if it satisfies:

(1) $(\forall x, y \in S)\ (\mu_A(xy) \geq \mu_A(y))$.

(2) $(\forall x, y \in S)\ (\gamma_A(xy) \leq \gamma_A(y))$.

(3) $x \leq y \Rightarrow \mu_A(x) \geq \mu_A(y), \gamma_A(x) \leq \gamma_A(y)$ for all $x, y \in S$.

Definition 2.6. An intuitionistic fuzzy set $A = (\mu_A, \gamma_A)$ in an ordered semigroup $(S, \cdot, \leq)$ is called an *intuitionistic fuzzy right ideal* of S if it satisfies:

(1) $(\forall x, y \in S)\ (\mu_A(xy) \geq \mu_A(x))$.

(2) $(\forall x, y \in S)\ (\gamma_A(xy) \leq \gamma_A(x))$.

(3) $x \leq y \Rightarrow \mu_A(x) \geq \mu_A(y), \gamma_A(x) \leq \gamma_A(y)$ for all $x, y \in S$.

If $A = (\mu_A, \gamma_A)$ is both an intuitionistic fuzzy left and intuitionistic fuzzy right ideal of a semigroup S, then $A = (\mu_A, \gamma_A)$ is called an *intuitionistic fuzzy ideal* of S.

3. intuitionistic fuzzy interior ideal

We first introduce the Intuitionistic fuzzification of notion of interiro in sn orderd semigroup.

Definition 3.1. An intuitionistic fuzzy set $A = (\mu_A, \gamma_A)$ in an ordered semigroup $(S, \cdot, \leq)$ is called an *intuitionistic fuzzy interior-ideal* of S if it satisfies:

(1) $\mu_A(xay) \geq \mu_A(a)$ for all $x, a, y \in S$.

(2) $\gamma_A(xay) \leq \gamma_A(a)$ for all $x, a, y \in S$.

(3) $x \leq y \Rightarrow \mu_A(x) \geq \mu_A(y), \gamma_A(x) \leq \gamma_A(y)$ for all $x, y \in S$.

Let X be a subset of an semigroup S. The *characterisic intuitionistic function* of X is a function $\widetilde{X}$ of X into $\{0, 1\}$ defined by

$$\mu_{\widetilde{X}}(x) := \begin{cases} 1 & \text{if } x \in X \\ 0 & \text{otherwise} \end{cases}$$

and

$$\gamma_{\widetilde{X}}(x) := \begin{cases} 0 & \text{if } x \in X \\ 1 & \text{otherwise} \end{cases}$$

for all $x \in S$. For the sake of simplicity, we shall use the symbol $\widetilde{X} = (\mu_{\widetilde{X}}, \gamma_{\widetilde{X}})$ for the $\widetilde{X} = \{\langle x, \mu_{\widetilde{X}}(x), \gamma_{\widetilde{X}}(x)\rangle \mid x \in X\}$.

Proposition 3.2. Let $(S,\cdot,\leq)$ be an orddered semigroup and let A be a nonemty subset of S. Then A is an interior ideal of S if and only if the characterisic intuitionistic function $\widetilde{A}=(\mu_{\widetilde{A}},\gamma_{\widetilde{A}})$ of S is a intuitionistic fuzzy interior ideal of S.

Proof. Assume that A is an interior ideal of S and let $x,a,y\in S$. If $a\in A$, then $xay\in SAS\subseteq A$. Then we have $\mu_{\widetilde{A}}(xay)=1$ and $\gamma_{\widetilde{A}}(xay)=0$. This show that $\mu_{\widetilde{A}}(xay)\geq\mu_{\widetilde{A}}(a)$ and $\gamma_{\widetilde{A}}(xay)\leq\gamma_{\widetilde{A}}(a)$. Thus conditions (1) and (2) of Defintion 3.1 is stisfied. Now we check (3) in Deinition 3.1 Let $x,y\in S$ be such that $x\leq y$. If $y\notin A$, then $\mu_{\widetilde{A}}(y)=0$ and $\gamma_{\widetilde{A}}(y)=1$. It follows that $\mu_{\widetilde{A}}(x)\geq\mu_{\widetilde{A}}(y)$ and $\gamma_{\widetilde{A}}(x)\leq\gamma_{\widetilde{A}}(y))$. If $y\in A$. Then $\mu_{\widetilde{A}}(y)=1$ and $\gamma_{\widetilde{A}}(y)=0$. Since $A=(A]$,there exists $a\in A$ such that $y\leq a$. Then we have $x\leq a$. It follows that $x\in A$ so that $\mu_{\widetilde{A}}(x)=1$ and $\gamma_{\widetilde{A}}(x)=0$. Hence $\mu_{\widetilde{A}}(x)\geq\mu_{\widetilde{A}}(y)$ and $\gamma_{\widetilde{A}}(x)\leq\gamma_{\widetilde{A}}(y))$. Therefore the characterisic intuitionistic function $\widetilde{A}$ of S is a intuitionistic fuzzy interior ideal of S.

For the converse,we assume that the characterisic intuitionistic function $\widetilde{A}=(\mu_{\widetilde{A}},\gamma_{\widetilde{A}})$ of S is a intuitionistic fuzzy interior ideal of S and proceed to establish that A is an interior ideal of S. Let $x,y\in S$, $a\in A$. Since $\widetilde{A}$ is intuitionistic fuzzy interior ideal of S, we have $\mu_{\widetilde{A}}(xay)\geq\mu_{\widetilde{A}}(a)$ and $\gamma_{\widetilde{A}}(xay)\leq\gamma_{\widetilde{A}}(a)$. Since $a\in A$, we have $\mu_{\widetilde{A}}(a)=1$ and $\gamma_{\widetilde{A}}(a)=0$. It follows that $\mu_{\widetilde{A}}(xay)=1$ and $\gamma_{\widetilde{A}}(xay)=0$. Hence $xay\in A$. This implies that $A\subseteq SAS$. Thus condition (1)of Defintion 2.2 is stisfied. Now we check (2) in Deinition 2.2 Since the inclusion $A\subseteq(A]$ always obtains,we have only to show that $(A]\subseteq A$ Let $x\in(A]$. Then there exists $y\in A$ sucht that $x\leq y$. By hypothesis, we have $\mu_{\widetilde{A}}(x)\geq\mu_{\widetilde{A}}(y),\gamma_{\widetilde{A}}(x)\leq\gamma_{\widetilde{A}}(y))$. Since $y\in A$, we have $\mu_{\widetilde{A}}(y)=1$ and $\gamma_{\widetilde{A}}(y)=0$. This implies that $\mu_{\widetilde{A}}(x)=1$ and $\gamma_{\widetilde{A}}(x)=0$. Hence $x\in A$. This show that $(A]\subseteq A$. Therefore A is an interior ideal of S. □

Lemma 3.3. Let $(S,\cdot,\leq)$ be an ordered semigroup and let A be a nonemty subset of S,every intuitionistic fuzzy ideal of S is an intuitionistic fuzzy interior ideal of S.

Proof. Assume that $A=(\mu_A,\gamma_A)$ is an intuitionistic fuzzy ideal of S. Let $x,a,y\in S$. Since A is intuitionistic fuzzy left ideal,we have $\mu_A(x(ay))\geq\mu_A(ay)$ and $\gamma_A(x(ay))\leq\gamma_A(ay)$. Since A is intuitionistic fuzzy right ideal,we have $\mu_A(ay)\geq\mu_A(a)$ and $\gamma_A(ay)\leq\gamma_A(a)$. This implies that that $\mu_A(xay)\geq\mu_A(a)$ and $\gamma_A(xay)\leq\gamma_A(a)$. Therefore A is intuitionistic fuzzy interior ideal of S. □

Recall that an ordered semigroup $(S,\cdot,\leq)$ is said to be *regular* if for any $a\in S$ there exists $x\in S$ such that $a\leq axa$.

Proposition 3.4. Let A be an intuitionistic fuzzy subset of a regular ordered semigroup$(S,\cdot,\leq)$. Then A is an intuitionistic fuzzy ideal of S if and only if A is an intuitionistic fuzzy interior ideal of S.

Proof. In Lemma 3.3 , we have shown that every intuitionistic fuzzy ideal of S is an intuitionistic fuzzy interior ideal of S. Hence it suffices to prove that every intuitionistic fuzzy interior ideal of S is an intuitionistic fuzzy ideal of S. Assume that A is intuitionistic fuzzy interior ideal of S. Let $x,y\in S$. Since S is regular,there exists $a\in S$ such that $x\leq xax$. Then we have $xy\leq(xax)y\leq(xa)xy$. Since A intuitionistic fuzzy interior ideal, we have

$$\mu_A(xy)\geq\mu_A((xa)xy)\geq\mu_A(x)$$

and

$$\gamma_A(xy)\leq\gamma_A((xa)xy)\leq\gamma_A(x).$$

Thus we have $\mu_A(xy)\geq\mu_A(x)$ and $\gamma_A(xy)\leq\gamma_A(x)$. Similary $\mu_A(xy)\geq\mu_A(y)$ and $\gamma_A(xy)\leq\gamma_A(y)$. Therefore A is intuitionistic fuzzy ideal of S. □

Lemma 3.5. If $A=(\mu_A,\gamma_A)$ is an intuitionistic fuzzy interior ideal an ordered semigroup $(S,\cdot,\leq)$. ,then so are $\Box A=(\mu_A,\overline{\mu}_A)$ and $\Diamond A=(\overline{\gamma}_A,\gamma_A)$.

Proof. Let $x,y\in S$ be such that $x\leq y$. Then $\mu_A(x)\geq\mu_A(y)$, and thus

$$\overline{\mu}_A(x)=1-\mu_A(x)\leq1-\mu_A(y)=\overline{\mu}_A(y).$$

For any x,y,a,we get $\mu_A(xay)\geq\mu_A(a)$, which implies

$$\overline{\mu}_A(xay)=1-\mu_A(xay)\geq1-\mu_A(a)=\overline{\mu}_A(a).$$

Therefore $\Box A$ is intuitionistic fuzzy interior ideal of S. The proof of second part is similar to the first. □

From Lemma 3.5, it is not difficult to see that the following Proposition is valid.

Proposition 3.6. Let $(S,\cdot,\leq)$ be an ordered semigroup. Then $A=(\mu_A,\gamma_A)$ is an intuitionistic fuzzy interior ideal of S if and only if $\Box A$ and $\Diamond A$ are intuitionistic fuzzy interior ideal of S.

Corollary 3.7. Let $(S, \cdot, \leq)$ be an ordered semigroup. Then $A = (\mu_A, \gamma_A)$ is an intuitionistic fuzzy interior ideal of S if and only if μ_A and $\overline{\gamma}_A$ are intuitionistic fuzzy interior ideal of S.

Recall that an ordered semigroup $(S, \cdot, \leq)$ is said to be *simple* if does not contain proper ideals.

Definition 3.8. An ordered semigroup $(S, \cdot, \leq)$ is called *intuitionistic fuzzy simple* if every intuitionistic fuzzy ideal of S is a constant function, or equivalently,if every intuitionistic fuzzy ideal $A = (\mu_A, \gamma_A)$ in S satisfies $\mu_A(a) = \mu_A(b)$ and $\gamma_A(a) = \gamma_A(b)$ for all $a, b \in S$.

Lemma 3.9. Let $(S, \cdot, \leq)$ be an orddered semigroup and let A be a nonemty subset of S. Then A is an ideal of S if and only if the characterisic intuitionistic function $\widetilde{A} = (\mu_{\widetilde{A}}, \gamma_{\widetilde{A}})$ of S is a intuitionistic fuzzy ideal of S.

Proof. Straightforward. □

Proposition 3.10. Let $(S, \cdot, \leq)$ be a ordered semigroup. Then S is simple if and only if S is intuitionistic fuzzy simple.

Proof. Assume that S is a simple semigroup. Let $A = (\mu_A, \gamma_A)$ be any intuitionistic fuzzy ideal of S and $a, b \in S$. Consider the set $I_a = \{x \in S | \mu_A(x) \geq \mu_A(a)$ and $\gamma_A(x) \leq \gamma_A(a)\}$. It is easy to check that I_a is ideal of S. Since S is simple, we have $I_a = S$. Since $b \in I_a$, it follows that $\mu_A(a) \geq \mu_A(b)$ and $\gamma_A(a) \leq \gamma_A(b)$. Similarly, we get $\mu_A(b) \geq \mu_A(a)$ and $\gamma_A(b) \leq \gamma_A(a)$. Hence $\mu_A(b) = \mu_A(a)$ and $\gamma_A(b) = \gamma_A(a)\}$. Therefore S is intuitionistic fuzzy simple semigroup.

Conversely,suppose S contains proper ideals and let I be an proper ideal of S. By Lemma 3.9, $\widetilde{I}$ is a intuitionistic fuzzy ideal of S. We show that $S \subseteq I$. Let $x \in S$. Since S is intuitionistic fuzzy simple, the intuitionistic fuzzy ideal $\widetilde{A}$ is a constant function. Then we have $\mu_{\widetilde{I}}(x) = \mu_{\widetilde{I}}(b)$ and $\gamma_{\widetilde{I}}(x) = \gamma_{\widetilde{I}}(b)$ for all $b \in S$. Let now $a \in I$. Then we have $\mu_{\widetilde{I}}(x) = \mu_{\widetilde{I}}(a) = 1$ and $\gamma_{\widetilde{I}}(x) = \gamma_{\widetilde{I}}(a) = 0$. Then $x \in I$. It follows that $S = I$, which is a contradiction. Hence S has no proper ideal. Threfore S is simple. □

Lemma 3.11. ([13]) An ordered semigroup $(S, \cdot, \leq)$ is simple if and only if $S = (SaS]$ for every $a \in S$.

Proposition 3.12. Let $(S, \cdot, \leq)$ be an ordered semigroup. Then S is simple if and only if every intuitionistic fuzzy interior ideal of S is a constant function.

Proof. Assume that S is simple. Let $A = (\mu_A, \gamma_A)$ be an intuitionistic fuzzy interior ideal of S and $a, b \in S$. Since S is simple, it follows from Lemma 3.11 that $S = (SbS]$. Since $a \in S$,we have $a \in (SbS]$. Thus $a \leq xby$ for some $x, y \in S$., Since $a \leq xby$,it follows from Defintion 3.1(3) that we obtain $\mu_A(a) \geq \mu_A(xby)$ and $\gamma_A(a) \leq \gamma_A(xby)$. Then,by Defintion3.1(1) and Defintion 3.1(2), we obtain $\mu_A(xby) \geq \mu_A(b)$ and $\gamma_A(xby) \leq \gamma_A(b)$. Then we have $\mu_A(a) \leq \mu_A(b)$ and $\gamma_A(a) \geq \gamma_A(b)$. Simlary $\mu_A(b) \leq \mu_A(a)$ and $\gamma_A(b) \geq \gamma_A(a)$. Threfore A is a constant function.

Conversely, assume that every intuitionistic fuzzy interior ideal of S is a constant function. Let A be an intuitionistic fuzzy ideal of S. Then it follows from Lemma3.3 that A is an intuitionistic fuzzy interir ideal of S. Hence by hypothesis, A is a constant function. Then S is a intuitionistic fuzzy simple semigroup. Thus by Proposition 3.10 , S is simple semigroup. □

Corollary 3.13. For an ordered semigroup S, the following conditions are equivalent:

(1) S is simple semigroup.

(2) $S = (SaS]$ for every $a \in S$.

(3) S is intuitionistic fuzzy simple semigroup

(4) Every intuitionistic fuzzy interior ideal of S is a constant function.

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