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# A Novel Approach to Weighted Interval-Valued Intuitionistic Fuzzy Soft Multi Sets Based Decision Making

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**Abstract**

***Soft Set theory is one of the recent topics gaining significance in finding rational and logical solutions to various real life problems which involve uncertainty, impreciseness and vagueness. In this article we have introduced the notions of reduct weighted intuitionistic fuzzy soft multi sets of weighted interval valued intuitionistic fuzzy soft multi set and propose an adjustable approach to weighted interval-valued intuitionistic fuzzy soft set based decision making by using reduct weighted intuitionistic fuzzy soft sets and level soft sets of reduct intuitionistic fuzzy soft sets. Some illustrative example is employed to show the feasibility of our approach in practical applications.***

**Keywords:** *Decision making, soft set, level soft set, intuitionistic fuzzy soft sets, weight function, opinion weighted vector, weighted interval valued intuitionistic fuzzy soft multi set, reduct weighted intuitionistic fuzzy soft multi set.*

# 1 Introduction

It is an open problem to use classical methods to solve some kind of problems given in communication system, sociology, economics, engineering, environmental science, computer science, medical science etc., since; these kinds of problems have their own uncertainties. There are many mathematical tools for dealing with uncertainties; some of them are fuzzy set theory [[27]] and soft set theory [[20]]. In soft set theory there is no limited condition to the description of objects; so researchers can choose the form of parameters they need, which greatly simplifies the decision making process and make the process more efficient in the absence of partial information. Soft set theory is standing in a unique way in the sense that it is free from the above difficulties.

Soft set theory has a rich potential for application in many directions, some of which are reported by Molodtsov [[20]] in his work. Later on Maji et al.[[18]] presented some new definitions on soft sets such as subset, union, intersection and complements of soft sets and discussed in details the application of soft set in decision making problem. Based on the analysis of several operations on soft sets introduced in [[20]], Ali et al. [[2]] presented some new algebraic operations for soft sets and proved that certain De Morgan's law holds in soft set theory with respect to these new definitions. Combining soft sets [[20]] with fuzzy sets [[27]] and intuitionistic fuzzy sets [[5]], Maji et al. [[[14]], [[15]], [[16]], [[17]]] defined fuzzy soft sets and intuitionistic fuzzy soft sets, which are rich potential for solving decision making problems. Alkhazaleh and others [[[1]],[[4]],[[7]],[[8]], [[26]]] as a generalization of Molodtsov's soft set, presented the definition of a soft multi set and its basic operations such as complement, union, and intersection etc.

Maji et al. [[19]] first applied soft sets to solve the decision making problems. Roy and Maji [[25]] presented a novel method to cope with fuzzy soft sets based decision making problems. Kong et al. [[13]] pointed out that the Roy-Maji method [[25]] was incorrect and they presented a revised algorithm. Feng et al. [[[9]],[[10]]] discussed the validity of the Roy-Maji method [[25]] and presented an adjustable approach to fuzzy soft sets based decision making and gave the application of level soft sets in decision making based on interval-valued fuzzy soft sets. Jiang et al. [[[11]],[[12]]] generalize the adjustable approach to fuzzy soft sets based decision making and present an adjustable approach to intuitionistic fuzzy soft sets based decision making by using level soft sets of intuitionistic fuzzy soft sets and also studied interval-valued intuitionistic fuzzy soft sets and their properties. There after Zhang et al. [[28]] presented a novel approach to interval-valued intuitionistic fuzzy soft set based decision making. In 2012, Alkhazaleh and Salleh [[3]] introduced the concept of fuzzy soft multi set theory as a generalization of soft multi set theory and studied the application of fuzzy soft multi set based decision making problems. Recently Mukherjee and Das [[22]] presented some new algebraic operations for fuzzy soft multi sets and proved that certain De Morgan's law holds in fuzzy soft multi set theory with respect to these new definitions.

As a generalization of fuzzy set theory [[27]], intuitionistic fuzzy set theory [[5]] and interval-valued intuitionistic fuzzy set theory [[6]] makes descriptions of the objective world more realistic, practical and accurate in some cases, making it very promising. Mukherjee and Das [[21]] introduced the concepts of intuitionistic fuzzy soft multi sets and studied intuitionistic fuzzy soft multi topological spaces in details. Mukherjee et al. [[23]] also introduced the concepts of interval valued intuitionistic fuzzy soft multi sets and studied their relation in details.

In fact all these concepts having a good application in other disciplines and real life problems are now catching momentum. But, it is seen that all these theories have their own difficulties that is why in this paper we propose an adjustable approach to weighted interval-valued intuitionistic fuzzy soft set based decision making by using reduct intuitionistic fuzzy soft sets and level soft sets of intuitionistic fuzzy soft sets, which is another one new mathematical tool for dealing with uncertain-ties and more feasible for some real life applications of decision making in an imprecise environment. Some illustrative example is employed to show the feasibility of our approach in practical applications.

# 2 Preliminaries

In this section, we recall some basic notions in soft set, interval valued intuitionistic fuzzy set theory and interval valued intuitionistic fuzzy soft multi set theory.

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

**Definition 2.1 ([20])** *A pair (F,A) is called a soft set over U, where F is a mapping given by F: A$\to$ P(U). In other words, soft set over U is a parameterized family of subsets of the universe U.*

**Definition 2.2 ([6])** *An interval valued intuitionistic fuzzy set A over a universe set U is defined as the object of the form* $A=\{<x, \mu_A(x), \nu_A(x)>: x\in U\}$, *where* $\mu_A:U\to Int([0,1])$ *and* $\nu_A:U\to Int([0, 1])$ *are functions such that the condition:* $\forall x\in U$, $sup\mu_A(x)+ sup\nu_A(x)\leq 1$ *is satisfied.*

*The class of all interval valued intuitionistic fuzzy sets on U is denoted by IVIFS(U). Let A, B$\in$IVIFS(U). Then*

- *the union of A and B is denoted by A$\cup$B where*

$A\cup B=\{(x, [max(inf\mu_A(x), inf\mu_B(x)), max(sup\mu_A(x), sup\mu_B(x))], [min(inf\nu_A(x), inf\nu_B(x)), min(sup\nu_A(x), sup\nu_B(x))]): x\in U\}$

- *the intersection of A and B is denoted by* $A \cap B$ *where*

$A \cap B = \{(x, [min(inf\mu_A(x), inf\nu_B(x)), min(sup\mu_A(x), sup\mu_B(x))], [max(inf\nu_A(x), inf\nu_B(x)), max(sup\nu_A(x), sup\nu_B(x))]) : x \in U\}$

*Atanassov and Gargov shows in [[6]] that* $A \cup B$ *and* $A \cap B$ *are again interval valued intuitionistic fuzzy sets.*

**Definition 2.3 ([3])** *Let* $\{U_i : i \in I\}$ *be a collection of universes such that* $\bigcap_{i \in I} U_i = \phi$ *and let* $\{E_{U_i} : i \in I\}$ *be a collection of sets of parameters. Let* $U = \Pi_{i \in I} IVIFS(U_i)$ *where* $IVIFS(U_i)$ *denotes the set of all interval valued intuitionistic fuzzy subsets of* $U_i$*,* $E = \Pi_{i \in I} E_{U_i}$ *and* $A \subseteq E$*. A pair (F,A) is called an interval valued intuitionistic fuzzy soft multi set over U, where F is a mapping given by F:* $A \rightarrow U$*, such that for all* $a \in A$*,*

$F(a) = (\{\frac{u}{([\mu^L_{F(A)}(u), \mu^U_{F(A)}(u)], [\nu^L_{F(A)}(u), \nu^U_{F(A)}(u)])} : u \in U_i\} : i \in I)$

For illustration, we consider the following example.

**Example 2.4** *Let us consider three universes* $U_1 = \{h_1, h_2, h_3\}$*,* $U_2 = \{c_1, c_2, c_3\}$ *and* $U_3 = \{v_1, v_2, v_3\}$ *be the sets of "houses," "cars," and "hotels", respectively. Suppose Mr. X has a budget to buy a house, a car and rent a venue to hold a wedding celebration. Let us consider an interval valued intuitionistic fuzzy soft multi set (F, A) which describes "houses," "cars," and "hotels" that Mr. X is considering for accommodation purchase, transportation purchase, and a venue to hold a wedding celebration, respectively. Let* $\{E_{U_1}, E_{U_2}, E_{U_3}\}$ *be a collection of sets of decision parameters related to the above universes, where*

$E_{U_1} = \{e_{U_1,1} = expensive,\ e_{U_1,2} = cheap,\ e_{U_1,3} = wooden\}$,

$E_{U_2} = \{e_{U_2,1} = expensive,\ e_{U_2,2} = cheap,\ e_{U_2,3} = sporty\}$,

$E_{U_3} = \{e_{U_3,1} = expensive,\ e_{U_3,2} = cheap,\ e_{U_3,3} = in\ Kuala\ Lumpur\}$.

*Let* $U = \Pi^3_{i=1} P(U_i)$*,* $E = \Pi^3_{i=1} E_{U_i}$ *and* $A \subseteq E$*, such that*

$A = \{a_1 = (e_{U_1,1}, e_{U_2,1}, e_{U_3,1}), a_2 = (e_{U_1,1}, e_{U_2,2}, e_{U_3,1}), a_3 = (e_{U_1,2}, e_{U_2,3}, e_{U_3,1}), a_4 = (e_{U_1,3}, e_{U_2,3}, e_{U_3,1}), a_5 = (e_{U_1,1}, e_{U_2,1}, e_{U_3,2}), a_6 = (e_{U_1,1}, e_{U_2,2}, e_{U_3,2})\}$

*Suppose Mr. X wants to choose objects from the sets of given objects with respect to the sets of choice parameters. Let the interval valued intuitionistic fuzzy soft multi set be (F, A) as in* ***Table 1****.*

***Table 1.*** *The tabular representation of an interval valued intuitionistic fuzzy soft multi set (F, A)*

| $U_i$ | | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ |
|---|---|---|---|---|---|---|
| $U_1$ | $h_1$ | ([0.2,0.3], [0.4,0.7]) | ([0.4,0.5], [0.3,0.4]) | ([0.1,0.3], [0.4,0.6]) | ([0.7,0.8], [0.1,0.2]) | ([0.2,0.3], [0.4,0.7]) |
| | $h_2$ | ([0.5,0.6], [0.3,0.2]) | ([0.4,0.6], [0.1,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.6], [0.3,0.4]) | ([0.5,0.6], [0.3,0.4]) |
| | $h_3$ | ([0.5,0.8], [0.1,0.4]) | ([0.7,0.8], [0.1,0.2]) | ([0.2,0.4], [0.3,0.5]) | ([0.5,0.8], [0.1,0.2]) | ([0.3,0.5], [0.3,0.5]) |
| $U_2$ | $c_1$ | ([0.7,0.8], [0.1,0.2]) | ([0.4,0.7], [0.2,0.3]) | ([0.6,0.7], [0.1,0.2]) | ([0.2,0.3], [0.4,0.7]) | ([0.4,0.5], [0.3,0.4])) |
| | $c_2$ | ([0.5,0.6], [0.3,0.4]) | ([0.5,0.6], [0.3,0.4]) | ([0.3,0.4], [0.3,0.4]) | ([0.5,0.6], [0.3,0.4]) | ([0.4,0.6], [0.2,0.3]) |
| | $c_3$ | ([0.5,0.8], [0.1,0.2]) | ([0.5,0.6], [0.2,0.3]) | ([0.4,0.8], [0.1,0.2]) | ([0.3,0.7], [0.1,0.3]) | ([0.7,0.8], [0.1,0.2]) |
| $U_3$ | $v_1$ | ([0.5,0.6], [0.3,0.4]) | ([0.5,0.8], [0.1,0.2]) | ([0.4,0.7], [0.2,0.3]) | ([0.2,0.4], [0.3,0.5]) | ([0.4,0.6], [0.2,0.3]) |
| | $v_2$ | ([0.2,0.3], [0.4,0.7]) | ([0.4,0.5], [0.3,0.4]) | ([0.3,0.4], [0.4,0.6]) | ([0.5,0.6], [0.3,0.4]) | ([0.2,0.5], [0.4,0.5]) |
| | $v_3$ | ([0.3,0.4], [0.4,0.5]) | ([0.4,0.5], [0.3,0.4]) | ([0.2,0.3], [0.4,0.6]) | ([0.5,0.6], [0.1,0.3]) | ([0.4,0.5], [0.3,0.4]) |

**Definition 2.5 ([3])** *For any interval valued intuitionistic fuzzy soft multi set (F,A), a pair* $(e_{U_i,j}, F_{e_{U_i},j})$ *is called a* $U_i$*-interval valued intuitionistic fuzzy soft multi set part,* $\forall e_{U_i,j} \in a_k$ *and* $F_{e_{U_i},j} \subseteq F(A)$ *is an interval valued intuitionistic fuzzy approximate value set, where* $a_k \in A$, $k=\{1,2,3,..,n\}$, $i \in \{1,2,3,..,m\}$ *and* $j \in \{1,2,3,..,r\}$.

**Example 2.6** *If we consider the interval valued intuitionistic fuzzy soft multiset (F, A)as in* ***Table1****, then the first interval valued intuitionistic fuzzy soft multiset part of (F, A) can be represent as in* ***Table2****.*

***Table 2.*** *The tabular representation of the* $U_1$*-interval valued intuitionistic fuzzy soft multiset part of (F,A)*

| $U_1$ | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ |
|---|---|---|---|---|---|
| $h_1$ | ([0.2,0.3], [0.4,0.7]) | ([0.4,0.5], [0.3,0.4]) | ([0.1,0.3], [0.4,0.6]) | ([0.7,0.8], [0.1,0.2]) | ([0.2,0.3], [0.4,0.7]) |
| $h_2$ | ([0.5,0.6], [0.3,0.2]) | ([0.4,0.6], [0.1,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.6], [0.3,0.4]) | ([0.5,0.6], [0.3,0.4]) |
| $h_3$ | ([0.5,0.8], [0.1,0.4]) | ([0.7,0.8], [0.1,0.2]) | ([0.2,0.4], [0.3,0.5]) | ([0.5,0.8], [0.1,0.2]) | ([0.3,0.5], [0.3,0.5]) |

**Definition 2.7 ([11])** *Let* $\varpi$ *be an intuitionistic fuzzy soft set over a finite universe U, where* $A \subseteq E$ *and E is the parameter set. Let* $\lambda : A \rightarrow [0,1] \times [0,1]$ *be*

*an intuitionistic fuzzy set in A, which is called a threshold intuitionistic fuzzy set. The level soft set of* $\varpi$ *with respect to* $\lambda$ *is a crisp soft set* $L(\varpi;\lambda) = (F_\lambda,A)$ *defined by* $F_\lambda(e)=\{u\in U:\mu_{F(e)}(u)\geq\mu_\lambda(e)$ *and* $\nu_{F(e)}(u)\leq\nu_\lambda(e)\}$, $\forall e\in A$.

*According to the definition, four types of special level soft set are also defined in [[11]], which are called Mid-level soft set* $L(\varpi;$ *mid), Top-Bottom-level soft set* $L(\varpi;$ *topbottom), Top-Top-level soft set* $L(\varpi;$ *toptop) and Bottom-bottom-level soft set* $L(\varpi;$ *bottombottom).*

# 3 Weighted interval valued intuitionistic fuzzy soft multi set based decision making

Feng et al. [[9]] defined the concept of weighted fuzzy soft sets and applied it to decision making problems and Jiang et al. [[11]] presented a concept of weighted intuitionistic fuzzy soft sets and applied it to some practical problems. Recently Zhang et al. [[28]] defined the concept of weighted interval valued intuitionistic fuzzy soft sets and applied it to decision making problems. However, the impor-tance of the parameters is not emphasized in the interval valued intuitionistic fuzzy soft multi set. In many practical situations, the weights of the parameters should be taken into account. If we allow the parameters to have different weights, then the weighted version of the interval valued intuitionistic fuzzy soft multi set can be defined. In this present section, we introduce the concept of weighted interval valued intuitionistic fuzzy soft multi set and examine its application to decision making problems.

**Definition 3.1** *A weighted interval valued intuitionistic fuzzy soft multi set is a triple* $<F,A,\omega>$*, where (F, A) is an interval valued intuitionistic fuzzy soft multi set over U and* $\omega$*:* $A\rightarrow[0,1]$ *is a weight function, specifying the weight* $w_i=\omega(a_i)$ *for each attribute* $a_i\in A$ *and a triple* $(e_{U_i,j},F_{e_{U_i},j},\omega)$ *is called a* $U_i$*-weighted interval valued intuitionistic fuzzy soft multi set part of* $<F,A,\omega>$*, where* $(e_{U_i,j},F_{e_{U_i},j})$ *is a* $U_i$ *- interval valued intuitionistic fuzzy soft multi set part of (F, A).*

**Example 3.2** *If we consider the interval valued intuitionistic fuzzy soft multi set be (F, A) as in **Table 1** and suppose that Mr. X has imposed the following weights for the parameters in A: for the parameters*

$a_1$*=(expensive, beautiful, expensive),* $w_1$*=0.9;*

$a_2$*=(expensive, model, expensive),* $w_2$*=0.7;*

$a_3$*=(cheap, sporty, expensive),* $w_3$*=0.5;*

$a_4$*=(wooden, sporty, expensive),* $w_4$*=0.8;*

$a_5$*=(expensive, beautiful, cheap),* $w_5$*=0.7;*

*then we have a weighted* $\omega$ *for an interval valued intuitionistic fuzzy soft multi set (F, A), where* $\omega$*:* $A\rightarrow[0,1]$ *and the interval valued intuitionistic fuzzy* *soft set (F, A) is changed into a weighted interval valued intuitionistic fuzzy soft multi set <F,A,ω> with its tabular representation as in* ***Table 3***.

***Table 3.*** *The tabular representation of weighted interval valued intuitionistic fuzzy soft multi set <F,A,ω>*

| $U_i$ | | $a_1$, $w_1$=0.9 | $a_2$, $w_2$=0.7 | $a_3$, $w_3$=0.5 | $a_4$, $w_4$=0.8 | $a_5$, $w_5$=0.7 |
|---|---|---|---|---|---|---|
| $U_1$ | $h_1$ | ([0.2,0.3], [0.4,0.7]) | ([0.4,0.5], [0.3,0.4]) | ([0.1,0.3], [0.4,0.6]) | ([0.7,0.8], [0.1,0.2]) | ([0.2,0.3], [0.4,0.7]) |
| | $h_2$ | ([0.5,0.6], [0.3,0.2]) | ([0.4,0.6], [0.1,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.6], [0.3,0.4]) | ([0.5,0.6], [0.3,0.4]) |
| | $h_3$ | ([0.5,0.8], [0.1,0.4]) | ([0.7,0.8], [0.1,0.2]) | ([0.2,0.4], [0.3,0.5]) | ([0.5,0.8], [0.1,0.2]) | ([0.3,0.5], [0.3,0.5]) |
| $U_2$ | $c_1$ | ([0.7,0.8], [0.1,0.2]) | ([0.4,0.7], [0.2,0.3]) | ([0.6,0.7], [0.1,0.2]) | ([0.2,0.3], [0.4,0.7]) | ([0.4,0.5], [0.3,0.4])) |
| | $c_2$ | ([0.5,0.6], [0.3,0.4]) | ([0.5,0.6], [0.3,0.4]) | ([0.3,0.4], [0.3,0.4]) | ([0.5,0.6], [0.3,0.4]) | ([0.4,0.6], [0.2,0.3]) |
| | $c_3$ | ([0.5,0.8], [0.1,0.2]) | ([0.5,0.6], [0.2,0.3]) | ([0.4,0.8], [0.1,0.2]) | ([0.3,0.7], [0.1,0.3]) | ([0.7,0.8], [0.1,0.2]) |
| $U_3$ | $v_1$ | ([0.5,0.6], [0.3,0.4]) | ([0.5,0.8], [0.1,0.2]) | ([0.4,0.7], [0.2,0.3]) | ([0.2,0.4], [0.3,0.5]) | ([0.4,0.6], [0.2,0.3]) |
| | $v_2$ | ([0.2,0.3], [0.4,0.7]) | ([0.4,0.5], [0.3,0.4]) | ([0.3,0.4], [0.4,0.6]) | ([0.5,0.6], [0.3,0.4]) | ([0.2,0.5], [0.4,0.5]) |
| | $v_3$ | ([0.3,0.4], [0.4,0.5]) | ([0.4,0.5], [0.3,0.4]) | ([0.2,0.3], [0.4,0.6]) | ([0.5,0.6], [0.1,0.3]) | ([0.4,0.5], [0.3,0.4]) |

***Table 4.*** *The tabular representation of $U_1$-weighted interval valued intuitionistic fuzzy soft multi set part of <F,A,ω>*

| $U_1$ | $a_1$, $w_1$=0.9 | $a_2$, $w_2$=0.7 | $a_3$, $w_3$=0.5 | $a_4$, $w_4$=0.8 | $a_5$, $w_5$=0.7 |
|---|---|---|---|---|---|
| $h_1$ | ([0.2,0.3], [0.4,0.7]) | ([0.4,0.5], [0.3,0.4]) | ([0.1,0.3], [0.4,0.6]) | ([0.7,0.8], [0.1,0.2]) | ([0.2,0.3], [0.4,0.7]) |
| $h_2$ | ([0.5,0.6], [0.3,0.2]) | ([0.4,0.6], [0.1,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.6], [0.3,0.4]) | ([0.5,0.6], [0.3,0.4]) |
| $h_3$ | ([0.5,0.8], [0.1,0.4]) | ([0.7,0.8], [0.1,0.2]) | ([0.2,0.4], [0.3,0.5]) | ([0.5,0.8], [0.1,0.2]) | ([0.3,0.5], [0.3,0.5]) |

# 4 Reduct weighted intuitionistic fuzzy soft multi sets

Qin et al. [[24]] initiated the concept of reduct intuitionistic fuzzy soft set by adjusting the value of opinion weighting vector, an interval-valued intuitionistic fuzzy soft set can be converted into an intuitionistic fuzzy soft set, which makes the making decision based on interval-valued fuzzy soft set much easier.

Similarly, we can introduce the idea to making decision based on weighted interval-valued intuitionistic fuzzy soft multi set; a weighted interval-valued intui-tionistic fuzzy soft set will be transformed to a weighted intuitionistic fuzzy soft multi set, which will facilitate the making decision based on weighted interval-valued intuitionistic fuzzy soft multi set. We define the notion of reduct weighted intuitionistic fuzzy soft multi set as follows to illustrate the idea.

**Definition 4.1** *Let <F, A, ω> be a weighted interval valued intuitionistic fuzzy soft multi set over U and* $\alpha,\beta,\gamma,\delta\in[0,1]$ *such that* $\alpha+\beta = 1$ *and* $\gamma+\delta = 1$. *Then the vector* $W = (\alpha,\beta,\gamma,\delta)$ *is called an opinion weighting vector. A reduct weighted intuitionistic fuzzy soft multi set of <F, A, ω> is a triple* $<F_W, A, \omega>$, *where* $(F_W, A)$ *is a intuitionistic fuzzy soft multi set over U, such that for all* $a\in A$, $F_W(a)=(\{\frac{u}{(\alpha\mu^L_{F(A)}(u)+\beta\mu^U_{F(A)}(u),\gamma\nu^L_{F(A)}(u)+\delta\nu^U_{F(A)}(u))}:u\in U_i\}:i\in I)$ *and* $\omega$: $A\to[0,1]$ *is a weight function.*

*By adjusting the value of* $\alpha,\beta,\gamma$ *and* $\delta$ *a weighted interval-valued intuitionistic fuzzy soft multi set can be converted into any reduct weighted intuitionistic fuzzy soft multi set decision maker desired. Specially, let* $\alpha=0,\beta=1,\gamma=1$ *and* $\delta= 0$, *we have the upper-lower-reduct weighted intuitionistic fuzzy soft multi set (ULWIFSM set), denoted by* $<F_{UL}, A, \omega>$ *and defined by for all* $a\in A$,

$F_{UL}(a)=(\{\frac{u}{(\mu^U_{F(A)}(u),\nu^L_{F(A)}(u))}:u\in U_i\}:i\in I)$.

*Let* $\alpha=1,\beta=0,\gamma=0$ *and* $\delta= 1$, *we have the lower- upper-reduct weighted intui-tionistic fuzzy soft multi set (LUWIFSM set), denoted by* $<F_{LU}, A, \omega>$ *and defined by for all* $a\in A$,

$F_{LU}(a)=(\{\frac{u}{(\mu^L_{F(A)}(u),\nu^U_{F(A)}(u))}:u\in U_i\}:i\in I)$.

*Let* $\alpha=0,\beta=1,\gamma=0$ *and* $\delta= 1$, *we have the upper-upper-reduct weighted intui-tionistic fuzzy soft multi set (UUWIFSM set), denoted by* $<F_{UU}, A, \omega>$ *and defined by for all* $a\in A$,

$F_{UU}(a)=(\{\frac{u}{(\mu^U_{F(A)}(u),\nu^U_{F(A)}(u))}:u\in U_i\}:i\in I)$.

*Let* $\alpha=1,\beta=0,\gamma=1$ *and* $\delta= 0$, *we have the lower-lower-reduct weighted intuitionistic fuzzy soft multi set (LLWIFSM set), denoted by* $<F_{LL}, A, \omega>$ *and defined by for all* $a\in A$, $F_{LL}(a)=(\{\frac{u}{(\mu^L_{F(A)}(u),\nu^L_{F(A)}(u))}:u\in U_i\}:i\in I)$.

*Let* $\alpha=0.5,\beta=0.5,\gamma=0.5$ *and* $\delta= 0.5$, *we have the neutral-neutral-reduct weighted intui-tionistic fuzzy soft multi set (NNWIFSM set), denoted by* $<F_{NN}, A, \omega>$ *and defined by for all* $a\in A$,

$$F_{NN}(a)=(\{\frac{u}{([\mu^L_{F(A)}(u)+\mu^U_{F(A)}(u)]/2,[\nu^L_{F(A)}(u)+\nu^U_{F(A)}(u)]/2)}:u\in U_i\}:i\in I).$$

**Example 4.2** *If we consider the weighted interval valued intuitionistic fuzzy soft multi set be <F, A, ω> as in* ***Table 3****, then the reduct weighted intuitionistic fuzzy soft multi set* $<F_{LU}, A, \omega>$ *can be represent as in* ***Table 5****.*

***Table 5.*** *The tabular representation of the reduct weighted intuitionistic fuzzy soft multi set* $<F_{LU}, A, \omega>$

| $U_i$ | | $a_1$, $w_1$=0.9 | $a_2$, $w_2$=0.7 | $a_3$, $w_3$=0.5 | $a_4$, $w_4$=0.8 | $a_5$, $w_5$=0.7 |
|---|---|---|---|---|---|---|
| | $h_1$ | (0.2,0.7) | (0.4,0.4) | (0.1,0.6) | (0.7,0.2) | (0.2,0.7) |
| $U_1$ | $h_2$ | (0.5,0.2) | (0.4,0.3) | (0.5,0.3) | (0.5,0.4) | (0.5,0.4) |
| | $h_3$ | (0.5,0.4) | (0.7,0.2) | (0.2,0.5) | (0.5,0.2) | (0.3,0.5) |
| | $c_1$ | (0.7,0.2) | (0.4,0.3) | (0.6,0.2) | (0.2,0.7) | (0.4,0.4) |
| $U_2$ | $c_2$ | (0.5,0.4) | (0.5,0.4) | (0.3,0.4) | (0.5,0.4) | (0.4,0.3) |
| | $c_3$ | (0.5,0.2) | (0.5,0.3) | (0.4,0.2) | (0.3,0.3) | (0.7,0.2) |
| | $v_1$ | (0.5,0.4) | (0.5,0.2) | (0.4,0.3) | (0.2,0.5) | (0.4,0.3) |
| $U_3$ | $v_2$ | (0.2,0.7) | (0.4,0.4) | (0.3,0.6) | (0.5,0.4) | (0.2,0.5) |
| | $v_3$ | (0.3,0.5) | (0.4,0.4) | (0.2,0.6) | (0.5,0.3) | (0.4,0.4) |

***Table 6.*** *The tabular representation of the* $U_1$*-weighted intuitionistic fuzzy soft multi set part of* $<F_{LU}, A, \omega>$

| $U_1$ | $a_1$, $w_1$=0.9 | $a_2$, $w_2$=0.7 | $a_3$, $w_3$=0.5 | $a_4$, $w_4$=0.8 | $a_5$, $w_5$=0.7 |
|---|---|---|---|---|---|
| $h_1$ | (0.2,0.7) | (0.4,0.4) | (0.1,0.6) | (0.7,0.2) | (0.2,0.7) |
| $h_2$ | (0.5,0.2) | (0.4,0.3) | (0.5,0.3) | (0.5,0.4) | (0.5,0.4) |
| $h_3$ | (0.5,0.4) | (0.7,0.2) | (0.2,0.5) | (0.5,0.2) | (0.3,0.5) |

# 5 An adjustable approach based on level soft sets

We begin this section with a novel algorithm designed for solving weighted intuitionistic fuzzy soft set-based decision-making prolems, which was presented in [[11]]. Jiang et al. [[11]] used the following adjustable approch to weighted intuitionistic fuzzy soft set based decision-making by using level soft sets.

**Algorithm 1.**

1. Input a weighted intuitionistic fuzzy soft set <F,A,$\omega$>.

2. Input a threshold intuitionistic fuzzy set $\lambda$ : A$\rightarrow$ [0,1]$\times$[0,1] (or give a threshold value (s,t)$\in$[0,1]$\times$[0,1]; or choose the mid-level decision rule; or choose the top-bottom-level decision rule, or choose the top-top-level decision rule or choose the bottom-bottom-level decision rule) for decision making.

3. Compute the level soft set L((F, A);$\lambda$) of <F,A,$\omega$> with respect to the threshold intuitionistic fuzzy set $\lambda$ (or the t-level soft set L((F, A);s,t); or L((F, A);mid); or L((F, A);topbottom); L((F, A);toptop); L((F, A);bottombottom).

4. Present the level soft set L((F, A);$\lambda$) (or L((F, A);s,t); or L((F, A);mid); or L((F, A);topbottom); L((F, A);toptop); L((F, A);bottombottom) in tabular form and compute the weighted choice value $s_i$ of $u_i \in U$, $\forall$i.

5. The optimal decision is to select $u_k$ if $s_k = \max_i s_i$.

6. If k has more than one value then any one of $u_k$ may be chosen.

### 5.1 Application of reduct weighted intuitionistic fuzzy soft multi sets in decision making problems

In this section we present our algorithm for decision making based on weighted interval-valued intuitionistic fuzzy soft multi sets. By considering appropriate reduct weighted intuitionistic fuzzy soft multi sets and level soft sets of intuitionistic fuzzy soft sets, weighted interval-valued intuitionistic fuzzy soft multi sets based decision making can be converted into only crisp soft sets based decision making. Firstly, by computing the reduct weighted intuitionistic fuzzy soft multi set, a weighted interval-valued intuitionistic fuzzy soft multi set is converted into a weighted intuitionistic fuzzy soft multi set and then the weighted intuitionistic fuzzy soft multi set is converted into a weighted intuitionistic fuzzy soft multi set parts. The weighted intuitionistic fuzzy soft multi set parts are further converted into a crisp soft sets by using level soft sets of intuitionistic fuzzy soft sets. Finally, decision making is performed on the crisp soft set.

The details of our algorithm are listed below.

**Algorithm2.**

1. Input the resultant weighted interval-valued intuitionistic fuzzy soft multi set <F,A,$\omega$>.

2. Input an opinion weighting vector $W = (\alpha,\beta,\gamma,\delta)$ and compute the reduct weighted intuitionistic fuzzy soft multi set $<F_W,A,\omega>$ of the weighted interval-valued intuitionistic fuzzy soft multi set $<F,A,\omega>$ with respect to the opinion weighting vector W (or choose $<F_{UL},A,\omega>$ or choose $<F_{LU},A,\omega>$ or choose $<F_{UU},A,\omega>$ or choose $<F_{LL},A,\omega>$ or choose $<F_{NN},A,\omega>$ of $<F,A,\omega>$.

3. Apply **Algorithm 1** to the first reduct weighted intuitionistic fuzzy soft multi set part in $<F_W,A,\omega>$ to get the decision $s_{k_1}$.

4. Redefine the reduct weighted intuitionistic fuzzy soft multi set $(F_W,A)$ by keep-ing all values in each row where $s_{k_1}$ is maximum and replacing the values in the other rows by zero, to get $<F_W,A,\omega>_1$.

5. Apply **Algorithm 1** to the second reduct weighted intuitionistic fuzzy soft multi set part in $<F_W,A,\omega>_1$ to get the decision $s_{k_2}$.

6. Redefine the reduct weighted intuitionistic fuzzy soft multi set $<F_W,A,\omega>_1$ by keeping the first and second parts and apply the method in step 3 to the third part, to get $<F_W,A,\omega>_2$.

7. Apply **Algorithm 1** to the reduct intuitionistic fuzzy soft multi set part in $<F_W,A,\omega>_2$ to get the decision $s_{k_3}$.

8. Continuing in this way we get the decision $(s_{k_1},s_{k_2},s_{k_3}.....)$.

**5.2 Remark** If there are too many optimal choices in Step 7, we may go back to the second step and change the decision rule (opinion weighting vector W) or go back in third step and change the decision rule (level soft set) such that only one optimal choice remain in the end. In our Algorithm 2, there have too many typical schemes for weighted interval-valued intuitionistic fuzzy soft multi set based decision making. Some of them are listed in **Table 7**.

**Table 7.** Typical schemes for weighted interval-valued intuitionistic fuzzy soft multi set based decision making

| Scheme | Reduct weighted intuitionistic fuzzy soft multi set | Level soft set |
|---|---|---|
| LU-mid | $<F_{LU}$,A,$\omega>$ | L(($F_{LU}$, A);mid) |
| LU-topbot | $<F_{LU}$,A,$\omega>$ | L(($F_{LU}$, A);topbottom) |
| LU-toptop | $<F_{LU}$,A,$\omega>$ | L(($F_{LU}$, A);toptop) |
| LU-botbot | $<F_{LU}$,A,$\omega>$ | L(($F_{LU}$, A);bottombottom) |
| UL-mid | $<F_{UL}$,A,$\omega>$ | L(($F_{UL}$, A);mid) |
| UL-topbot | $<F_{UL}$,A,$\omega>$ | L(($F_{UL}$, A);topbottom) |
| UL-toptop | $<F_{UL}$,A,$\omega>$ | L(($F_{UL}$, A);toptop) |
| UL-botbot | $<F_{UL}$,A,$\omega>$ | L(($F_{UL}$, A);bottombottom) |
| UU-mid | $<F_{UU}$,A,$\omega>$ | L(($F_{UU}$, A);mid) |
| UU-topbot | $<F_{UU}$,A,$\omega>$ | L(($F_{UU}$, A);topbottom) |
| UU-toptop | $<F_{UU}$,A,$\omega>$ | L(($F_{UU}$, A);toptop) |
| UU-botbot | $<F_{UU}$,A,$\omega>$ | L(($F_{UU}$, A);bottombottom) |
| LL-mid | $<F_{LL}$,A,$\omega>$ | L(($F_{LL}$, A);mid) |
| LL-topbot | $<F_{LL}$,A,$\omega>$ | L(($F_{LL}$, A);topbottom) |
| LL-toptop | $<F_{LL}$,A,$\omega>$ | L(($F_{LL}$, A);toptop) |
| LL-botbot | $<F_{LL}$,A,$\omega>$ | L(($F_{LL}$, A);bottombottom) |
| NN-mid | $<F_{NN}$,A,$\omega>$ | L(($F_{NN}$, A);mid) |
| NN-topbot | $<F_{NN}$,A,$\omega>$ | L(($F_{NN}$, A);topbottom) |
| NN-toptop | $<F_{NN}$,A,$\omega>$ | L(($F_{NN}$, A);toptop) |
| NN-botbot | $<F_{NN}$,A,$\omega>$ | L(($F_{NN}$, A);bottombottom) |

# 6 Application in Decision-Making Problems

Let us consider the decision making problem involving the weighted interval-valued intuitionistic fuzzy soft multi set (F, A) with its tabular representation given by **Table 3**. If we deal with this problem by the first scheme "LU-mid", as in **Table 7**, to solve the problem, at first we compute the reduct weighted intuitionistic fuzzy soft multi set $<F_{LU}$,A,$\omega>$ as in **Table 5**, then we shall use the mid-threshold of $U_1$ - weighted intuitionistic fuzzy soft multi set part in $<F_{LU}$,A,$\omega>$ and obtain the mid-level soft set of $U_1$ -intuitionistic fuzzy soft multi set part in ($F_{LU}$,A), with weighted choice values in **Table 8**.

**Table 8.** The mid-level soft set of $U_1$-intuitionistic fuzzy soft multi set part in ($F_{LU}$,A) of $<F_{LU}$,A,$\omega>$ with weighted choice values

| $U_1$ | $a_1$, $w_1$=0.9 | $a_2$, $w_2$=0.7 | $a_3$, $w_3$=0.5 | $a_4$, $w_4$=0.8 | $a_5$, $w_5$=0.7 | Weighted choice value($S_k$) |
|---|---|---|---|---|---|---|
| $h_1$ | 0 | 0 | 0 | 1 | 0 | $S_1$=0.8 |
| $h_2$ | 1 | 0 | 1 | 0 | 1 | $S_2$=2.1 |
| $h_3$ | 1 | 1 | 0 | 0 | 0 | $S_3$= 1.6 |

From **Table 8**, it is clear that the maximum weighted choice value is 2.1, scored by $h_2$. Now we redefine the reduct weighted intuitionistic fuzzy soft multi set $<F_{LU},A,\omega>$ by keeping all values in each row where $h_2$ is maximum and replacing the values in the other rows by zero, to get $<F_{LU},A,\omega>_1$.

**Table 9.** The reduct weighted intuitionistic fuzzy soft multi set $<F_{LU},A,\omega>_1$

| $U_i$ | | $a_1$, $w_1$=0.9 | $a_2$, $w_2$=0.7 | $a_3$, $w_3$=0.5 | $a_4$, $w_4$=0.8 | $a_5$, $w_5$=0.7 |
|---|---|---|---|---|---|---|
| | $h_1$ | (0.2,0.7) | (0.4,0.4) | (0.1,0.6) | (0.7,0.2) | (0.2,0.7) |
| $U_1$ | $h_2$ | (0.5,0.2) | (0.4,0.3) | (0.5,0.3) | (0.5,0.4) | (0.5,0.4) |
| | $h_3$ | (0.5,0.4) | (0.7,0.2) | (0.2,0.5) | (0.5,0.2) | (0.3,0.5) |
| | $c_1$ | (0.7,0.2) | 0 | (0.6,0.2) | 0 | (0.4,0.4) |
| $U_2$ | $c_2$ | (0.5,0.4) | 0 | (0.3,0.4) | 0 | (0.4,0.3) |
| | $c_3$ | (0.5,0.2) | 0 | (0.4,0.2) | 0 | (0.7,0.2) |
| | $v_1$ | (0.5,0.4) | 0 | (0.4,0.3) | 0 | (0.4,0.3) |
| $U_3$ | $v_2$ | (0.2,0.7) | 0 | (0.3,0.6) | 0 | (0.2,0.5) |
| | $v_3$ | (0.3,0.5) | 0 | (0.2,0.6) | 0 | (0.4,0.4) |

Now we apply **Algorithm 1** to the second weighted intuitionistic fuzzy soft multi set part in $<F_{LU},A,\omega>_1$ to take the decision from the availability set $U_2$.

**Table 10.** The mid-level soft set of $U_2$ -intuitionistic fuzzy soft multi set part in $(F_{LU},A)_1$ of $<F_{LU},A,\omega>_1$ with weighted choice values

| $U_2$ | $a_1$, $w_1$=0.9 | $a_2$, $w_2$=0.7 | $a_3$, $w_3$=0.5 | $a_4$, $w_4$=0.8 | $a_5$, $w_5$=0.7 | Weighted choice value($S_k$) |
|---|---|---|---|---|---|---|
| $c_1$ | 1 | 0 | 1 | 0 | 0 | $S_1$=1.4 |
| $c_2$ | 0 | 0 | 0 | 0 | 0 | $S_2$=0 |
| $c_3$ | 0 | 0 | 0 | 0 | 1 | $S_3$= 0.7 |

From **Table 10**, it is clear that the maximum weighted choice value is 1.4, scored by $c_1$. Now we redefine the reduct weighted intuitionistic fuzzy soft multi set $<F_{LU},A,\omega>1$ by keeping all values in each row where $c_1$ is maximum and replacing the values in the other rows by zero, to get $<F_{LU},A,\omega>_2$.

**Table 11.** The reduct weighted intuitionistic fuzzy soft multi set $<F_{LU},A,\omega>_2$

| $U_i$ | | $a_1$, $w_1$=0.9 | $a_2$, $w_2$=0.7 | $a_3$, $w_3$=0.5 | $a_4$, $w_4$=0.8 | $a_5$, $w_5$=0.7 |
|---|---|---|---|---|---|---|
| | $h_1$ | (0.2,0.7) | (0.4,0.4) | (0.1,0.6) | (0.7,0.2) | (0.2,0.7) |
| $U_1$ | $h_2$ | (0.5,0.2) | (0.4,0.3) | (0.5,0.3) | (0.5,0.4) | (0.5,0.4) |
| | $h_3$ | (0.5,0.4) | (0.7,0.2) | (0.2,0.5) | (0.5,0.2) | (0.3,0.5) |
| | $c_1$ | (0.7,0.2) | 0 | (0.6,0.2) | 0 | (0.4,0.4) |
| $U_2$ | $c_2$ | (0.5,0.4) | 0 | (0.3,0.4) | 0 | (0.4,0.3) |
| | $c_3$ | (0.5,0.2) | 0 | (0.4,0.2) | 0 | (0.7,0.2) |
| | $v_1$ | (0.5,0.4) | 0 | (0.4,0.3) | 0 | 0 |
| $U_3$ | $v_2$ | (0.2,0.7) | 0 | (0.3,0.6) | 0 | 0 |
| | $v_3$ | (0.3,0.5) | 0 | (0.2,0.6) | 0 | 0 |

Now we apply **Algorithm 1** to the third reduct weighted intuitionistic fuzzy soft multi set part in $<F_{LU},A,\omega>_2$ to take the decision from the availability set $U_3$.

**Table 12.** The mid-level soft set of $U_3$ -weighted intuitionistic fuzzy soft multi set part in $(F_{LU},A)_2$ of $<F_{LU},A,\omega>_2$ with weighted choice values

| $U_3$ | $a_1$, $w_1$=0.9 | $a_2$, $w_2$=0.7 | $a_3$, $w_3$=0.5 | $a_4$, $w_4$=0.8 | $a_5$, $w_5$=0.7 | Weighted choice value($S_k$) |
|---|---|---|---|---|---|---|
| $v_1$ | 1 | 0 | 1 | 0 | 0 | $S_1$=1.4 |
| $v_2$ | 0 | 0 | 0 | 0 | 0 | $S_2$=0 |
| $v_3$ | 0 | 0 | 0 | 0 | 0 | $S_3$= 0 |

From the **Table 12**, it is clear that the maximum weighted choice value $s_k$ =1.4, by v2. Then from the above results the decision for Mr. X is ($h_2$,$c_1$,$v_1$).

# 7 Remark

**Algorithm 2** can be seen as an adjustable approach to weighted interval-valued intuitionistic fuzzy soft multi set based decision making because the final optimal decision is in relation to the opinion weighting vectors and thresholds on membership values or in other words, the decision criteria used by decision makers. For instance, if we choose the NN-topbottom decision rule in the second step of **Algorithm 2**, we shall consider the weighted choice value of each object in the L(($F_{NN}$, A);topbottom), if another decision criterion such as the LU-mid decision rule is used; we shall consider weighted choice values in L(($F_{LU}$, A);mid). In general, the weighted choice value of an object in LU-mid decision rule need not coincide with the value in NN-topbottom decision rule. Consequently, the optimal objects determined by the LU-mid decision rule may be different from those selected according to the NN-topbottom rule.

As was mentioned above, many decision making problems are essentially humanistic and subjective in nature; hence for decision making in an imprecise environment, there actually does not exist a unique or uniform criterion. This adjustable feature makes **Algorithm 2** not only efficient but more appropriate for many real-world applications.

# 8 Conclusion

In this study, we have introduced the notions of reduct weighted intuitionistic fuzzy soft multi sets of weighted interval valued intuitionistic fuzzy soft multi set and propose an adjustable approach to weighted interval-valued intuitionistic fuzzy soft set based decision making by using reduct weighted intuitionistic fuzzy soft sets and level soft sets of reduct intuitionistic fuzzy soft sets and illustrate this method with some concrete examples. A weighted interval-valued intuitionistic fuzzy soft multi set based decision making problem is converted into a crisp soft set based decision making problem after choosing certain opinion weighting vectors and thresholds. This makes our algorithm simpler and easier for application in practical problems. In addition, a large variety of opinions weighting vectors and thresholds that can be used to find the optimal alternatives make our algorithm more flexible and adjustable.

# 9 Open Problem

The open problem here is to solve weighted interval valued intuitionistic fuzzy soft multi sets based decision making problems and consequently we obtain the notions of reduct weighted intuitionistic fuzzy soft multi sets of weighted interval-valued intuitionistic fuzzy soft multi set and propose an adjustable approach to weighted interval-valued intuitionistic fuzzy soft sets based decision making by using reduct weighted intuitionistic fuzzy soft sets.

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