Intuitionistic (S,T)-Fuzzy H$_v$-Ideals and their Characterizations

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Abstract: In this paper, we apply the concept of intuitionistic fuzzy set to H$_v$-rings. The notion of an intuitionistic (S,T)-fuzzy H$_v$-ideals of an H$_v$-ring is introduced and some related properties are investigated.

Keywords: H$_v$-ring, H$_v$-ideal, fuzzy H$_v$-ring, fuzzy H$_v$-ideal, intuitionistic (S,T)- fuzzy H$_v$-ideal.
Mathematics Subject Classification: 20N20

1. Introduction

The concept of hyperstructure was introduced in 1934 by Marty [12]. Hyperstructures have many applications to several branches of pure and applied sciences. Vougiouklis [14] introduced the notion of H$_v$-structures, and Davvaz [5] surveyed the theory of H$_v$-structures. After the introduction of fuzzy sets by Zadeh [16], there have been a number of generalizations of this fundamental concept. The notion of intuitionistic fuzzy sets introduced by Atanassov [1] is one among them. For more details on intuitionistic fuzzy sets, we refer the reader to [2, 3].

In [4] Biswas applied the concept of intuitoinistic fuzzy sets to the theory of groups and studied intuitionistic fuzzy subgroups of a group. In [10] Kim et al. introduced the notion of fuzzy subquasigroups of a quasigroup. In [11] Kim and Jun introduced the concept of fuzzy ideals of a semigroup. Zhan et al. [17] introduced the notion of an intuitionistic (S,T)-fuzzy H$_v$-submodule of an H$_v$-module. This paper continues this line of research for fuzzy H$_v$-ideal of H$_v$-ring. In this paper, the notion of an intuitionistic (S,T)-fuzzy H$_v$-ideal of an H$_v$-ring is
introduced and some related properties are investigated.

The paper is organized as follows: in section 2 some fundamental definitions on H$_v$-structures and fuzzy sets are explored, in section 3 we define intuitionistic (S, T)-fuzzy H$_v$-ideals and establish some useful theorems.

2. Basic Definitions

We first give some basic definitions for proving the further results.

Definition 2.1 [6] Let X be a non-empty set. A mapping $\mu : X \to [0,1]$ is called a fuzzy set in X .The complement of μ, denoted by μ^c, is the fuzzy set in X given by

$$\mu^c(x) = 1 - \mu(x) \quad \forall x \in X .$$

Definition 2.2 [6] Let f be a mapping from a set X to a set Y. Let μ be a fuzzy set in X and λ be a fuzzy set in Y. Then the inverse image $f^{-1}(\lambda)$ of λ is a fuzzy set in X defined by

$$f^{-1}(\lambda)(x) = \lambda(f(x)) \quad \forall x \in X .$$

The image $f(\mu)$ of μ is the fuzzy set in Y defined by

$$f(\mu)(y) = \begin{cases} \sup\limits_{x \in f^{-1}(y)} \mu(x), & f^{-1}(y) \neq \phi \\ 0, & otherwise \end{cases}$$

For all $y \in Y$.

Definition 2.3 [6] An intuitionistic fuzzy set A in a non-empty set X is an object having the form $A=\{(x,\mu_A(x),\lambda_A(x)):x\in X\}$, where the functions $\mu_A:X\to[0,1]$ and $\lambda_A:X\to[0,1]$ denote the degree of membership and degree of non membership of each element $x\in X$ to the set A respectively and $0\le\mu_A(x)+\lambda_A(x)\le 1$ for all $x\in X$. We shall use the symbol $A=\{\mu_A,\lambda_A\}$ for the intuitionistic fuzzy set $A=\{(x,\mu_A(x),\lambda_A(x)):x\in X\}$.

Definition 2.4 [6] Let $A=\{\mu_A,\lambda_A\}$ and $B=\{\mu_B,\lambda_B\}$ be intuitionistic fuzzy sets in X. Then

(1) $A\subseteq B \Leftrightarrow \mu_A(x)\le\mu_B(x)\ and\ \lambda_A(x)\le\lambda_B(x)$,

(2) $A^c=\{(x,\lambda_A(x),\mu_A(x)):x\in X\}$,

(3) $A\cap B=\left\{\begin{matrix}(x,\min\{\mu_A(x),\mu_B(x)\},\\ \max\{\lambda_A(x),\lambda_B(x)\}):x\in X\end{matrix}\right\}$,

(4) $A\cup B=\left\{\begin{matrix}(x,\max\{\mu_A(x),\mu_B(x)\},\\ \min\{\lambda_A(x),\lambda_B(x)\}):x\in X\end{matrix}\right\}$,

(5) $\Box A=\left\{(x,\mu_A(x),\mu_A^c(x)):x\in X\right\}$,

(6) $\Diamond A=\left\{(x,\lambda_A^c(x),\lambda_A(x)):x\in X\right\}$.

Definition 2.5 [15] Let G be a non–empty set and $*:G\times G\to\wp^*(G)$ be a hyperoperation, where $\wp^*(G)$ is the set of all the non-empty subsets of G. Where $A*B=\bigcup_{a\in A,\,b\in B} a*b,\ \forall A,B\subseteq G$.

The $*$ is called weak commutative if $x*y\cap y*x\ne\phi,\quad \forall x,y\in G$.
The $*$ is called weak associative if $(x*y)*z\cap x*(y*z)\ne\phi,\quad \forall x,y,z\in G$.

A hyperstructure $(G,*)$ is called an H$_v$–group if
(i) $*$ is weak associative.
(ii) $a*G=G*a=G,\quad \forall a\in G$ (Reproduction axiom).

Definition 2.6 [7] Let G be a hypergroup (or H$_v$-group) and let μ be a fuzzy subset of G. Then μ is said to be a fuzzy subhypergroup (or fuzzy H$_v$-subgroup) of G if the following axioms hold:

$(i)\min\{\mu(x),\mu(y)\}\le\inf_{\alpha\in x*y}\{\mu(\alpha)\},\quad \forall x,y\in G$ *(ii)* For all $x,a\in G$ there exists $y\in G$ such that $x\in a*y$ and $\min\{\mu(a),\mu(x)\}\le\{\mu(y)\}$.

Definition 2.7 [13] Let G be a hypergroup (or H$_v$-group). An intuitionistic fuzzy set $A=\{\mu_A,\lambda_A\}$ of G is called intuitionistic fuzzy subhypergroup (or intuitionistic fuzzy H$_v$-subgroup) of G if the following axioms hold:

$(i)\min\{\mu_A(x),\mu_A(y)\}\le\inf_{\alpha\in x*y}\{\mu_A(\alpha)\},\quad \forall x,y\in G.$

(ii) For all $x,a\in G$ there exists $y\in G$ such that $x\in a*y$ and $\min\{\mu_A(a),\mu_A(x)\}\le\{\mu_A(y)\}$.

$(iii)\ \sup_{\alpha\in x*y}\{\lambda_A(\alpha)\}\le\max\{\lambda_A(x),\lambda_A(y)\},\quad \forall x,y\in G.$

(iv) For all $x,a\in G$ there exists $y\in G$ such that $x\in a*y$ and $\{\lambda_A(y)\}\le\max\{\lambda_A(a),\lambda_A(x)\}$.

Definition 2.8 [15] An H$_v$–ring is a system $(R,+,\cdot)$ with two hyperoperations satisfying the ring-like axioms:

(i) $(R,+,\cdot)$ is an H$_v$-group, that is,

$$((x+y)+z)\cap(x+(y+z))\ne\phi\quad \forall x,y\in R,$$
$$a+R=R+a=R\quad \forall a\in R;$$

(ii) $(R,\cdot)$ is an H$_v$-semigroup;

(iii) $(\cdot)$ is weak distributive with respect to $(+)$, that is, for all $x,y,z\in R$,

$$(x\cdot(y+z))\cap(x\cdot y+x\cdot z)\neq\phi,$$
$$((x+y)\cdot z)\cap(x\cdot z+y\cdot z)\neq\phi.$$

Definition 2.9 [9] Let R be an H$_v$-ring. A nonempty subset I of R is called a left (resp., right) H$_v$-ideal if the following axioms hold:

(i) $(I,+)$ is an H$_v$-subgroup of $(R,+)$,

(ii) $R\cdot I\subseteq I$ (resp., $I\cdot R\subseteq I$).

Definition 2.10 [9] Let $(R,+,\cdot)$ be an H$_v$–ring and μ a fuzzy subset of R. Then μ is said to be a left (resp., right) fuzzy H$_v$-ideal of R if the following axioms hold:

(1) $\min\{\mu(x),\mu(y)\}\leq\inf\{\mu(z):z\in x+y\}$
$\forall x,y\in R,$

(2) For all $x,a\in R$ there exists $y\in R$ such that $x\in a+y$ and $\min\{\mu(a),\mu(x)\}\leq\mu(y),$

(3) For all $x,a\in R$ there exists $z\in R$ such that $x\in z+a$ and $\min\{\mu(a),\mu(x)\}\leq\mu(z),$

(4) $\mu(y)\leq\inf\{\mu(z):z\in x\cdot y\}$ [respectively $\mu(x)\leq\inf\{\mu(z):z\in x\cdot y\}$ $\forall x,y\in R$].

Definition 2.11 [9] An intuitionistic fuzzy set $A=\{\mu_A,\lambda_A\}$ in R is called a left (resp., right) intuitionistic fuzzy H$_v$-ideal of R if

(1) $\min\{\mu_A(x),\mu_A(y)\}\leq\inf\{\mu_A(z):z\in x+y\}$
$\max\{\lambda_A(x),\mu_A(y)\}\geq\sup\{\lambda_A(z):z\in x+y\}$
$\forall x,y\in R;$

(2) For all $x,a\in R$ there exists $y\in R$ such that $x\in a+y$ and $\min\{\mu_A(a),\mu_A(x)\}\leq\mu_A(y)$ and $\max\{\lambda_A(a),\lambda_A(x)\}\geq\lambda_A(y);$

(3) For all $x,a\in R$ there exists $z\in R$ such that $x\in z+a$ and $\min\{\mu_A(a),\mu_A(x)\}\leq\mu_A(z)$ and $\max\{\lambda_A(a),\lambda_A(x)\}\geq\lambda_A(z);$

(4) $\mu_A(y)\leq\inf\{\mu_A(z):z\in x\cdot y\}$ [respectively $\mu_A(x)\leq\inf\{\mu_A(z):z\in x\cdot y\}$ $\forall x,y\in R$] and $\lambda_A(y)\geq\sup\{\lambda_A(z):z\in x\cdot y\}$ [respectively $\lambda_A(x)\geq\sup\{\lambda_A(z):z\in x\cdot y\}$ $\forall x,y\in R$].

Definition 2.12 [17] By a t-norm T, we mean a function $T:[0,1]\times[0,1]\rightarrow[0,1]$ satisfying the following conditions:

$(i)\,T(x,1)=x,$
$(ii)\,T(x,y)\leq T(x,z)\quad if\ \ y\leq z,$
$(iii)\,T(x,y)=T(y,x),$
$(iv)\,T(x,T(y,z))=T(T(x,y),z)$
For all $x,y,z\in[0,1]$.

Definition 2.13 [17] By a s-norm S, we mean a function $S:[0,1]\times[0,1]\rightarrow[0,1]$ satisfying the following conditions:

$(i)\, S(x,0)=x,$

$(ii)\, S(x,y)\le S(x,z) \quad if\ \ y\le z,$

$(iii)\, S(x,y)=S(y,x),$

$(iv)\, S(x,S(y,z))=S(S(x,y),z)$

For all $x,y,z\in[0,1]$.

It is clear that

$T(\alpha,\beta)\le \min\{\alpha,\beta\}\le \max\{\alpha,\beta\}\le S(\alpha,\beta)$ For all $\alpha,\beta\in[0,1]$.

3. Intuitionistic (S,T)-fuzzy H$_v$-ideal

In this section we give the definition of intuitionistic (S,T)-fuzzy H$_v$-ideal and prove some related results.

Definition 3.1 Let R be a H$_v$-ring. An intuitionistic fuzzy set $A=\{\mu_A,\lambda_A\}$ of R is called intuitionistic (S,T)-fuzzy H$_v$-ideal of R if the following axioms hold:

(1)$T\{\mu_A(x),\mu_A(y)\}\le \inf\{\mu_A(z): z\in x+y\}$
$S\{\lambda_A(x),\mu_A(y)\}\ge \sup\{\lambda_A(z): z\in x+y\}$ (2) For all $x,a\in R$ there exists $y\in R$ such that $x\in a+y$ and $\forall x,y\in R$;
$T\{\mu_A(a),\mu_A(x)\}\le \mu_A(y)$ and $S\{\lambda_A(a),\lambda_A(x)\}\ge \lambda_A(y)$; (3) For all $x,a\in R$ there exists $z\in R$ such that $x\in z+a$ and $T\{\mu_A(a),\mu_A(x)\}\le \mu_A(z)$ and $S\{\lambda_A(a),\lambda_A(x)\}\ge \lambda_A(z)$;
(4)$\mu_A(y)\le \inf\{\mu_A(z): z\in x\cdot y\}$ [respectively $\mu_A(x)\le \inf\{\mu_A(z): z\in x\cdot y\}$ $\forall x,y\in R$] and $\lambda_A(y)\ge \sup\{\lambda_A(z): z\in x\cdot y\}$ [respectively $\lambda_A(x)\ge \sup\{\lambda_A(z): z\in x\cdot y\}$ $\forall x,y\in R$].

Definition 3.2 The norms T and S are called dual if for all $a,b\in[0,1]$, $\overline{T(a,b)}=S(\bar{a},\bar{b})$. **Lemma 3.3** Let T and S be dual norms. If $A=\{\mu_A,\lambda_A\}$ is an intuitionistic (S,T)-fuzzy H$_v$-ideal of R, then so is $\square A=\{\mu_A, {\mu^c}_A\}$.

Proof It is sufficient to show that μ_A^c satisfies the conditions of Definition 3.1.

For $x,y\in R$ we have $T\{\mu_A(x),\mu_A(y)\}\le \inf\{\mu_A(z): z\in x+y\}$ and so $T\{1-\mu_A^c(x),1-\mu_A^c(y)\}\le \inf\{1-\mu_A^c(z): z\in x+y\}$

Hence $T\{1-\mu_A^c(x),1-\mu_A^c(y)\}\le 1-\sup\{\mu_A^c(z): z\in x+y\}$

Which implies $\sup\{\mu_A^c(z): z\in x+y\}\le 1-T\{1-\mu_A^c(x),1-\mu_A^c(y)\}$

Since T and S are dual. Therefore $\sup\{\mu_A^c(z): z\in x+y\}\le S\{\mu_A^c(x),\mu_A^c(y)\}$

Now, let $a,x\in R$. Then there exists $y\in R$ such that $x\in a+y$ and $T\{\mu_A(a),\mu_A(x)\}\le\{\mu_A(y)\}$

It follows that

$T\{1-\mu_A^c(a),1-\mu_A^c(x)\}\le\{1-\mu_A^c(y)\}$ $\mu_A^c(y)\le 1-T\{1-\mu_A^c(a),1-\mu_A^c(x)\}=S\{\mu_A^c(a),\mu_A^c(x)\}$

So that

$\{\mu_A^c(y)\}\le S\{\mu_A^c(a),\mu_A^c(x)\}$

Similarly, let $a, x \in R$ then there exists $z \in R$ such that $x \in z + a$ and $\{\mu_A^c(z)\} \leq S\{\mu_A^c(a), \mu_A^c(x)\}$

Now, let $x, y \in R$, we have $\mu_A(y) \leq \inf\{\mu_A(z) : z \in x \cdot y\}$ since μ_A is a T fuzzy H$_v$-ideal of R. Hence $1 - \mu_A^c(y) \leq \inf\{1 - \mu_A^c(z) : z \in x \cdot y\}$ which implies $\sup\{\mu_A^c(z) : z \in x \cdot y\} \leq \mu_A^c(y)$. Therefore $\Box A = \{\mu_A, \mu^c{}_A\}$ is an intuitionistic (S, T)-fuzzy H$_v$-ideal of R

Lemma 3.4 Let T and S be dual norms. If $A = \{\mu_A, \lambda_A\}$ is an intuitionistic (S, T)- fuzzy H$_v$-ideal of R, then so is $\Diamond A = \{\lambda_A^c, \lambda_A\}$.

Proof The proof is similar to the proof of Theorem 3.2.

Combining the above two lemmas it is not difficult to verify that the following theorem is valid.

Theorem 3.5 Let T and S be dual norms. Then $A = \{\mu_A, \lambda_A\}$ is an intuitionistic (S, T)- fuzzy H$_v$-ideal of R if and only if $\Box A$ and $\Diamond A$ are intuitionistic (S, T)- fuzzy H$_v$-ideal of R

Corollary 3.6 Let T and S be dual norms. Then $A = \{\mu_A, \lambda_A\}$ is an intuitionistic (S, T)- fuzzy H$_v$-ideal of R if and only if μ_A and λ_A^c are intuitionistic (S, T)-fuzzy H$_v$-ideal of R

Definition 3.7 For any $t \in [0,1]$ and a fuzzy set μ in R the set $U(\mu; t) = \{x \in R : \mu(x) \geq t\}$ $L(\mu; t) = \{x \in R : \mu(x) \leq t\}$

is called an upper (respectively, lower) t-level cut of μ.

Definition 3.8 An intuitionistic (S, T)-fuzzy H_v-ideal $A = \{\mu_A, \lambda_A\}$ of R is said to be imaginable if μ_A and λ_A satisfy the imaginable property.

The following are obvious.

Lemma 3.9 Every imaginable intuitionistic (S, T)- fuzzy H$_v$-ideal of R is intuitionistic fuzzy H_v-ideal.

Lemma 3.10 [8] A fuzzy set μ in R is a fuzzy H$_v$-ideal of R if and only if the non empty set $U(\mu; t), t \in [0,1]$ is an H$_v$-ideal of R

Lemma 3.11 [8] A fuzzy set μ in R is a fuzzy H$_v$-ideal of R if and only if the non empty set μ^c is an anti-fuzzy H$_v$-ideal of R

By the above Lemmas, we can give the following results.

Theorem 3.12 If $A = \{\mu_A, \lambda_A\}$ is an imaginable intuitionistic fuzzy set in R Then $A = \{\mu_A, \lambda_A\}$ is an intuitionistic (S, T)- fuzzy H$_v$-ideal of R if and only if the non-empty sets $U(\mu_A; t)$ and $L(\lambda_A; t)$ are H$_v$-ideal of R for every $t \in [0,1]$.

Theorem 3.13 If $A = \{\mu_A, \lambda_A\}$ is an intuitionistic (S, T)-fuzzy H_v-ideal of R then $\mu_A(x) = \sup\{\alpha \in [0,1] : x \in U(\mu_A; \alpha)\}$ And $\lambda_A(x) = \inf\{\alpha \in [0,1] : x \in L(\lambda_A; \alpha)\}$ For all $x \in R$.

Definition 3.14 Let $f : R \to R'$ be a strong epimorphism of H_v-rings. If $A = \{\mu_A, \lambda_A\}$ is an intuitionistic fuzzy set in R', then the inverse image of A under f, denoted by $f^{-1}(A)$, is an intuitionistic fuzzy set in R defined by $f^{-1}(A) = (f^{-1}(\mu_A), f^{-1}(\lambda_A))$.

By the above Definition, we can give the following result.

Theorem 3.15 Let $f: R \to R'$ be a strong epimorphism of H_v-ring. If $A = \{\mu_A, \lambda_A\}$ is an intuitionistic (S,T)-fuzzy H_v-ideal of R'. Then the inverse image $f^{-1}(A) = \left(f^{-1}(\mu_A), f^{-1}(\lambda_A)\right)$ of A under f is an intuitionistic (S,T)-fuzzy H_v-ideal of R

Definition 3.16 A fuzzy set μ in a set X is said to have sup property if for every non-empty subset S of X, there exists $x_0 \in S$ such that

$$\mu(x_0) = \sup_{x \in S} \{\mu(x)\}$$

Proposition 3.17 Let R and R' be two H_v-rings and $f: R \to R'$ be a surjection. If $A = \{\mu_A, \lambda_A\}$ is an intuitionistic (S,T)-fuzzy H_v-ideal of R such that μ_A and λ_A have sup property, then

$(i)\ f\left(U(\mu_A;t)\right) = U\left(f(\mu_A);t\right);$

$(ii)\ f\left(L(\lambda_A;t)\right) \supseteq L\left(f(\lambda_A);t\right).$

Proof

$$(i)\ y \in f\left(U(\mu_A;t)\right) \Leftrightarrow f(\mu_A)(y) \geq t$$
$$\Leftrightarrow \sup_{x \in f^{-1}(y)} \{\mu_A(x)\} \geq t$$
$$\Leftrightarrow \exists x_0 \in f^{-1}(y), \mu_A(x_0) \geq t$$
$$\Leftrightarrow \exists x_0 \in f^{-1}(y), x_0 \in U(\mu_A;t)$$
$$\Leftrightarrow f(x_0) = y, x_0 \in U(\mu_A;t)$$
$$\Leftrightarrow y \in f\left(U(\mu_A;t)\right)$$

$$(ii)\ y \in L\left(f(\lambda_A);t\right) \Rightarrow f(\lambda_A)(y) \leq t$$
$$\Rightarrow \sup_{x \in f^{-1}(y)} \{\lambda_A(x)\} \leq t$$
$$\Rightarrow \sup_{x \in f^{-1}(y)} \lambda_A(x) \leq t \quad \forall x \in f^{-1}(y)$$
$$\Rightarrow x \in L(\lambda_A;t) \quad \forall x \in f^{-1}(y)$$
$$\Rightarrow y \in f\left(L(\lambda_A;t)\right)$$

Proposition 3.18 Let R and R' be two H_v-rings and $f: R \to R'$ be a map. If $B = \{\mu_B, \lambda_B\}$ is an intuitionistic (S,T)-fuzzy H_v-ideal of R' then

$(i)\ f^{-1}\left(U(\mu_B;t)\right) = U\left(f^{-1}(\mu_B);t\right);$

$(ii)\ f^{-1}\left(L(\lambda_B;t)\right) = L\left(f^{-1}(\lambda_B);t\right).$

For every $t \in [0,1]$.

Proof

$$\begin{aligned}(i)\, x \in U\left(f^{-1}(\mu_B);t\right) &\Leftrightarrow f^{-1}(\mu_B)(x) \geq t \\ &\Leftrightarrow \mu_B\left(f(x)\right) \geq t \\ &\Leftrightarrow f(x) \in U\left(\mu_B;t\right) \\ &\Leftrightarrow x \in f^{-1}\left(U\left(\mu_B;t\right)\right)\end{aligned}$$

$$\begin{aligned}(ii)\, x \in L\left(f^{-1}(\lambda_B);t\right) &\Leftrightarrow f^{-1}(\lambda_B)(x) \leq t \\ &\Leftrightarrow \lambda_B\left(f(x)\right) \leq t \\ &\Leftrightarrow f(x) \in L\left(\lambda_B;t\right) \\ &\Leftrightarrow x \in f^{-1}\left(L\left(\lambda_B;t\right)\right)\end{aligned}$$

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