Cut sets, Convex and Concave type Intuitionistic fuzzy soft sets

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Abstract:

We introduced lower cut sets, upper cut sets, convex, concave, quasi convex and quasi concave sets in intuitionistic fuzzy soft sets. Also we derive the relations among them.

Keywords: Convex set, Concave set

1. INTRODUCTION

The concept of fuzzy sets was introduced by Zadeh [13] in 1965. And in 1983, Atanassov [1] gave the notion of intuitionistic fuzzy sets (IFSs) which is characterized by a membership function and a non-membership function. Since then, the theories and applications of IFSs are developed rapidly [4, 5, 7, 9, 11, 12, 14]. As is well known, the cut set of fuzzy sets are the bridge between the fuzzy sets and the crisp sets. Li [6] and Zou [15] gave the concepts of upper cut sets and lower cut sets of IFSs respectively, and they also discussed the decomposition theorem, representation theorem of IFSs by using the cut sets. Because the convexity plays an important role in operational research and applied mathematics, the convexity of fuzzy sets received much attention. Syau [8], Chen [2] and Wu[10] described the notion of convex fuzzy sets and investigated the properties. Then it was generalized to the *L*-fuzzy convex sets where *L* is a completely distributive lattice by Huang [3]. In this paper, we generalized the notion of convex fuzzy sets to convex (concave) IFSs. We presented some of their equivalent characterizations in terms of the cut sets of IFSs. Moreover, the binary operation between two IFSs was defined, and its properties are also discussed

2. CUT SETS

2.1 Definition:

Let (I,A)=I(e)={<x,$\mu_{I(e)}$(x),$\gamma_{I(e)}$(x)>/x∈ η} be an intuitionistic fuzzy soft set and $\kappa, \iota \in [0,1]$, $\kappa + \iota \leq 1$.Then

$(\mathrm{I}, \mathrm{A})_{[\kappa,\iota]} = \{x: \mu_{I(e)}(\mathrm{x}) \geq \kappa, \gamma_{I(e)}(\mathrm{x}) \leq \iota\}$

$(\mathrm{I}, \mathrm{A})_{(\kappa,\iota)} = \{x: \mu_{I(e)}(\mathrm{x}) > \kappa, \gamma_{I(e)}(\mathrm{x}) < \iota\}$

$(\mathrm{I}, \mathrm{A})_{[\kappa,\iota)} = \{x: \mu_{I(e)}(\mathrm{x}) \geq \kappa, \gamma_{I(e)}(\mathrm{x}) < \iota\}$

$(\mathrm{I}, \mathrm{A})_{(\kappa,\iota]} = \{x: \mu_{I(e)}(\mathrm{x}) > \kappa, \gamma_{I(e)}(\mathrm{x}) \leq \iota\}$ are

$[\kappa, \iota] -$ upper cut set, $[\kappa, \iota] -$ upper cut set, $[\kappa, \iota] -$ upper cut set, $[\kappa, \iota] -$ upper cut set of

(I, A) respectively.

2.2 Example: Let X be an universal set and E is a set of parameters. Let A⊆E and I:A→ $IF(X)$.Let an Intuitionistic fuzzy soft set be

(I,A)=I(e)={x<0.4,0.6>,y<0.2,0.5>,z<0.5,0.4>/x,y,z∈ X}.Then
$(\mathrm{I}, \mathrm{A})_{[0.2,0.6]}$,$(\mathrm{I}, \mathrm{A})_{(0.1,0.7)}$, $(\mathrm{I}, \mathrm{A})_{[0.2,0.7)}$, $(\mathrm{I}, \mathrm{A})_{(0.1,0.6]}$ are upper cut sets.

2.3 Definition:

Let (I, A) =I (e) = {<x,$\mu_{I(e)}$(x),$\gamma_{I(e)}$(x)>/x∈ X} be an intuitionistic fuzzy soft set and $\kappa, \iota \in [0,1]$, $\kappa + \iota \leq 1$.Then

$(\mathrm{I}, \mathrm{A})^{[\kappa,\iota]} = \{x: \mu_{I(e)}(\mathrm{x}) \leq \kappa, \gamma_{I(e)}(\mathrm{x}) \geq \iota\}$

$(\mathrm{I}, \mathrm{A})^{(\kappa,\iota)} = \{x: \mu_{I(e)}(\mathrm{x}) < \kappa, \gamma_{I(e)}(\mathrm{x}) > \iota\}$

$(\mathrm{I}, \mathrm{A})^{[\kappa,\iota)} = \{x: \mu_{I(e)}(\mathrm{x}) \leq \kappa, \gamma_{I(e)}(\mathrm{x}) > \iota\}$

$(\mathrm{I}, \mathrm{A})^{(\kappa,\iota]} = \{x: \mu_{I(e)}(\mathrm{x}) < \kappa, \gamma_{I(e)}(\mathrm{x}) \geq \iota\}$ are

$[\kappa, \iota] -$ lower cut set, $[\kappa, \iota] -$ lower cut set, $[\kappa, \iota] -$ lower cut set, $[\kappa, \iota] -$ lower cut set of

(I,A) respectively.

2.4 Example: Let X be an universal set and E is a set of parameters.Let A⊆E and I:A→ $IF(X)$.Let an Intuitionistic fuzzy soft set be (I,A)=I(e)={x<0.4,0.6>,y<0.2,0.5>,z<0.5,0.4>/x,y,z∈ X}.

Then are $(\mathrm{I},\mathrm{A})^{[0.5,0.4]}$, $(\mathrm{I},\mathrm{A})^{(0.5,0.4)}$ are lower cut sets.

3. CONVEX AND CONCAVE TYPE INTUITIONISTIC FUZZY SOFT SETS

3.1 Definition:

An Intuitionistic fuzzy soft set (I,A) is called a convex Intuitionistic fuzzy soft set if for all x, y∈X, $\lambda \in[0,1]$, $\mu_{I(e)}[\lambda x+(1-\lambda)y] \geq \lambda\, \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$ and

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \leq \lambda\, \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$.

3.2 Definition:

An Intuitionistic fuzzy soft set (I,A) is called a concave Intuitionistic fuzzy soft set if for all x, y∈X, $\lambda \in[0,1]$, $\mu_{I(e)}[\lambda x+(1-\lambda)y] \leq \lambda\, \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$ and

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \geq \lambda\, \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$.

3.3 Definition:

An Intuitionistic fuzzy soft set (I,A) is called a quasi convex Intuitionistic fuzzy soft set if for all x, y∈X, $\lambda \in[0,1]$, $\mu_{I(e)}[\lambda x+(1-\lambda)y] \geq \min(\mu_{I(e)}(x),\mu_{I(e)}(y))$ and

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \leq \max(\gamma_{I(e)}(x),\gamma_{I(e)}(y))$.

3.4 Definition:

An Intuitionistic fuzzy soft set (I,A) is called a quasi concave Intuitionistic fuzzy soft set if for all x, y∈X, $\lambda \in[0,1]$, $\mu_{I(e)}[\lambda x+(1-\lambda)y] \leq \min(\mu_{I(e)}(x),\mu_{I(e)}(y))$ and

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \geq \max(\gamma_{I(e)}(x),\gamma_{I(e)}(y))$.

Note: Here we define L={(k,l)/(k.l) $\in (0,1), \mathrm{k}+\mathrm{l} \leq 1$}

3.5 Proposition:

If (I,A) is an intuitionistic fuzzy soft set then for all (k, l) ∈ L, the following conditions are equivalent

(1) (I, A) is a convex intuitionistic fuzzy soft set

(2) $(\mathrm{I},\mathrm{A})_{[\kappa,\iota]}$ is convex set

Proof:

To prove (1)=(2)

(i) To prove (1)⇒(2)

Let (I, A) be a convex intuitionistic fuzzy soft set.

For all x,y∈ $(\mathrm{I},\mathrm{A})_{[\kappa,\iota]}$, $\lambda \in [0,1]$, we have

$\mu_{I(e)}[\lambda x+(1-\lambda)y] \geq \lambda\, \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$

$= \lambda\, \kappa + (1-\lambda)\, \kappa$

$= \lambda\, \kappa + \kappa - \lambda\, \kappa$

$= \kappa$

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \leq \lambda\, \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$

$= \lambda\, \iota + (1-\lambda)\, \iota$

$= \lambda\, \iota + \iota - \lambda\, \iota$

$= \iota$

There fore λx+(1- λ)y∈ $(\mathrm{I},\mathrm{A})_{[\kappa,\iota]}$

$(\mathrm{I},\mathrm{A})_{[\kappa,\iota]}$ is a convex set.

(ii) To prove (2)⇒(1)

Let $(\mathrm{I},\mathrm{A})_{[\kappa,\iota]}$ is a convex set.

Then $\mu_{I(e)}[\lambda x+(1-\lambda)y] \geq \kappa$

$= \lambda\, \kappa + \kappa - \lambda\, \kappa$

$= \lambda\, \kappa + (1-\lambda)\, \kappa$

$= \lambda\, \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \leq \iota$

$= \lambda\, \iota + \iota - \lambda\, \iota$

$= \lambda\ \iota + (1-\lambda)\ \iota$

$= \lambda\ \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$

Therefore $\mu_{I(e)}[\lambda x+(1-\lambda)y] \geq \lambda\ \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$

and $\gamma_{I(e)}[\lambda x+(1-\lambda)y] \leq \lambda\ \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$.

Hence (I, A) is a convex intuitionistic fuzzy soft set.

From (i) and (ii) we proved that (1) and (2) are equivalent.

3.6 Proposition:

If (I, A) is an intuitionistic fuzzy soft set then for all (k, l) ∈ L, the following conditions are equivalent

(1) (I, A) is a convex intuitionistic fuzzy soft set

(2) $(I, A)_{[\kappa,\iota]}$ is convex set

Proof:

To prove (1) = (2)

(i) To prove (1)⇒(2)

Let (I, A) be a concave intuitionistic fuzzy soft set.

For all x,y∈ $(I, A)_{[\kappa,\iota]}$, $\lambda \in [0,1]$, we have

$\mu_{I(e)}[\lambda x+(1-\lambda)y] \leq \lambda\ \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$

$= \lambda\ \kappa + (1-\lambda)\ \kappa$

$= \lambda\ \kappa + \kappa - \lambda\ \kappa$

$= \kappa$

$\gamma_{I(e)}[\lambda x+ (1-\ \lambda)\ y] \geq \lambda\ \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$

$= \lambda\ \iota + (1-\lambda)\ \iota$

$= \lambda\ \iota + \iota - \lambda\ \iota$

$= \iota$

There fore $\lambda x+(1-\lambda)y \in (I, A)_{[\kappa,\iota]}$

$(I, A)_{[\kappa,\iota]}$ Is a convex set.

(ii) To prove (2)⇒(1)

Let $(I, A)_{[\kappa,\iota]}$ is a convex set.

Then $\mu_{I(e)}[\lambda$x+(1- λ)y]≤ κ

= λ κ +κ- λ κ

= λ κ + (1- λ) κ

= λ $\mu_{I(e)}$(x)+(1- λ)$\mu_{I(e)}$(y)

$\gamma_{I(e)}[\lambda$x+(1- λ)y] ≥ ɩ

= λ ɩ +ɩ- λ ɩ

= λ ɩ + (1- λ) ɩ

= λ $\gamma_{I(e)}$(x)+(1- λ)$\gamma_{I(e)}$(y)

Therefore $\mu_{I(e)}[\lambda$x+(1- λ)y]≤ λ $\mu_{I(e)}$(x)+(1- λ)$\mu_{I(e)}$(y)

and $\gamma_{I(e)}[\lambda$x+(1- λ)y]≥ λ $\gamma_{I(e)}$(x)+(1- λ)$\gamma_{I(e)}$(y).

Hence (I, A) is a concave intuitionistic fuzzy soft set.

From (i) and (ii) we proved that (1) and (2) are equivalent.

3.8 Proposition:

If (I, A) is a quasi concave intuitionistic fuzzy soft set then $(\mathrm{I,A})_{[\kappa,ɩ]}$ is convex set.

Proof:

Let (I, A) be a quasi concave intuitionistic fuzzy soft set.

For all x,y∈ $(\mathrm{I,A})_{[\kappa,ɩ]}$, $\lambda \in [0,1]$, we have

$\mu_{I(e)}[\lambda$x+(1- λ)y]≤ min($\mu_{I(e)}$(x),$\mu_{I(e)}$(y)) ≤ κ

$\gamma_{I(e)}[\lambda$x+(1- λ)y]≥ max($\gamma_{I(e)}$(x),$\gamma_{I(e)}$(y)) ≥ ɩ

There fore λx+(1- λ)y∈ $(\mathrm{I,A})_{[\kappa,ɩ]}$

Hence $(\mathrm{I,A})_{[\kappa,ɩ]}$ is a convex set.

3.9 Proposition:

If (I, A) is a quasi convex intuitionistic fuzzy soft set then $(\mathrm{I,A})_{[\kappa,ɩ]}$ is convex set.

Proof:

Let (I, A) be a quasi convex intuitionistic fuzzy soft set.

For all x,y∈ $(\mathrm{I}, \mathrm{A})_{[\kappa,\iota]}$, $\lambda \in [0,1]$, we have

$\mu_{I(e)}[\lambda x+(1-\lambda)y] \geq \max(\mu_{I(e)}(x),\mu_{I(e)}(y)) \geq \kappa$

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \leq \min(\gamma_{I(e)}(x),\gamma_{I(e)}(y)) \leq \iota$

There fore $\lambda x+(1-\lambda)y \in (\mathrm{I}, \mathrm{A})_{[\kappa,\iota]}$

Hence $(\mathrm{I}, \mathrm{A})_{[\kappa,\iota]}$ is a convex set.

3.10 Proposition:

If (I,A) is an intuitionistic fuzzy soft set then for all (k, l) ∈ L, the following conditions are equivalent

(1) (I, A) is a convex intuitionistic fuzzy soft set

(2). $(\mathrm{I}, \mathrm{A})^{[\kappa,\iota]}$ is convex set

Proof:

To prove (1)⇒(2)

Let (I, A) be a convex intuitionistic fuzzy soft set.

For all x,y∈ $(\mathrm{I}, \mathrm{A})_{[\kappa,\iota]}$, $\lambda \in [0,1]$, we have

$\mu_{I(e)}[\lambda x+(1-\lambda)y] \geq \lambda\, \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$

$= \lambda\, \kappa + (1-\lambda)\, \kappa$

$= \lambda\, \kappa + \kappa - \lambda\, \kappa$

$= \kappa$

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \leq \lambda\, \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$

$= \lambda\, \iota + (1-\lambda)\, \iota$

$= \lambda\, \iota + \iota - \lambda\, \iota$

$= \iota$

There fore $\lambda x+(1-\lambda)y \in (\mathrm{I}, \mathrm{A})_{[\kappa,\iota]}$

$(\mathrm{I}, \mathrm{A})^{[\kappa,\iota]}$ is a convex set.

(iii) To prove (2)⇒(1)

Let $(\mathrm{I},\mathrm{A})^{[\kappa,\iota]}$ is a convex set.

Then $\mu_{I(e)}[\lambda x+(1-\lambda)y] \geq \kappa$

$= \lambda\, \kappa + \kappa - \lambda\, \kappa$

$= \lambda\, \kappa + (1-\lambda)\, \kappa$

$= \lambda\, \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \leq \iota$

$= \lambda\, \iota + \iota - \lambda\, \iota$

$= \lambda\, \iota + (1-\lambda)\, \iota$

$= \lambda\, \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$

Therefore $\mu_{I(e)}[\lambda x+(1-\lambda)y] \geq \lambda\, \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$

and $\gamma_{I(e)}[\lambda x+(1-\lambda)y] \leq \lambda\, \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$.

Hence (I, A) is a convex intuitionistic fuzzy soft set.

From (i) and (ii) we proved that (1) and (2) are equivalent.

3.11 Proposition:

If (I,A) is an intuitionistic fuzzy soft set then for all (k, l) ∈ L, the following conditions are equivalent

(1).(I, A) is a convex intuitionistic fuzzy soft set

(2). $(\mathrm{I},\mathrm{A})^{[\kappa,\iota]}$ is convex set

Proof:

To prove (1)=(2)

(i) To prove (1)⇒(2)

Let (I, A) be a concave intuitionistic fuzzy soft set.

For all x,y∈ $(\mathrm{I},\mathrm{A})^{[\kappa,\iota]}$ $\lambda \in [0,1]$, we have

$\mu_{I(e)}[\lambda x+(1-\lambda)y] \leq \lambda\, \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$

$= \lambda\, \kappa + (1-\lambda)\, \kappa$

$= \lambda\, \kappa + \kappa - \lambda\, \kappa$

$= \kappa$

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \geq \lambda\, \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$

$= \lambda\, \iota + (1-\lambda)\, \iota$

$= \lambda\, \iota + \iota - \lambda\, \iota$

$= \iota$

There fore $\lambda x+(1-\lambda)y \in (I,A)^{[\kappa,\iota]}$

$(I,A)^{[\kappa,\iota]}$ is a convex set.

(ii) To prove (2)⇒(1)

Let $(I,A)^{[\kappa,\iota]}$ is a convex set.

Then $\mu_{I(e)}[\lambda x+(1-\lambda)y] \leq \kappa$

$= \lambda\, \kappa + \kappa - \lambda\, \kappa$

$= \lambda\, \kappa + (1-\lambda)\, \kappa$

$= \lambda\, \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$

$\gamma_{I(e)}[\lambda x+(1-\lambda)y] \geq \iota$

$= \lambda\, \iota + \iota - \lambda\, \iota$

$= \lambda\, \iota + (1-\lambda)\, \iota$

$= \lambda\, \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$

Therefore $\mu_{I(e)}[\lambda x+(1-\lambda)y] \leq \lambda\, \mu_{I(e)}(x)+(1-\lambda)\mu_{I(e)}(y)$

and $\gamma_{I(e)}[\lambda x+(1-\lambda)y] \geq \lambda\, \gamma_{I(e)}(x)+(1-\lambda)\gamma_{I(e)}(y)$.

Hence (I, A) is a concave intuitionistic fuzzy soft set.

From (i) and (ii) we proved that (1) and (2) are equivalent.

3.12 Proposition:

If (I, A) is a quasi concave intuitionistic fuzzy soft set then $(I,A)^{[\kappa,\iota]}$ is convex set.

Proof:

Let (I, A) be a quasi concave intuitionistic fuzzy soft set.

For all x,y$\in (I,A)^{[\kappa,\iota]}$, $\lambda \in [0,1]$, we have

$\mu_{I(e)}[\lambda$x+(1- λ)y]≤ min($\mu_{I(e)}$(x),$\mu_{I(e)}$(y)) ≤ κ

$\gamma_{I(e)}[\lambda$x+(1- λ)y]≥ max($\gamma_{I(e)}$(x),$\gamma_{I(e)}$(y)) ≥ ι

There fore λx+(1- λ)y∈ $(\mathrm{I},\mathrm{A})^{[\kappa,\iota]}$

Hence $(\mathrm{I},\mathrm{A})^{[\kappa,\iota]}$ is a convex set.

3.13 Proposition:

If (I, A) is a quasi convex intuitionistic fuzzy soft set then $(\mathrm{I},\mathrm{A})^{[\kappa,\iota]}$ is convex set.

Proof:

Let (I, A) be a quasi convex intuitionistic fuzzy soft set.

For all x,y∈ $(\mathrm{I},\mathrm{A})^{[\kappa,\iota]}$, $\lambda \in [0,1]$, we have

$\mu_{I(e)}[\lambda$x+(1- λ)y]≥ max($\mu_{I(e)}$(x),$\mu_{I(e)}$(y)) ≥ κ

$\gamma_{I(e)}[\lambda$x+(1- λ)y]≤ min($\gamma_{I(e)}$(x),$\gamma_{I(e)}$(y)) ≤ ι

There fore λx+(1- λ)y∈ $(\mathrm{I},\mathrm{A})^{[\kappa,\iota]}$

Hence $(\mathrm{I},\mathrm{A})^{[\kappa,\iota]}$ is a convex set.

4. CONCLUSION

In this paper we studied about cut set, convex and concave type intuitionistic fuzzy soft sets. Also we derived some relations among them.

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