

Lower and Upper Soft Interval Valued Neutrosophic Rough Approximations of An IVNSS-Relation

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Abstract: In this paper, we extend the lower and upper soft interval valued intuitionistic fuzzy rough approximations of IVIFS –relations proposed by Anjan et al. to the case of interval valued neutrosophic soft set relation (IVNSS-relation for short)

Keywords: Interval valued neutrosophic soft, Interval valued neutrosophic soft set relation

0. Introduction

This paper is an attempt to extend the concept of interval valued intuitionistic fuzzy soft relation (IVIFSS-relations) introduced by A. Mukherjee et al [45] to IVNSS relation.

The organization of this paper is as follow: In section 2, we briefly present some basic definitions and preliminary results are given which will be used in the rest of the paper. In section 3, relation interval neutrosophic soft relation is presented. In section 4 various type of interval valued neutrosophic soft relations. In section 5, we concludes the paper

1. Preliminaries

Throughout this paper, let U be a universal set and E be the set of all possible parameters under consideration with respect to U , usually, parameters are attributes, characteristics, or properties of objects in U . We now recall some basic notions of neutrosophic set, interval neutrosophic set, soft set, neutrosophic soft set and interval neutrosophic soft set.

Definition 2.1.

Let U be an universe of discourse then the neutrosophic set A is an object having the form $A = \{ \langle x: \mu_{A(x)}, \nu_{A(x)}, \omega_{A(x)} \rangle, x \in U \}$, where the functions $\mu, \nu, \omega : U \rightarrow]^{-}0, 1^{+}[$ define respectively the degree of membership, the degree of indeterminacy, and the degree of non-membership of the element $x \in X$ to the set A with the condition.

$$^{-}0 \leq \mu_{A(x)} + \nu_{A(x)} + \omega_{A(x)} \leq 3^{+}.$$

From philosophical point of view, the neutrosophic set takes the value from real standard or non-standard subsets of $]0,1+[$.so instead of $]0,1+[$ we need to take the interval $[0,1]$ for technical applications, because $]0,1+[$ will be difficult to apply in the real applications such as in scientific and engineering problems.

Definition 2.2. A neutrosophic set A is contained in another neutrosophic set B i.e. $A \subseteq B$ if $\forall x \in U, \mu_A(x) \leq \mu_B(x), \nu_A(x) \geq \nu_B(x), \omega_A(x) \geq \omega_B(x)$.

Definition 2.3. Let X be a space of points (objects) with generic elements in X denoted by x. An interval valued neutrosophic set (for short IVNS) A in X is characterized by truth-membership function $\mu_A(x)$, indeterminacy-membership function $\nu_A(x)$ and falsity-membership function $\omega_A(x)$. For each point x in X, we have that $\mu_A(x), \nu_A(x), \omega_A(x) \in [0,1]$.

For two IVNS, $A_{IVNS} = \{ \langle x, [\mu_A^L(x), \mu_A^U(x)], [\nu_A^L(x), \nu_A^U(x)], [\omega_A^L(x), \omega_A^U(x)] \rangle \mid x \in X \}$

And $B_{IVNS} = \{ \langle x, [\mu_B^L(x), \mu_B^U(x)], [\nu_B^L(x), \nu_B^U(x)], [\omega_B^L(x), \omega_B^U(x)] \rangle \mid x \in X \}$ the two relations are defined as follows:

(1) $A_{IVNS} \subseteq B_{IVNS}$ if and only if $\mu_A^L(x) \leq \mu_B^L(x), \mu_A^U(x) \leq \mu_B^U(x), \nu_A^L(x) \geq \nu_B^L(x), \nu_A^U(x) \geq \nu_B^U(x), \omega_A^L(x) \geq \omega_B^L(x), \omega_A^U(x) \geq \omega_B^U(x)$

(2) $A_{IVNS} = B_{IVNS}$ if and only if, $\mu_A(x) = \mu_B(x), \nu_A(x) = \nu_B(x), \omega_A(x) = \omega_B(x)$ for any $x \in X$

As an illustration ,let us consider the following example.

Example 2.4. Assume that the universe of discourse $U = \{x_1, x_2, x_3\}$, where x_1 characterizes the capability, x_2 characterizes the trustworthiness and x_3 indicates the prices of the objects. It may be further assumed that the values of x_1, x_2 and x_3 are in $[0,1]$ and they are obtained from some questionnaires of some experts. The experts may impose their opinion in three components viz. the degree of goodness, the degree of indeterminacy and that of poorness to explain the characteristics of the objects. Suppose A is an interval neutrosophic set (INS) of U, such that,
 $A = \{ \langle x_1, [0.3 \ 0.4], [0.5 \ 0.6], [0.4 \ 0.5] \rangle, \langle x_2, [0.1 \ 0.2], [0.3 \ 0.4], [0.6 \ 0.7] \rangle, \langle x_3, [0.2 \ 0.4], [0.4 \ 0.5], [0.4 \ 0.6] \rangle \}$, where the degree of goodness of capability is 0.3, degree of indeterminacy of capability is 0.5 and degree of falsity of capability is 0.4 etc.

Definition 2.5.

Let U be an initial universe set and E be a set of parameters. Let $P(U)$ denotes the power set of U. Consider a nonempty set A, $A \subset E$. A pair (K, A) is called a soft set over U, where K is a mapping given by $K : A \rightarrow P(U)$.

As an illustration, let us consider the following example.

Example 2.6 .

Suppose that U is the set of houses under consideration, say $U = \{h_1, h_2, \dots, h_5\}$. Let E be the set of some attributes of such houses, say $E = \{e_1, e_2, \dots, e_8\}$, where $e_1, e_2, \dots, e_8$ stand for the attributes “beautiful”, “costly”, “in the green surroundings”, “moderate”, respectively.

In this case, to define a soft set means to point out expensive houses, beautiful houses, and so on. For example, the soft set (K, A) that describes the “attractiveness of the houses” in the opinion of a buyer, say Thomas, may be defined like this:

$A = \{e_1, e_2, e_3, e_4, e_5\}$;

$K(e_1) = \{h_2, h_3, h_5\}, K(e_2) = \{h_2, h_4\}, K(e_3) = \{h_1\}, K(e_4) = U, K(e_5) = \{h_3, h_5\}$.

Definition 2.7 .

Let U be an initial universe set and $A \subset E$ be a set of parameters. Let $IVNS(U)$ denotes the

set of all interval neutrosophic subsets of U . The collection (K, A) is termed to be the soft interval neutrosophic set over U , where F is a mapping given by $K : A \rightarrow IVNS(U)$.

The interval neutrosophic soft set defined over an universe is denoted by INSS.

To illustrate let us consider the following example:

Let U be the set of houses under consideration and E is the set of parameters (or qualities).

Each parameter is a interval neutrosophic word or sentence involving interval neutrosophic words. Consider $E = \{ \text{beautiful, costly, in the green surroundings, moderate, expensive} \}$. In this case, to define a interval neutrosophic soft set means to point out beautiful houses, costly houses, and so on. Suppose that, there are five houses in the universe U given by, $U = \{h_1, h_2, h_3, h_4, h_5\}$ and the set of parameters $A = \{e_1, e_2, e_3, e_4\}$, where each e_i is a specific criterion for houses:

e_1 stands for 'beautiful',

e_2 stands for 'costly',

e_3 stands for 'in the green surroundings',

e_4 stands for 'moderate',

Suppose that,

$K(\text{beautiful}) = \{ \langle h_1, [0.5, 0.6], [0.6, 0.7], [0.3, 0.4] \rangle, \langle h_2, [0.4, 0.5], [0.7, 0.8], [0.2, 0.3] \rangle, \langle h_3, [0.6, 0.7], [0.2, 0.3], [0.3, 0.5] \rangle, \langle h_4, [0.7, 0.8], [0.3, 0.4], [0.2, 0.4] \rangle, \langle h_5, [0.8, 0.4], [0.2, 0.6], [0.3, 0.4] \rangle \}$.
 $K(\text{costly}) = \{ \langle h_1, [0.5, 0.6], [0.6, 0.7], [0.3, 0.4] \rangle, \langle h_2, [0.4, 0.5], [0.7, 0.8], [0.2, 0.3] \rangle, \langle h_3, [0.6, 0.7], [0.2, 0.3], [0.3, 0.5] \rangle, \langle h_4, [0.7, 0.8], [0.3, 0.4], [0.2, 0.4] \rangle, \langle h_5, [0.8, 0.4], [0.2, 0.6], [0.3, 0.4] \rangle \}$.

$K(\text{in the green surroundings}) = \{ \langle h_1, [0.5, 0.6], [0.6, 0.7], [0.3, 0.4] \rangle, \langle h_2, [0.4, 0.5], [0.7, 0.8], [0.2, 0.3] \rangle, \langle h_3, [0.6, 0.7], [0.2, 0.3], [0.3, 0.5] \rangle, \langle h_4, [0.7, 0.8], [0.3, 0.4], [0.2, 0.4] \rangle, \langle h_5, [0.8, 0.4], [0.2, 0.6], [0.3, 0.4] \rangle \}$.
 $K(\text{moderate}) = \{ \langle h_1, [0.5, 0.6], [0.6, 0.7], [0.3, 0.4] \rangle, \langle h_2, [0.4, 0.5], [0.7, 0.8], [0.2, 0.3] \rangle, \langle h_3, [0.6, 0.7], [0.2, 0.3], [0.3, 0.5] \rangle, \langle h_4, [0.7, 0.8], [0.3, 0.4], [0.2, 0.4] \rangle, \langle h_5, [0.8, 0.4], [0.2, 0.6], [0.3, 0.4] \rangle \}$.

Definition 2.8.

Let U be an initial universe and (F, A) and (G, B) be two interval valued neutrosophic soft set. Then a relation between them is defined as a pair $(H, A \times B)$, where H is mapping given by $H: A \times B \rightarrow IVNS(U)$. This is called an interval valued neutrosophic soft sets relation (IVNSS-relation for short). the collection of relations on interval valued neutrosophic soft sets on $A \times B$ over U is denoted by $\sigma_U(A \times B)$.

Definition 2.9. Let $P, Q \in \sigma_U(A \times B)$ and the order of their relational matrices are same. Then $P \subseteq Q$ if $H(e_j, e_j) \subseteq J(e_j, e_j)$ for $(e_j, e_j) \in A \times B$ where $P = (H, A \times B)$ and $Q = (J, A \times B)$

Example:

P

U	(e_1, e_2)	(e_1, e_4)	(e_3, e_2)	(e_3, e_4)
h_1	$([0.2, 0.3], [0.2, 0.3], [0.4, 0.5])$	$([0.4, 0.6], [0.7, 0.8], [0.1, 0.4])$	$([0.4, 0.6], [0.7, 0.8], [0.1, 0.4])$	$([0.4, 0.6], [0.7, 0.8], [0.1, 0.4])$
h_2	$([0.6, 0.8], [0.3, 0.4], [0.1, 0.7])$	$([1, 1], [0, 0], [0, 0])$	$([0.1, 0.5], [0.4, 0.7], [0.5, 0.6])$	$([0.1, 0.5], [0.4, 0.7], [0.5, 0.6])$
h_3	$([0.3, 0.6], [0.2, 0.7], [0.3, 0.4])$	$([0.4, 0.7], [0.1, 0.3], [0.2, 0.4])$	$([1, 1], [0, 0], [0, 0])$	$([0.4, 0.7], [0.1, 0.3], [0.2, 0.4])$
h_4	$([0.6, 0.7], [0.3, 0.4], [0.2, 0.4])$	$([0.3, 0.4], [0.7, 0.9], [0.1, 0.2])$	$([0.3, 0.4], [0.7, 0.9], [0.1, 0.2])$	$([1, 1], [0, 0], [0, 0])$

Q

U	(e_1, e_2)	(e_1, e_4)	(e_3, e_2)	(e_3, e_4)
h_1	$([0.3, 0.4], [0, 0], [0, 0])$	$([0.4, 0.6], [0.7, 0.8], [0.1, 0.4])$	$([0.4, 0.6], [0.7, 0.8], [0.1, 0.4])$	$([0.4, 0.6], [0.7, 0.8], [0.1, 0.4])$
h_2	$([0.6, 0.8], [0.3, 0.4], [0.1, 0.7])$	$([1, 1], [0, 0], [0, 0])$	$([0.1, 0.5], [0.4, 0.7], [0.5, 0.6])$	$([0.1, 0.5], [0.4, 0.7], [0.5, 0.6])$

h_3	$([0.3, 0.6], [0.2, 0.7], [0.3, 0.4])$	$([0.4, 0.7], [0.1, 0.3], [0.2, 0.4])$	$([1, 1], [0, 0], [0, 0])$	$([0.4, 0.7], [0.1, 0.3], [0.2, 0.4])$
h_4	$([0.6, 0.7], [0.3, 0.4], [0.2, 0.4])$	$([0.3, 0.4], [0.7, 0.9], [0.1, 0.2])$	$([0.3, 0.4], [0.7, 0.9], [0.1, 0.2])$	$([1, 1], [0, 0], [0, 0])$

Definition 2.10.

Let U be an initial universe and (F, A) and (G, B) be two interval valued neutrosophic soft sets. Then a null relation between them is denoted

by O_U and is defined as $O_U = (H_O, A \times B)$ where $H_O(e_i, e_j) = \{ \langle h_k, [0, 0], [1, 1], [1, 1] \rangle; h_k \in U \}$ for $(e_i, e_j) \in A \times B$.

Example. Consider the interval valued neutrosophic soft sets (F, A) and (G, B) . Then a null relation between them is given by

U	(e_1, e_2)	(e_1, e_4)	(e_3, e_2)	(e_3, e_4)
h_1	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$
h_2	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$
h_3	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$
h_4	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$	$([0, 0], [1, 1], [1, 1])$

Remark. It can be easily seen that $P \cup O_U = P$ and $P \cap O_U = O_U$ for any $P \in \sigma_U(A \times B)$

Definition 2.11.

Let U be an initial universe and (F, A) and (G, B) be two interval valued neutrosophic soft sets. Then an absolute relation between them is denoted by I_U and is defined as $I_U = (H_I, A \times B)$ where $H_I(e_i, e_j) = \{ \langle h_k, [1, 1], [0, 0], [0, 0] \rangle; h_k \in U \}$ for $(e_i, e_j) \in A \times B$.

U	(e_1, e_2)	(e_1, e_4)	(e_3, e_2)	(e_3, e_4)
h_1	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$
h_2	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$
h_3	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$
h_4	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$	$([1, 1], [0, 0], [0, 0])$

Defintion.2.12 Let $P \in \sigma_U(A \times B)$, $P = (H, A \times B)$, $Q = (J, A \times B)$ and the order of their relational matrices are same. Then we define

- (i) $P \cup Q = (H \circ J, A \times B)$ where $H \circ J : A \times B \rightarrow IVNS(U)$ is defined as $(H \circ J)(e_i, e_j) = H(e_i, e_j) \vee J(e_j, e_j)$ for $(e_i, e_j) \in A \times B$, where $\vee$ denotes the interval valued neutrosophic union.
- (ii) $P \cap Q = (H \blacksquare J, A \times B)$ where $H \blacksquare J : A \times B \rightarrow IVNS(U)$ is defined as $(H \blacksquare J)(e_i, e_j) = H(e_i, e_j) \wedge J(e_j, e_j)$ for $(e_j, e_j) \in A \times B$, where $\wedge$ denotes the interval valued neutrosophic intersection
- (iii) $P^c = (\sim H, A \times B)$, where $\sim H : A \times B \rightarrow IVNS(U)$ is defined as $\sim H(e_i, e_j) = [H(e_i, e_j)]^c$ for $(e_i, e_j) \in A \times B$, where c denotes the interval valued neutrosophic complement.

Defintion.2.13.

Let R be an equivalence relation on the universal set U . Then the pair (U, R) is called a Pawlak approximation space. An equivalence class of R containing x will be denoted by $[x]_R$. Now for $X \subseteq U$, the lower and upper approximation of X with respect to (U, R) are denoted by respectively R_*X and R^*X and are defined by

$$R * X = \{x \in U: [x]_R \subseteq X\},$$

$$R^* X = \{x \in U: [x]_R \cap X \neq \emptyset\}.$$

Now if $R * X = R^* X$, then X is called definable; otherwise X is called a rough set.

3-Lower and upper soft interval valued neutrosophic rough approximations of an IVNSS-relation

Defntion 3.1 . Let $R \in \sigma_U(A \times A)$ and $R = (H, A \times A)$. Let $\Theta = (f, B)$ be an interval valued neutrosophic soft set over U and $S = (U, \Theta)$ be the soft interval valued neutrosophic approximation space. Then the lower and upper soft interval valued neutrosophic rough approximations of R with respect to S are denoted by $Lwr_S(R)$ and $Upr_S(R)$ respectively, which are IVNSS- relations over $A \times B$ in U given by:

$$Lwr_S(R) = (J, A \times B) \quad \text{and} \quad Upr_S(R) = (K, A \times B)$$

$$J(e_i, e_k) = \{<x, [\bigwedge_{e_j \in A} (\inf \mu_H(e_i, e_j)(x) \wedge \inf \mu_f(e_k)(x)), \bigwedge_{e_j \in A} (\sup \mu_H(e_i, e_j)(x) \wedge \sup \mu_f(e_k)(x))]\},$$

$$[\bigwedge_{e_j \in A} (\inf v_H(e_i, e_j)(x) \vee \inf v_f(e_k)(x)), \bigwedge_{e_j \in A} (\sup v_H(e_i, e_j)(x) \vee \sup v_f(e_k)(x))],$$

$$[\bigwedge_{e_j \in A} (\inf \omega_H(e_i, e_j)(x) \vee \inf \omega_f(e_k)(x)), \bigwedge_{e_j \in A} (\sup \omega_H(e_i, e_j)(x) \vee \sup \omega_f(e_k)(x))] : x \in U\}.$$

$$K(e_i, e_k) = \{<x, [\bigwedge_{e_i \in A} (\inf \mu_H(e_i, e_j)(x) \vee \inf \mu_f(e_k)(x)), \bigwedge_{e_j \in A} (\sup \mu_H(e_i, e_j)(x) \vee \sup \mu_f(e_k)(x))]\},$$

$$[\bigwedge_{e_j \in A} (\inf v_H(e_i, e_j)(x) \wedge \inf v_f(e_k)(x)), \bigwedge_{e_j \in A} (\sup v_H(e_i, e_j)(x) \wedge \sup v_f(e_k)(x))],$$

$$[\bigwedge_{e_j \in A} (\inf \omega_H(e_i, e_j)(x) \wedge \inf \omega_f(e_k)(x)), \bigwedge_{e_j \in A} (\sup \omega_H(e_i, e_j)(x) \wedge \sup \omega_f(e_k)(x))] : x \in U\}.$$

For $e_i \in A, e_k \in B$

Theorem 3.2. Let Θ be an interval valued neutrosophic soft over U and $S = (U, \Theta)$ be the soft approximation space. Let $R_1, R_2 \in \sigma_U(A \times A)$ and $R_1 = (G, A \times A)$ and $R_2 = (H, A \times A)$. Then

- (i) $Lwr_S(O_U) = O_U$
- (ii) $Lwr_S(1_U) = 1_U$
- (iii) $R_1 \subseteq R_2 \Rightarrow Lwr_S(R_1) \subseteq Lwr_S(R_2)$
- (iv) $R_1 \subseteq R_2 \Rightarrow Upr_S(R_1) \subseteq Upr_S(R_2)$
- (v) $Lwr_S(R_1 \cap R_2) \subseteq Lwr_S(R_1) \cap Lwr_S(R_2)$
- (vi) $Upr_S(R_1 \cap R_2) \subseteq Upr_S(R_1) \cap Upr_S(R_2)$
- (vii) $Lwr_S(R_1) \cup Lwr_S(R_2) \subseteq Lwr_S(R_1 \cup R_2)$
- (viii) $Upr_S(R_1) \cup Upr_S(R_2) \subseteq Upr_S(R_1 \cup R_2)$

Proof. (i) –(iv) are straight forward.

Let $Lwr_S(R_1 \cap R_2) = (S, A \times B)$. Then for $(e_i, e_k) \in A \times B$, we have

$$S(e_i, e_k) = \{<x, [\bigwedge_{e_j \in A} (\inf \mu_{G \circ H}(e_i, e_j)(x) \wedge \inf \mu_f(e_k)(x)), \bigwedge_{e_j \in A} (\sup \mu_{G \circ H}(e_i, e_j)(x) \wedge \sup \mu_f(e_k)(x))]\},$$

$$[\bigwedge_{e_j \in A} (\inf v_{G \circ H}(e_i, e_j)(x) \vee \inf v_f(e_k)(x)), \bigwedge_{e_j \in A} (\sup v_{G \circ H}(e_i, e_j)(x) \vee \sup v_f(e_k)(x))],$$

$$[\bigwedge_{e_j \in A} (\inf \omega_{G \circ H}(e_i, e_j)(x) \vee \inf \omega_f(e_k)(x)), \bigwedge_{e_j \in A} (\sup \omega_{G \circ H}(e_i, e_j)(x) \vee \sup \omega_f(e_k)(x))] : x \in U\}$$

$$=\{<x, [\bigwedge_{e_j \in A} (\min(\inf \mu_{\mathbf{G}}(e_i, e_j)(x), \inf \mu_{\mathbf{H}}(e_i, e_j)(x)) \wedge \inf \mu_{\mathbf{f}}(e_k)(x)) \\ , \bigwedge_{e_j \in A} (\min(\sup \mu_{\mathbf{G}}(e_i, e_j)(x), \sup \mu_{\mathbf{H}}(e_i, e_j)(x)) \wedge \sup \mu_{\mathbf{f}}(e_k)(x))],$$

$$[\bigwedge_{e_j \in A} (\max(\inf v_{\mathbf{G}}(e_i, e_j)(x), \inf v_{\mathbf{H}}(e_i, e_j)(x)) \vee \inf v_{\mathbf{f}}(e_k)(x)) \\ , \bigwedge_{e_j \in A} (\max(\sup v_{\mathbf{G}}(e_i, e_j)(x), \sup v_{\mathbf{H}}(e_i, e_j)(x)) \vee \sup v_{\mathbf{f}}(e_k)(x))],$$

$$[\bigwedge_{e_j \in A} (\max(\inf \omega_{\mathbf{G}}(e_i, e_j)(x), \inf \omega_{\mathbf{H}}(e_i, e_j)(x)) \vee \inf \omega_{\mathbf{f}}(e_k)(x)) \\ , \bigwedge_{e_j \in A} (\max(\sup \omega_{\mathbf{G}}(e_i, e_j)(x), \sup \omega_{\mathbf{H}}(e_i, e_j)(x)) \vee \sup \omega_{\mathbf{f}}(e_k)(x))] : x \in U\}$$

Also for $\text{Lwr}_S(\mathbf{R}_1) \cap \text{Lwr}_S(\mathbf{R}_2) = (Z, A \times B)$ and $(e_i, e_k) \in A \times B$, we have ,

$$Z(e_i, e_k) = \{<x, [\text{Min}(\bigwedge_{e_j \in A} (\inf \mu_{\mathbf{G}}(e_i, e_j)(x) \wedge \inf \mu_{\mathbf{f}}(e_k)(x)) , \bigwedge_{e_j \in A} (\inf \mu_{\mathbf{H}}(e_i, e_j)(x) \wedge \\ \inf \mu_{\mathbf{f}}(e_k)(x))) , \text{Min}(\bigwedge_{e_j \in A} (\sup \mu_{\mathbf{G}}(e_i, e_j)(x) \wedge \sup \mu_{\mathbf{f}}(e_k)(x)) , \bigwedge_{e_j \in A} (\sup \mu_{\mathbf{H}}(e_i, e_j)(x) \wedge \\ \sup \mu_{\mathbf{f}}(e_k)(x)))], \\ [\text{Max}(\bigwedge_{e_j \in A} (\inf v_{\mathbf{G}}(e_i, e_j)(x) \vee \inf v_{\mathbf{f}}(e_k)(x)) , \bigwedge_{e_j \in A} (\inf v_{\mathbf{H}}(e_i, e_j)(x) \vee \inf v_{\mathbf{f}}(e_k)(x))) , \\ \text{Max}(\bigwedge_{e_j \in A} (\sup v_{\mathbf{G}}(e_i, e_j)(x) \vee \sup v_{\mathbf{f}}(e_k)(x)) , \bigwedge_{e_j \in A} (\sup v_{\mathbf{H}}(e_i, e_j)(x) \vee \sup v_{\mathbf{f}}(e_k)(x)))],$$

$$[\text{Max}(\bigwedge_{e_j \in A} (\inf \omega_{\mathbf{G}}(e_i, e_j)(x) \vee \inf \omega_{\mathbf{f}}(e_k)(x)) , \bigwedge_{e_j \in A} (\inf \omega_{\mathbf{H}}(e_i, e_j)(x) \vee \inf \omega_{\mathbf{f}}(e_k)(x))) , \\ \text{Max}(\bigwedge_{e_j \in A} (\sup \omega_{\mathbf{G}}(e_i, e_j)(x) \vee \sup \omega_{\mathbf{f}}(e_k)(x)) , \bigwedge_{e_j \in A} (\sup \omega_{\mathbf{H}}(e_i, e_j)(x) \vee \sup \omega_{\mathbf{f}}(e_k)(x)))] : x \in U\}$$

Now since $\min(\inf \mu_{\mathbf{G}}(e_i, e_j)(x), \inf \mu_{\mathbf{H}}(e_i, e_j)(x)) \leq \inf \mu_{\mathbf{G}}(e_i, e_j)(x)$ and

$\min(\inf \mu_{\mathbf{G}}(e_i, e_j)(x), \inf \mu_{\mathbf{H}}(e_i, e_j)(x)) \leq \inf \mu_{\mathbf{H}}(e_i, e_j)(x)$ we have

$$\bigwedge_{e_j \in A} (\min(\inf \mu_{\mathbf{G}}(e_i, e_j)(x), \inf \mu_{\mathbf{H}}(e_i, e_j)(x)) \wedge \inf \mu_{\mathbf{f}}(e_k)(x)) \leq \text{Min}(\bigwedge_{e_j \in A} (\inf \mu_{\mathbf{G}}(e_i, e_j)(x) \wedge \\ \inf \mu_{\mathbf{f}}(e_k)(x)) , \bigwedge_{e_j \in A} (\inf \mu_{\mathbf{H}}(e_i, e_j)(x) \wedge \inf \mu_{\mathbf{f}}(e_k)(x))).$$

Similarly we can get

$$\bigwedge_{e_j \in A} (\min(\sup \mu_{\mathbf{G}}(e_i, e_j)(x), \sup \mu_{\mathbf{H}}(e_i, e_j)(x)) \wedge \sup \mu_{\mathbf{f}}(e_k)(x)) \leq \text{Min}(\bigwedge_{e_j \in A} (\sup \mu_{\mathbf{G}}(e_i, e_j)(x) \wedge \\ \sup \mu_{\mathbf{f}}(e_k)(x)) , \bigwedge_{e_j \in A} (\sup \mu_{\mathbf{H}}(e_i, e_j)(x) \wedge \sup \mu_{\mathbf{f}}(e_k)(x))).$$

Again as $\max(\inf v_{\mathbf{G}}(e_i, e_j)(x), \inf v_{\mathbf{H}}(e_i, e_j)(x)) \geq \inf v_{\mathbf{G}}(e_i, e_j)(x)$, and

$\max(\inf v_{\mathbf{G}}(e_i, e_j)(x), \inf v_{\mathbf{H}}(e_i, e_j)(x)) \geq \inf v_{\mathbf{H}}(e_i, e_j)(x)$

we have

$$\bigwedge_{e_j \in A} (\max(\inf v_{\mathbf{G}}(e_i, e_j)(x), \inf v_{\mathbf{H}}(e_i, e_j)(x)) \vee \inf v_{\mathbf{f}}(e_k)(x)) \geq \text{Max}(\bigwedge_{e_j \in A} (\inf v_{\mathbf{G}}(e_i, e_j)(x) \vee \\ \inf v_{\mathbf{f}}(e_k)(x)) , \bigwedge_{e_j \in A} (\inf v_{\mathbf{H}}(e_i, e_j)(x) \vee \inf v_{\mathbf{f}}(e_k)(x))).$$

Similarly we can get

$$\bigwedge_{e_j \in A} (\max(\sup v_{\mathbf{G}}(e_i, e_j)(x), \sup v_{\mathbf{H}}(e_i, e_j)(x)) \vee \sup v_{\mathbf{f}}(e_k)(x)) \geq \text{Max}(\bigwedge_{e_j \in A} (\sup v_{\mathbf{G}}(e_i, e_j)(x) \vee \\ \sup v_{\mathbf{f}}(e_k)(x)) , \bigwedge_{e_j \in A} (\sup v_{\mathbf{H}}(e_i, e_j)(x) \vee \sup v_{\mathbf{f}}(e_k)(x))).$$

Again as $\max(\inf \omega_{\mathbf{G}}(e_i, e_j)(x), \inf \omega_{\mathbf{H}}(e_i, e_j)(x)) \geq \inf \omega_{\mathbf{G}}(e_i, e_j)(x)$, and

$\max(\inf \omega_{\mathbf{G}}(e_i, e_j)(x), \inf \omega_{\mathbf{H}}(e_i, e_j)(x)) \geq \inf \omega_{\mathbf{H}}(e_i, e_j)(x)$

we have

$$\bigwedge_{e_j \in A} (\max(\inf \omega_{\mathbf{G}}(e_i, e_j)(x), \inf \omega_{\mathbf{H}}(e_i, e_j)(x)) \vee \inf \omega_{\mathbf{f}}(e_k)(x)) \geq \text{Max} (\bigwedge_{e_j \in A} (\inf \omega_{\mathbf{G}}(e_i, e_j)(x) \vee \inf \omega_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\inf \omega_{\mathbf{H}}(e_i, e_j)(x) \vee \inf \omega_{\mathbf{f}}(e_k)(x))).$$

Similarly we can get

$$\bigwedge_{e_j \in A} (\max(\sup \omega_{\mathbf{G}}(e_i, e_j)(x), \sup \omega_{\mathbf{H}}(e_i, e_j)(x)) \vee \sup \omega_{\mathbf{f}}(e_k)(x)) \geq \text{Max} (\bigwedge_{e_j \in A} (\sup \omega_{\mathbf{G}}(e_i, e_j)(x) \vee \sup \omega_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\sup \omega_{\mathbf{H}}(e_i, e_j)(x) \vee \sup \omega_{\mathbf{f}}(e_k)(x))).$$

Consequently, $\text{Lwr}_S(R_1 \cap R_2) \subseteq \text{Lwr}_S(R_1) \cap \text{Lwr}_S(R_2)$
(vi) Proof is similar to (v)

(vii) Let $\text{Lwr}_S(R_1 \cup R_2) = (S, A \times B)$. Then for $(e_i, e_k) \in A \times B$, we have

$$\begin{aligned} S(e_i, e_k) &= \{ \langle x, [\bigwedge_{e_j \in A} (\inf \mu_{\mathbf{G} \blacksquare \mathbf{H}}(e_i, e_j)(x) \wedge \inf \mu_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\sup \mu_{\mathbf{G} \blacksquare \mathbf{H}}(e_i, e_j)(x) \wedge \sup \mu_{\mathbf{f}}(e_k)(x))] \}, \\ &[\bigwedge_{e_j \in A} (\inf v_{\mathbf{G} \blacksquare \mathbf{H}}(e_i, e_j)(x) \vee \inf v_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\inf v_{\mathbf{G} \blacksquare \mathbf{H}}(e_i, e_j)(x) \vee \inf v_{\mathbf{f}}(e_k)(x))] \}, \\ &[\bigwedge_{e_j \in A} (\inf \omega_{\mathbf{G} \blacksquare \mathbf{H}}(e_i, e_j)(x) \vee \inf \omega_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\inf \omega_{\mathbf{G} \blacksquare \mathbf{H}}(e_i, e_j)(x) \vee \inf \omega_{\mathbf{f}}(e_k)(x))] : x \in U \} \\ &= \{ \langle x, [\bigwedge_{e_j \in A} (\max(\inf \mu_{\mathbf{G}}(e_i, e_j)(x), \inf \mu_{\mathbf{H}}(e_i, e_j)(x)) \wedge \inf \mu_{\mathbf{f}}(e_k)(x)) \\ & \vee \bigwedge_{e_j \in A} (\max(\sup \mu_{\mathbf{G}}(e_i, e_j)(x), \sup \mu_{\mathbf{H}}(e_i, e_j)(x)) \wedge \sup \mu_{\mathbf{f}}(e_k)(x))] \}, \\ &[\bigwedge_{e_j \in A} (\min(\inf v_{\mathbf{G}}(e_i, e_j)(x), \inf v_{\mathbf{H}}(e_i, e_j)(x)) \vee \inf v_{\mathbf{f}}(e_k)(x)) \\ & \vee \bigwedge_{e_j \in A} (\min(\sup v_{\mathbf{G}}(e_i, e_j)(x), \sup v_{\mathbf{H}}(e_i, e_j)(x)) \vee \sup v_{\mathbf{f}}(e_k)(x))] \}, \\ &[\bigwedge_{e_j \in A} (\min(\inf \omega_{\mathbf{G}}(e_i, e_j)(x), \inf \omega_{\mathbf{H}}(e_i, e_j)(x)) \vee \inf \omega_{\mathbf{f}}(e_k)(x)) \\ & \vee \bigwedge_{e_j \in A} (\min(\sup \omega_{\mathbf{G}}(e_i, e_j)(x), \sup \omega_{\mathbf{H}}(e_i, e_j)(x)) \vee \sup \omega_{\mathbf{f}}(e_k)(x))] : x \in U \} \end{aligned}$$

Also for $\text{Lwrs}(R_1) \cup \text{Lwrs}(R_2) = (Z, A \times B)$ and $(e_i, e_k) \in A \times B$, we have ,

$$\begin{aligned} Z(e_i, e_k) &= \{ \langle x, [\text{Max} (\bigwedge_{e_j \in A} (\inf \mu_{\mathbf{G}}(e_i, e_j)(x) \wedge \inf \mu_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\inf \mu_{\mathbf{H}}(e_i, e_j)(x) \wedge \inf \mu_{\mathbf{f}}(e_k)(x)) \\ & \vee \text{Max} (\bigwedge_{e_j \in A} (\sup \mu_{\mathbf{G}}(e_i, e_j)(x) \wedge \sup \mu_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\sup \mu_{\mathbf{H}}(e_i, e_j)(x) \wedge \sup \mu_{\mathbf{f}}(e_k)(x)))] \}, \\ &[\text{Min} (\bigwedge_{e_j \in A} (\inf v_{\mathbf{G}}(e_i, e_j)(x) \vee \inf v_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\inf v_{\mathbf{H}}(e_i, e_j)(x) \vee \inf v_{\mathbf{f}}(e_k)(x)) \\ & \vee \text{Min} (\bigwedge_{e_j \in A} (\sup v_{\mathbf{G}}(e_i, e_j)(x) \vee \sup v_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\sup v_{\mathbf{H}}(e_i, e_j)(x) \vee \sup v_{\mathbf{f}}(e_k)(x)))] \}, \\ &[\text{Min} (\bigwedge_{e_j \in A} (\inf \omega_{\mathbf{G}}(e_i, e_j)(x) \vee \inf \omega_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\inf \omega_{\mathbf{H}}(e_i, e_j)(x) \vee \inf \omega_{\mathbf{f}}(e_k)(x)) \\ & \vee \text{Min} (\bigwedge_{e_j \in A} (\sup \omega_{\mathbf{G}}(e_i, e_j)(x) \vee \sup \omega_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\sup \omega_{\mathbf{H}}(e_i, e_j)(x) \vee \sup \omega_{\mathbf{f}}(e_k)(x)))] : x \in U \} \end{aligned}$$

Now since $\max(\inf \mu_{\mathbf{G}}(e_i, e_j), \inf \mu_{\mathbf{H}}(e_i, e_j)(x)) \geq \inf \mu_{\mathbf{G}}(e_i, e_j)(x)$ and

$\max(\inf \mu_{\mathbf{G}}(e_i, e_j), \inf \mu_{\mathbf{H}}(e_i, e_j)(x)) \geq \inf \mu_{\mathbf{H}}(e_i, e_j)(x)$ we have

$$\bigwedge_{e_j \in A} (\max(\inf \mu_{\mathbf{G}}(e_i, e_j)(x), \inf \mu_{\mathbf{H}}(e_i, e_j)(x)) \wedge \inf \mu_{\mathbf{f}}(e_k)(x)) \geq \max (\bigwedge_{e_j \in A} (\inf \mu_{\mathbf{G}}(e_i, e_j)(x) \wedge \inf \mu_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\inf \mu_{\mathbf{H}}(e_i, e_j)(x) \wedge \inf \mu_{\mathbf{f}}(e_k)(x))).$$

Similarly we can get

$$\bigwedge_{e_j \in A} (\max(\sup \mu_{\mathbf{G}}(e_i, e_j)(x), \sup \mu_{\mathbf{H}}(e_i, e_j)(x)) \wedge \sup \mu_{\mathbf{f}}(e_k)(x)) \geq \max (\bigwedge_{e_j \in A} (\sup \mu_{\mathbf{G}}(e_i, e_j)(x) \wedge \sup \mu_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\sup \mu_{\mathbf{H}}(e_i, e_j)(x) \wedge \sup \mu_{\mathbf{f}}(e_k)(x))).$$

Again as $\min(\inf v_{\mathbf{G}}(e_i, e_j), \inf v_{\mathbf{H}}(e_i, e_j)(x)) \leq \inf v_{\mathbf{G}}(e_i, e_j)(x)$, and
 $\min(\inf v_{\mathbf{G}}(e_i, e_j), \inf v_{\mathbf{H}}(e_i, e_j)(x)) \leq \inf v_{\mathbf{H}}(e_i, e_j)(x)$

we have

$$\bigwedge_{e_j \in A} (\min(\inf v_{\mathbf{G}}(e_i, e_j)(x), \inf v_{\mathbf{H}}(e_i, e_j)(x)) \vee \inf v_{\mathbf{f}}(e_k)(x)) \leq \text{Min} (\bigwedge_{e_j \in A} (\inf v_{\mathbf{G}}(e_i, e_j)(x) \vee \inf v_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\inf v_{\mathbf{H}}(e_i, e_j)(x) \vee \inf v_{\mathbf{f}}(e_k)(x))).$$

Similarly we can get

$$\bigwedge_{e_j \in A} (\min(\sup v_{\mathbf{G}}(e_i, e_j)(x), \sup v_{\mathbf{H}}(e_i, e_j)(x)) \vee \sup v_{\mathbf{f}}(e_k)(x)) \leq \text{Min} (\bigwedge_{e_j \in A} (\sup v_{\mathbf{G}}(e_i, e_j)(x) \vee \sup v_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\sup v_{\mathbf{H}}(e_i, e_j)(x) \vee \sup v_{\mathbf{f}}(e_k)(x))).$$

Again as $\min(\inf \omega_{\mathbf{G}}(e_i, e_j), \inf \omega_{\mathbf{H}}(e_i, e_j)(x)) \leq \inf \omega_{\mathbf{G}}(e_i, e_j)(x)$, and
 $\min(\inf \omega_{\mathbf{G}}(e_i, e_j), \inf \omega_{\mathbf{H}}(e_i, e_j)(x)) \leq \inf \omega_{\mathbf{H}}(e_i, e_j)(x)$

we have

$$\bigwedge_{e_j \in A} (\min(\inf \omega_{\mathbf{G}}(e_i, e_j)(x), \inf \omega_{\mathbf{H}}(e_i, e_j)(x)) \vee \inf \omega_{\mathbf{f}}(e_k)(x)) \leq \text{Min} (\bigwedge_{e_j \in A} (\inf \omega_{\mathbf{G}}(e_i, e_j)(x) \vee \inf \omega_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\inf \omega_{\mathbf{H}}(e_i, e_j)(x) \vee \inf \omega_{\mathbf{f}}(e_k)(x))).$$

Similarly we can get

$$\bigwedge_{e_j \in A} (\min(\sup \omega_{\mathbf{G}}(e_i, e_j)(x), \sup \omega_{\mathbf{H}}(e_i, e_j)(x)) \vee \sup \omega_{\mathbf{f}}(e_k)(x)) \leq \text{Min} (\bigwedge_{e_j \in A} (\sup \omega_{\mathbf{G}}(e_i, e_j)(x) \vee \sup \omega_{\mathbf{f}}(e_k)(x)), \bigwedge_{e_j \in A} (\sup \omega_{\mathbf{H}}(e_i, e_j)(x) \vee \sup \omega_{\mathbf{f}}(e_k)(x))).$$

Consequently $\text{Lwr}_S(\mathbf{R}_1) \cup \text{Lwr}_S(\mathbf{R}_2) \subseteq \text{Lwr}_S(\mathbf{R}_1 \cap \mathbf{R}_2)$

(vii) Proof is similar to (vii).

Conclusion

In the present paper we extend the concept of Lower and upper soft interval valued intuitionistic fuzzy rough approximations of an IVIFSS-relation to the case IVNSS and investigated some of their properties.

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