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SINGLE VALUED NEUTROSOPHIC SOFT EXPERT SETS AND THEIR APPLICATION IN DECISION MAKING

Said Broumi[1,*] <broumisaid78@gmail.com>
Florentin Smarandache[2] <fsmarandache@gmail.com>

[1]Faculty of Letters and Humanities, Hay El Baraka Ben M'sik Casablanca B.P. 7951, University of Hassan II -Casablanca, Morocco.
[2]Department of Mathematics, University of New Mexico, 705 Gurley Avenue, Gallup, NM 87301, USA.

Abstract - In this paper, we first introduce the concept of single valued neutrosophic soft expert sets (SVNSESs for short) which combines single valued neutrosophic sets and soft expert sets.We also defineits basic operations, namely complement, union, intersection, AND and OR, and study some related properties supporting proofs.This concept is a generalization of fuzzy soft expert sets (FSESs) and intuitionistic fuzzy soft expert sets (IFSESs). Finally, an approach for solving MCDM problems is explored by applying the single valued neutrosophic soft expert sets, and an example is provided to illustrate the application of the proposed method.

Keywords - Single valued neutrosophic sets, Soft expert sets, Single valued neutrosophic soft expert sets, Decision making

1. Introduction.

Neutrosophy has been introduced by Smarandache [12, 13, 14] as a new branch of philosophy and generalization of fuzzy logic, intuitionistic fuzzy logic, paraconsistent logic. Fuzzy sets [38] and intuitionistic fuzzy sets [32] are defined by membership functions while intuitionistic fuzzy sets are characterized by membership and non-membership functions, respectively. In some real life problems for proper description of an object in uncertain and ambiguous environment, we need to handle the indeterminate and incomplete information. But fuzzy sets and intuitionistic fuzzy sets don't handle the indeterminate and inconsistent information. Thus neutrosophic set (NS in short) is defined by Samarandache [13], as a new mathematical tool for dealing with problems involving incomplete, indeterminacy, inconsistent knowledge. In NS, the indeterminacy is quantified

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[*]*Corresponding Author.*

explicitly and truth-membership, indeterminacy membership, and false-membership are completely independent. From scientific or engineering point of view, the neutrosophic set and set- theoretic view, operators need to be specified. Otherwise, it will be difficult to apply in the real applications. Therefore, H. Wang et al [15] defined a single valued neutrosophic set (SVNS) and then provided the set theoretic operations and various properties of single valued neutrosophic sets. The works on single valued neutrosophic set (SVNS) and their hybrid structure in theories and application have been progressing rapidly [3, 4, 5, 6, 7, 8, 9, 11, 23, 24, 25, 26, 27, 28, 29, 30, 31, 39, 58, 66, 67, 68, 71, 75, 78, 79, 80, 81, 83,85].

In 1999, Molodtsov [10] initiated the theory of soft set theory as a general mathematical tool for dealing with uncertainty and vagueness and the soft set theory is free from the parameterization inadequacy syndrome of fuzzy set theory, rough set theory, probability theory. In fact, a soft set is a set-valued map which gives an approximation description of objects under consideration based on some parameters. Later Maji et al.[54] defined several operations on soft set. Many authors [33, 37, 40, 43, 45, 46, 47, 48, 49, 51, 52, 53, 56, 61] have combined soft sets with other sets to generate hybrid structures like fuzzy soft sets, generalized fuzzy soft sets, rough soft sets, intuitionstic fuzzy soft, intuitionistic fuzzy soft set theory, possibility fuzzy soft set, generalized intuitionistic fuzzy soft, generalized neutrosophic soft set, possibility vague soft set and so on. All these research aim to solvemost of our real life problems in medical sciences, engineering, management, environment and social science which involve data that are not crisp and precise. But most of these models deals with only one opinion (or) with only one expert. This causes a problem with the user when questioners are used for the data collection.Alkhazaleh and Salleh in 2011 [61] defined the concept of soft expert set and created a model in which the user can know the opinion of the experts in the model without any operations and presented an application of this concept in decision making problem. Also, they introduced the concept of the fuzzy soft expert set [60] as a combination between the soft expert set and the fuzzy set. Later on, many researchers have worked with the concept of soft expert sets [1,2, 15, 16, 20, 34, 35, 42, 44, 54, 55, 82, 84]. But most of these concepts cannot dealing with indeterminate and inconsistent information.

Based on [13], Maji [55] introduced the concept of neutrosophic soft set a more generalized concept, which is a combination of neutrosophic set and soft set and studied its properties. New operators on neutrosophic soft set presented by Şahin and Küçük [58]. Based on Çağman [46], Karaaslan [85] redefined neutrosophic soft sets and their operations. Various kinds of extended neutrosophic soft sets such as intuitionistic neutrosophic soft set [63, 65, 74], generalized neutrosophic soft set [57, 64], interval valued neutrosophic soft set [21], neutrosophic parameterized fuzzy soft set [70], Generalized interval valued neutrosophic soft sets [73], neutrosophic soft relation [18, 19], neutrosophic soft multiset theory [22] and cyclic fuzzy neutrosophic soft group [59] were presented. The combination of neutrosophic soft sets and rough set [72, 76, 75] is another interesting topic. Until now, there is no study on soft experts in neutrosophic environment, so there is a need to develop a new mathematical tool called " single valued neutrosophic soft expert sets" .

The remaining part of this paper is organized as follows. In Section 2, we first recall the necessary background on neutrosophic sets, single valued neutrosophic sets, soft set, neutrosophic soft sets, soft expert sets, fuzzy soft expert sets and intutionistic fuzzy soft expert sets. Section 3 reviews various proposals for the definition of single valued neutrosophic soft expert sets and derive their respective properties. Section 4 presents basic operations on single valued neutrosophic soft expert sets. Section 5 presents an application of this concept in solving a decision making problem. Finally, we conclude the paper.

2. Preliminaries

In this section, we will briefly recall the basic concepts of neutrosophic sets, single valued neutrosophic sets, soft set, neutrosophic soft sets, soft expert sets, fuzzy soft expert sets, and intutionistic fuzzy soft expert sets.

Let U be an initial universe set of objects and E the set of parameters in relation to objects in U. Parameters are often attributes, characteristics or properties of objects. Let P (U) denote the power set of U and A ⊆ E.

2.1. Neutrosophic Set

Definition 2.1 [13]: Let U be an universe of discourse then the neutrosophic set A is an object having the form A = {< x: μ_A(x), ν_A(x), ω_A(x)>,x ∈ U},where the functions

$$\mu_A(x),\ \nu_A(x), \omega_A(x) : U \rightarrow]^-0,1^+[$$

define respectively the degree of membership , the degree of indeterminacy, and the degree of non-membership of the element x ∈ U 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.

For two NS,

$$A_{NS} = \{<x, \mu_A(x), \nu_A(x), \omega_A(x)> \mid x \in U\}$$

and

$$B_{NS} = \{<x, \mu_B(x), \nu_B(x), \omega_B(x)> \mid x \in U\}$$

Then,

1. $A_{NS} \subseteq B_{NS}$ if and only if

$$\mu_A(x) \leq \mu_B(x), \nu_A(x) \geq \nu_B(x), \omega_A(x) \geq \omega_B(x)$$

2. $A_{NS} = B_{NS}$ if and only if ,

$$\mu_A(x) = \mu_B(x),\ \nu_A(x) = \nu_B(x),\ \omega_A(x) = \omega_B(x) \text{ for any } x \in U.$$

3. The complement of A_{NS} is denoted by A_{NS}^{o} and is defined by

$$A_{NS}^{o} = \{<x, \omega_A(x), 1-\nu_A(x), \mu_A(x) \mid x \in U\}$$

4. $A \cap B = \{<x, \min\{\mu_A(x), \mu_B(x)\}, \max\{\nu_A(x), \nu_B(x)\}, \max\{\omega_A(x), \omega_B(x)\}>: x \in U\}$

5. $A \cup B = \{<x, \max\{\mu_A(x), \mu_B(x)\}, \min\{\nu_A(x), \nu_B(x)\}, \min\{\omega_A(x), \omega_B(x)\}>: x \in U\}$

As an illustration, let us consider the following example.

Example 2.2. Assume that the universe of discourse $U=\{x_1,x_2,x_3,x_4\}$. It may be further assumed that the values of x_1, x_2, x_3 and x_4 are in [0, 1] Then, A is a neutrosophic set (NS) of U, such that,

$A = \{< x_1,0.4,0.6,0.5 >, < x_2,0.3,0.4, 0.7>, < x_3,0.4,0.4,0.6] >,<x_4,0.5,0.4,0.8 >\}$

2.2. Soft Sets

Definition 2.3. [10] Let U be an initial universe set and E be a set of parameters. Let P(U) denote the power set of U. Consider a nonempty set A, A ⊂ E. A pair (K, A) is called a soft set over U, where K is a mapping given by K : A → P(U).

As an illustration, let us consider the following example.

Example 2.4. Suppose that U is the set of houses under consideration, say $U = \{h_1, h_2, \ldots, h_5\}$. Let E be the set of some attributes of such houses, say $E = \{e_1, e_2, \ldots, e_8\}$, where $e_1, e_2, \ldots, e_8$ 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:

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

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

2.3. Neutrosophic Soft Sets

Definition 2.5 [55, 85] Let U be an initial universe set and $A \subset E$ be a set of parameters. Let NS(U) denotes the set of all neutrosophic subsets of U. The collection (F, A) is termed to be the neutrosophic soft set over U, where F is a mapping given by $F: A \to NS(U)$.

Example 2.6 Let U be the set of houses under consideration and E is the set of parameters. Each parameter is a neutrosophic word or sentence involving neutrosophic words. Consider E ={beautiful, wooden, costly, very costly, moderate, green surroundings, in good repair, in bad repair, cheap, expensive}. In this case, to define a neutrosophic soft set means to point out beautiful houses, wooden houses, in the green surroundings houses and so on. Suppose that, there are five houses in the universe Ugiven by $U = \{h_1, h_2, \ldots, h_5\}$ and the set of parameters

$A = \{e_1, e_2, e_3, e_4\}$,where e_1 stands for the parameter `beautiful', $e_2$ stands for the parameter `wooden', e_3 stands for the parameter `costly' and the parameter $e_4$stands for `moderate'. Then the neutrosophic set (F, A) is defined as follows:

$$(F, A) = \left\{\begin{array}{l} \left(e_1\left\{\frac{h_1}{(0.5,0.6,0.3)}, \frac{h_2}{(0.4,0.7,0.6)}, \frac{h_3}{(0.6,0.2,0.3)}, \frac{h_4}{(0.7,0.3,0.2)}, \frac{h_5}{(0.8,0.2,0.3)}\right\}\right) \\ \left(e_2\left\{\frac{h_1}{(0.6,0.3,0.5)}, \frac{h_2}{(0.7,0.4,0.3)}, \frac{h_3}{(0.8,0.1,0.2)}, \frac{h_4}{(0.7,0.1,0.3)}, \frac{h_5}{(0.8,0.3,0.6)}\right\}\right) \\ \left(e_3\left\{\frac{h_1}{(0.7,0.4,0.3)}, \frac{h_2}{(0.6,0.7,0.2)}, \frac{h_3}{(0.7,0.2,0.5)}, \frac{h_4}{(0.5,0.2,0.6)}, \frac{h_5}{(0.7,0.3,0.4)}\right\}\right) \\ \left(e_4\left\{\frac{h_1}{(0.8,0.6,0.4)}, \frac{h_2}{(0.7,0.9,0.6)}, \frac{h_3}{(0.7,0.6,0.4)}, \frac{h_4}{(0.7,0.8,0.6)}, \frac{h_5}{(0.9,0.5,0.7)}\right\}\right) \end{array}\right\}$$

2.4. Soft Expert Sets

Definition 2.7[61] Let U be a universe set, E be a set of parameters and X be a set of experts (agents). Let O= {1=agree, 0=disagree} be a set of opinions. Let Z= E × X × O and A ⊆ Z . A pair (F, A) is called a soft expert set over U, where F is a mapping given by

F: A→ P(U) and P(U) denote the power set of U.

Definition 2.8 [61] An agree- soft expert set $(F, \mathrm{A})_1$ over U, is a soft expert subset of $(F$,A) defined as :

$$(F, \mathrm{A})_1 = \{\mathrm{F}(\alpha){:}\alpha \in \mathrm{E} \times \mathrm{X} \times \{1\}\}.$$

Definition 2.9 [61] A disagree- soft expert set $(F, \mathrm{A})_0$ over U, is a soft expert subset of $(F$,A) defined as :

$$(F, \mathrm{A})_0 = \{\mathrm{F}(\alpha){:}\alpha \in \mathrm{E} \times \mathrm{X} \times \{0\}\}.$$

2.5. Fuzzy Soft Expert Sets

Definition 2.10 [42] Let O= {1=agree, 0=disagree} be a set of opinions. Let Z= E × X × O and A ⊆ Z .A pair (F, A) is called a fuzzy soft expert set over U, where F is a mapping given by F : A→ I^U,and I^Udenote the set of all fuzzy subsets of U.

2.6. Intuitiontistic Fuzzy Soft Expert Sets

Definition 2.11 [82] Let U= { $u_1, u_2, u_3, \ldots, u_n$ } be a universal set of elements, E={ $e_1, e_2, e_3, \ldots, e_m$ } be a universal set of parameters, X={ $x_1, x_2, x_3, \ldots, x_i$ } be a set of experts (agents) and O= {1=agree, 0=disagree} be a set of opinions. Let Z={ E × X ×O } and A ⊆ Z. Then the pair (U, Z) is called a soft universe. Let F: Z → $(I \times I)^U$ where $(I \times I)^U$ denotes the collection of all intuitionistic fuzzy subsets of U. Suppose F: Z → $(I \times I)^U$ a function defined as:

$$F(z) = F(z)(u_i), \text{ for all } u_i \in U.$$

Then $F(z)$ is called an intuitionistic fuzzy soft expert set (IFSES in short) over the soft universe (U, Z)

For each $z_i \in Z$. $F(z)$ = F(z_i)(u_i) where F(z_i) represents the degree of belongingnessand non-belongingness of the elements of U in F(z_i). Hence $F(z_i)$ can be written as:

$$F(z_i) = \{(\frac{u_i}{F(z_i)(u_i)}),\ldots,(\frac{u_i}{F(z_i)(u_i)})\} \text{ ,for i=1,2,3,…n}$$

where F(z_i)(u_i) = < $\mu_{F(z_i)}(u_i), \omega_{F(z_i)}(u_i)$> with $\mu_{F(z_i)}(u_i)$ and $\omega_{F(z_i)}(u_i)$ representing the membership function and non-membership function of each of the elements $u_i \in U$ respectively.

Sometimes we write F as (F, Z) . If A ⊆ Z. we can also have IFSES (F, A).

3. Single Valued Neutrosophic Soft Expert Sets.

In this section, we generalize the fuzzy soft expert sets as introduced by Alhhazaleh and Salleh [60] and intuitionistic fuzzy soft expert sets as introduced by S. Broumi [83] to the single valued neutrosophic soft expert sets and give the basic properties of this concept.

Let U be universal set of elements, E be a set of parameters, X be a set of experts (agents), O= { 1=agree, 0=disagree} be a set of opinions. Let Z= E × X ×O and

Definition 3.1 Let U={ $u_1, u_2, u_3, \ldots, u_n$ } be a universal set of elements, E={ $e_1, e_2, e_3, \ldots, e_m$ } be a universal set of parameters, X={ $x_1, x_2, x_3, \ldots, x_i$ } be a set of experts (agents) and O= {1=agree, 0=disagree} be a set of opinions. Let Z= { E × X × O } and A ⊆ Z. Then the pair (U, Z) is called a soft universe. Let F: Z → SVN^U, where SVN^U denotes the collection of all single valued neutrosophic subsets of U.

Suppose F :Z→ SVN^U be a function defined as:

$$F(z) = \text{F(z)}(u_i) \text{ for all } u_i \in \text{U}.$$

Then $F(z)$ is called a single valued neutrosophic soft expert value (SVNSEV in short) over the soft universe (U, Z)

For each $z_i \in$ Z. $F(z)$ = F(z_i)(u_i), where F(z_i) represents the degree of belongingness, degree of indeterminacy and non-belongingness of the elements of U in F(z_i). Hence $F(z_i)$ can be written as:

$$F(z_i) \{ (\frac{u_1}{F(z_1)(u_1)}), \ldots, (\frac{u_n}{F(z_n)(u_n)}), \} \text{ ,for i=1,2,3,…n}$$

where F(z_i)(u_i) =< $\mu_{F(z_i)}(u_i)$, $\nu_{F(z_i)}(u_i)$, $\omega_{F(z_i)}(u_i)$> with $\mu_{F(z_i)}(u_i)$,$\nu_{F(z_i)}(u_i)$ and $\omega_{F(z_i)}(u_i)$ representing the membership function, indeterminacy function and non-membership function of each of the elements $u_i \in$U respectively.

Sometimes we write F as (F, Z) . If A ⊆ Z. we can also have SVNSES (F, A).

Example 3.2 Let U={u_1,u_2, u_3} be a set of elements, E={e_1,e_2} be a set of decision parameters, where e_i(i= 1, 2,3} denotes the parameters E ={e_1= beautiful, e_2= cheap} and X= {x_1, x_2} be a set of experts. Suppose that F: Z→ SVN^U is function defined as follows:

$$F(e_1,x_1, 1) = \{ (\frac{u_1}{<0.1,0.8,0.3>}), (\frac{u_2}{<0.1,0.6,0.4>}), (\frac{u_3}{<0.4,0.7,0.2>}) \},$$

$$F(e_2, x_1, 1) = \{ (\frac{u_1}{<0.7,0.5,0.25>}), (\frac{u_2}{<0.25,0.6,0.4>}), (\frac{u_3}{<0.4,0.4,0.6>}) \},$$

$$F(e_1, x_2, 1) = \{ (\frac{u_1}{<0.3,0.2,0.7>}), (\frac{u_2}{<0.4,0.3,0.3>}), (\frac{u_3}{<0.1,0.6,0.2>}) \},$$

$$F(e_2, x_2, 1) = \{ (\frac{u_1}{<0.2,0.2,0.6>}), (\frac{u_2}{<0.7,0.3,0.2>}), (\frac{u_3}{<0.3,0.1,0.5>}) \},$$

$$F(e_1, x_1, 0) = \{ (\frac{u_1}{<0.2,0.4,0.5>}), (\frac{u_2}{<0.1,0.9,0.1>}), (\frac{u_3}{<0.1,0.2,0.5>}) \},$$

$$F(e_2, x_1, 0) = \{ (\frac{u_1}{<0.3,0.4,0.6>}), (\frac{u_2}{<0.2,0.7,0.6>}), (\frac{u_3}{<0.1,0.5,0.2>}) \},$$

$$F(e_1, x_2, 0) = \{ (\frac{u_1}{<0.2,0.8,0.4>}), (\frac{u_2}{<0.1,0.6,0.5>}), (\frac{u_3}{<0.7,0.6,0.3>}) \}$$

$$F(e_2, x_2, 0) = \{ (\frac{u_1}{<0.4,0.4,0.7>}), (\frac{u_2}{<0.3,0.8,0.2>}), (\frac{u_3}{<0.6,0.2,0.4>})$$

Then we can view the single valued neutrosophic soft expert set (F, Z) as consisting of the following collection of approximations:

$$(F, \mathrm{Z}) = \{ (e_1, x_1, 1) = \{ (\frac{u_1}{<0.1,0.8,0.3>}), (\frac{u_2}{<0.1,0.6,0.4>}), (\frac{u_3}{<0.4,0.7,0.2>}) \}\},$$

$$\{(e_2, x_1, 1) = \{ (\frac{u_1}{<0.7,0.5,0.25>}), (\frac{u_2}{<0.25,0.6,0.4>}), (\frac{u_3}{<0.4,0.4,0.6>}) \}\},$$

$$\{(e_1, x_2, 1) = \{ (\frac{u_1}{<0.3,0.2,0.7>}), (\frac{u_2}{<0.4,0.3,0.3>}), (\frac{u_3}{<0.1,0.6,0.2>}) \}\},$$

$$\{ (e_2, x_2, 1) = \{ (\frac{u_1}{<0.2,0.2,0.6>}), (\frac{u_2}{<0.7,0.3,0.2>}), (\frac{u_3}{<0.3,0.1,0.5>}) \}\},$$

$$\{(e_1, x_1, 0) = \{ (\frac{u_1}{<0.2,0.4,0.5>}), (\frac{u_2}{<0.1,0.9,0.1>}), (\frac{u_3}{<0.1,0.2,0.5>}) \}\},$$

$$\{ (e_2, x_1, 0) = \{ (\frac{u_1}{<0.3,0.4,0.6>}), (\frac{u_2}{<0.2,0.7,0.6>}), (\frac{u_3}{<0.1,0.5,0.2>}) \}\},$$

$$\{(e_1, x_2, 0) = \{ (\frac{u_1}{<0.2,0.8,0.4>}), (\frac{u_2}{<0.1,0.6,0.5>}), (\frac{u_3}{<0.7,0.6,0.3>}) \}\},$$

$$\{(e_2, x_2, 0) = \{ (\frac{u_1}{<0.4,0.4,0.7>}), (\frac{u_2}{<0.3,0.8,0.2>}), (\frac{u_3}{<0.6,0.2,0.4>}) \}\}.$$

Then (F, Z) is a single valued neutrosophic soft expert set over the soft universe (U, Z).

Definition 3.3. For two single valued neutrosophic soft expert sets (F, A) and (G, B) over a soft universe (U, Z). Then (F, A) is said to be a single valued neutrosophic soft expert subset of (G, B) if

i. $\mathrm{B} \subseteq \mathrm{A}$
ii. $F(\varepsilon)$ is a single valued neutrosophic subset of $G(\varepsilon)$, for all $\varepsilon \in \mathrm{A}$.

This relationship is denoted as $(F, \mathrm{A}) \,\tilde{\subseteq}\, (G, \mathrm{B})$. In this case, (G, B) is called a single valued neutrosophic soft expert superset (SVNSE superset) of (F, A) .

Definition 3.4. Two single valued neutrosophic soft expert sets (F, A) and (G, B) over soft universe (U, Z) are said to be equal if (F, A) is a single valued neutrosophic soft expert subset of (G, B) and (G, B) is a single valued neutrosophic soft expert subset of (F, A).

Definition 3.5. A SVNSES (F, A) is said to be a null single valued neutrosophic soft expert set denoted $(\tilde{\emptyset}, \mathrm{A})$ and defined as :

$$(\tilde{\emptyset}, \mathrm{A}) = \mathrm{F}(\alpha) \text{ where } \alpha \in \mathrm{Z}.$$

Where F(α)= <0, 0, 1>, that is $\mu_{F(\alpha)}$=0, $\nu_{F(\alpha)}$= 0 and $\omega_{F(\alpha)}$= 1 for all $\alpha \in$ Z.

Definition 3.6. A SVNSES (F, A) is said to be an absolute single valued neutrosophic soft expert set denoted $(F, \mathrm{A})_{\mathrm{abs}}$ and defined as :

$$(F, \mathrm{A})_{\mathrm{abs}} = \mathrm{F}(\alpha), \text{ where } \alpha \in \mathrm{Z}.$$

Where F(α)= <1, 0, 0>, that is $\mu_{F(\alpha)}$= 1, $\nu_{F(\alpha)}$= 0 and $\omega_{F(\alpha)}$= 0 ,for all $\alpha \in$ Z.

Definition 3.7. Let (F, A) be a SVNSES over a soft universe (U, Z). An agree-single valued neutrosophic soft expert set (agree-SVNSES) over U, denoted as $(F, \mathrm{A})_1$ is a single valued neutrosophic soft expert subset of (F,A) which is defined as :

$$(F, \mathrm{A})_1 = \{\mathrm{F}(\alpha) : \alpha \in \mathrm{E} \times \mathrm{X} \times \{1\}\}.$$

Definition 3.8. Let (F, A) be a SVNSES over a soft universe (U, Z). A disagree-single valued neutrosophic soft expert set (disagree-SVNSES) over U, denoted as $(F, \mathrm{A})_0$ is asingle valued neutrosophic soft expert subset of (F, A) which is defined as:

$$(F, \mathrm{A})_0 = \{\mathrm{F}(\alpha) : \alpha \in \mathrm{E} \times \mathrm{X} \times \{0\}\}.$$

Example 3.9 Consider example 3.2.Then the Agree-single valued neutrosophic soft expert set $(F, \mathrm{A})_1$

$$(F, \mathrm{A})_1 = \{((e_1, x_1, 1), \{(\frac{u_1}{<0.1,0.8,0.3>}), (\frac{u_2}{<0.1,0.6,0.4>}), (\frac{u_3}{<0.4,0.7,0.2>})\}),$$
$$((e_2, x_1, 1), \{(\frac{u_1}{<0.7,0.5,0.25>}), (\frac{u_2}{<0.25,0.6,0.4>}), (\frac{u_3}{<0.4,0.4,0.6>})\}),$$
$$((e_1, x_2, 1), \{(\frac{u_1}{<0.3,0.2,0.7>}), (\frac{u_2}{<0.4,0.3,0.3>}), (\frac{u_3}{<0.1,0.6,0.2>})\}),$$
$$((e_2, x_2, 1), \{(\frac{u_1}{<0.2,0.2,0.6>}), (\frac{u_2}{<0.7,0.3,0.2>}), (\frac{u_3}{<0.3,0.1,0.5>})\})\}$$

And the disagree-single valued neutrosophic soft expert set over U

$$(F, \mathrm{A})_0 = \{((e_2, x_2, 1), \{(\frac{u_1}{<0.2,0.2,0.6>}), (\frac{u_2}{<0.7,0.3,0.2>}), (\frac{u_3}{<0.3,0.1,0.5>})\}),$$
$$((e_1, x_1, 0), \{(\frac{u_1}{<0.2,0.4,0.5>}), (\frac{u_2}{<0.1,0.9,0.1>}), (\frac{u_3}{<0.1,0.2,0.5>})\}),$$
$$((e_2, x_1, 0), \{(\frac{u_1}{<0.3,0.4,0.6>}), (\frac{u_2}{<0.2,0.7,0.6>}), (\frac{u_3}{<0.1,0.5,0.2>})\}),$$
$$((e_1, x_2, 0), \{(\frac{u_1}{<0.2,0.8,0.4>}), (\frac{u_2}{<0.1,0.6,0.5>}), (\frac{u_3}{<0.7,0.6,0.3>})\})$$

$((e_2, x_2, 0), \{(\frac{u_1}{<0.4,0.4,0.7>}), (\frac{u_2}{<0.3,0.8,0.2>}), (\frac{u_3}{<0.6,0.2,0.4>})\})\}$

4. Basic Operations on Single Valued Neutrosophic Soft Expert Sets

In this section, we introduce some basic operations on SVNSES, namely the complement, AND, OR, union and intersection of SVNSES, derive their properties, and give some examples.

Definition 4.1 Let (F, A) be a SVNSES over a soft universe (U, Z). Then the complement of (F, A) denoted by $(F, A)^c$ is defined as:

$$(F, A)^c = \tilde{c}\ (F(\alpha)) \text{for all } \alpha \in U.$$

where $\tilde{c}$ is single valued neutrosophic complement .

Example 4.2 Consider the SVNSES (F, Z) over a soft universe (U, Z) as given in Example 3.2. By using the single valued neutrosophic complement for F(α), we obtain $(F, Z)^c$ which is defined as:

$(F, Z)^c = \{ (e_1, x_1, 1) = \{(\frac{u_1}{<0.3,0.8,0.1>}), (\frac{u_2}{<0.4,0.6,0.1>}), (\frac{u_3}{<0.2,0.7,0.4>})\}\},$

$\{(e_2, x_1, 1) = \{(\frac{u_1}{<0.25,0.5,0.7>}), (\frac{u_2}{<0.4,0.6,0.25>}), (\frac{u_3}{<0.6,0.4,0.4>})\}\},$

$\{(e_1, x_2, 1) = \{(\frac{u_1}{<0.7,0.2,0.3>}), (\frac{u_2}{<0.3,0.3,0.4>}), (\frac{u_3}{<0.2,0.6,0.1>})\}\},$

$\{(e_2, x_2, 1) = \{(\frac{u_1}{<0.6,0.2,0.2>}), (\frac{u_2}{<0.2,0.3,0.7>}), (\frac{u_3}{<0.5,0.1,0.3>})\}\},$

$\{(e_1, x_1, 0) = \{(\frac{u_1}{<0.5,0.4,0.2>}), (\frac{u_2}{<0.1,0.9,0.1>}), (\frac{u_3}{<0.5,0.2,0.1>})\}\},$

$\{(e_2, x_1, 0) = \{(\frac{u_1}{<0.6,0.4,0.3>}), (\frac{u_2}{<0.6,0.7,0.2>}), (\frac{u_3}{<0.2,0.5,0.1>})\}\},$

$\{(e_1, x_2, 0) = \{(\frac{u_1}{<0.4,0.8,0.2>}), (\frac{u_2}{<0.5,0.6,0.1>}), (\frac{u_3}{<0.3,0.6,0.7>})\}\},$

$\{(e_2, x_2, 0) = \{(\frac{u_1}{<0.7,0.4,0.4>}), (\frac{u_2}{<0.2,0.8,0.3>}), (\frac{u_3}{<0.4,0.2,0.6>})\}\}.$

Proposition 4.3 If (F, A) is a SVNSES over a soft universe (U, Z). Then,

$$((F, \mathrm{A})^{\mathrm{c}})^{\mathrm{c}} = (\mathrm{F}, \mathrm{A}).$$

Proof. Suppose that is (F, A) is a SVNSES over a soft universe (U, Z) defined as $(\mathrm{F}, \mathrm{A}) = \mathrm{F}(\mathrm{e})$. Now let SVNSES $(\mathrm{F}, \mathrm{A})^{\mathrm{c}} = (G, \mathrm{B})$. Then by Definition 4.1, $(G, \mathrm{B}) = \mathrm{G}(\mathrm{e})$ such that $\mathrm{G}(\mathrm{e}) = \tilde{c}\ (\mathrm{F}(e))$, Thus it follows that:

$$(G, \mathrm{B})^{\mathrm{c}} = \tilde{c}\ (\mathrm{G}(e)) = (\tilde{c}\ (\tilde{c}\ (\mathrm{F}(e))) = \mathrm{F}(\mathrm{e}) = (\mathrm{F}, \mathrm{A}).$$

Therefore

$((F, \mathrm{A})^{\mathrm{c}})^{\mathrm{c}} = (G, \mathrm{B})^{\mathrm{c}} = (\mathrm{F}, \mathrm{A})$. Hence it is proven that $((F, \mathrm{A})^{\mathrm{c}})^{\mathrm{c}} = (\mathrm{F}, \mathrm{A})$.

Defintion 4.4 Let (F, A) and (G, B) be any two SVNSESs over a soft universe (U, Z). Then the union of (F, A) and (G, B), denoted by $(F, \mathrm{A})\ \tilde{\cup}\ (G, \mathrm{B})$ is a SVNSES defined as $(F, \mathrm{A})\ \tilde{\cup}\ (G, \mathrm{B}) = (H, \mathrm{C})$, where $\mathrm{C} = \mathrm{A} \cup \mathrm{B}$ and

$$\mathrm{H}(\alpha) = \mathrm{F}(\alpha) \cup \mathrm{G}(\alpha), \text{ for all } \alpha \in \mathrm{C}$$

where

$$\mathrm{H}(\alpha) = \begin{cases} \mathrm{F}(\alpha), & \alpha \in A - B \\ \mathrm{G}(\alpha), & \alpha \in B - A \\ \cup\big(F(\alpha), G(\alpha)\big), & \alpha \in A \cap B, \end{cases}$$

Where $\cup\big(F(\alpha), G(\alpha)\big) = \{<u, \max\ \{\mu_{\mathrm{F}}(\alpha), \mu_G(\alpha)\}, \min\ \{\nu_{\mathrm{F}}(\alpha), \nu_G(\alpha)\}, \min\{\omega_{\mathrm{F}}(\alpha), \omega_G(\alpha)\}>: u \in U\}$

Proposition 4.5 Let (F, A), (G, B) and (H, C) be any three SVNSES over a soft universe (U, Z).Then the following properties hold true.

(i) $(F, \mathrm{A})\ \tilde{\cup}\ (G, \mathrm{B}) = (G, \mathrm{B})\ \tilde{\cup}\ (F, \mathrm{A})$
(ii) $(F, \mathrm{A})\ \tilde{\cup}\ ((G, \mathrm{B})\ \tilde{\cup}\ (H, \mathrm{C})) = ((F, \mathrm{A})\ \tilde{\cup}\ (G, \mathrm{B}))\ \tilde{\cup}\ (H, \mathrm{C})$
(iii) $(F, \mathrm{A})\ \tilde{\cup}\ (F, \mathrm{A}) \subseteq (F, \mathrm{A})$
(iv) $(F, \mathrm{A})\ \tilde{\cup}\ (\Phi\ , A) = (F, \mathrm{A})$

Proof. (i) Let $(F, \mathrm{A})\ \tilde{\cup}\ (G, \mathrm{B}) = (H, \mathrm{C})$. Then by definition 4.4,for all $\alpha \in \mathrm{C}$, we have $(H, \mathrm{C}) = \mathrm{H}(\alpha)$. Where $\mathrm{H}(\alpha) = \mathrm{F}(\alpha) \cup \mathrm{G}(\alpha)$ However

$$\mathrm{H}(\alpha) = \mathrm{F}(\alpha) \cup \mathrm{G}(\alpha) = \mathrm{G}(\alpha) \cup \mathrm{F}(\alpha)$$

since the union of these sets are commutative by definition 4.4. Therfore

$$(H, \mathrm{C}) = (G, \mathrm{B})\ \tilde{\cup}\ (F, \mathrm{A}).$$

Thus the union of two SVNSES are commutative i.e $(F, \mathrm{A})\ \tilde{\cup}\ (G, \mathrm{B}) = (G, \mathrm{B})\ \tilde{\cup}\ (F, \mathrm{A})$.

(ii) The proof is similar to proof of part(i) and is therefore omitted

(iii) The proof is straightforward and is therefore omitted.

(iv) The proof is straightforward and is therefore omitted.

Definition 4.6 Let (F, A) and (G, B) be any two SVNSES over a soft universe (U, Z). Then the intersection of $(F, \mathrm{A})$and (G, B), denoted by $(F, \mathrm{A}) \tilde{\cap} (G, \mathrm{B})$is SVNSES defined as $(F, \mathrm{A}) \tilde{\cap} (G, \mathrm{B})$ =(H, C) where C= A ∪ B and H(α) = F(α) ∩ G(α), for all $\alpha \in$ C. Where

$$\mathrm{H}(\alpha) = \begin{cases} \mathrm{F}(\alpha), & \alpha \in A - B \\ \mathrm{G}(\alpha), & \alpha \in B - A \\ \cap\big(F(\alpha), G(\alpha)\big), & \alpha \in A \cap B \end{cases}$$

Where $\cap\big(F(\alpha), G(\alpha)\big)$ ={<u, min $\{\mu_{\mathrm{F}}(\alpha), \mu_G(\alpha)\}$, max $\{\nu_{\mathrm{F}}(\alpha), \nu_G(\alpha)\}$, max $\{\omega_{\mathrm{F}}(\alpha), \omega_G(\alpha)\}$>:u ∈ U }

Proposition 4.7 If Let (F, A), $(G, \mathrm{B})$and (H, C) are three SVNSES over a soft universe (U, Z). Then,

(i) $(F, \mathrm{A}) \tilde{\cap} (G, \mathrm{B}) = (G, \mathrm{B}) \tilde{\cap} (F, \mathrm{A})$

(ii) $(F, \mathrm{A}) \tilde{\cap} ((G, \mathrm{B}) \tilde{\cap} (H, \mathrm{C})) = ((F, \mathrm{A}) \tilde{\cap} (G, \mathrm{B})) \tilde{\cap} (H, \mathrm{C})$

(iii) $(\mathrm{F}, \mathrm{A}) \tilde{\cap} (\mathrm{F}, \mathrm{A}) \subseteq (\mathrm{F}, \mathrm{A})$

(iv) $(F, A) \tilde{\cap} (\Phi, A) = (\Phi, A)$

Proof.

(i) The proof is similar to that of Proposition 4.5 (i) and is therefore omitted

(ii) The prof is similar to the prof of part (i) and is therefore omitted

(iii) The proof is straightforward and is therefore omitted.

(iv) The proof is straightforward and is therefore omitted.

Proposition 4.8 If Let (F, A), (G, B) and (H, C) are three SVNSES over a soft universe (U, Z). Then,

(i) $(F, \mathrm{A}) \tilde{\cup} ((G, \mathrm{B}) \tilde{\cap} (H, \mathrm{C})) = ((F, \mathrm{A}) \tilde{\cup} (G, \mathrm{B})) \tilde{\cap} ((F, \mathrm{A}) \tilde{\cup} ((H, \mathrm{C}))$

(ii) $(F, \mathrm{A}) \tilde{\cap} ((G, \mathrm{B}) \tilde{\cup} (H, \mathrm{C})) = ((F, \mathrm{A}) \tilde{\cap} (G, \mathrm{B})) \tilde{\cup} ((F, \mathrm{A}) \tilde{\cap} (H, \mathrm{C}))$

Proof. The proof is straightforward by definitions 4.4 and 4.6 and is therefore omitted.

Proposition 4.9 If (F, A), (G, B) are two SVNSES over a soft universe (U, Z). Then,

i. $((F, \mathrm{A}) \tilde{\cup} (G, \mathrm{B}))^c = (F, \mathrm{A})^{\mathrm{c}} \tilde{\cap} (G, \mathrm{B})^{\mathrm{c}}$.

ii. $((F, \mathrm{A}) \tilde{\cap} (G, \mathrm{B}))^c = (F, \mathrm{A})^{\mathrm{c}} \tilde{\cup} (G, \mathrm{B})^{\mathrm{c}}$.

Proof. (i) Suppose that (F, A) and(G, B) be SVNSES over a soft universe (U, Z) defined as: (F, A)= F(α) for all $\alpha \in \mathrm{A} \subseteq$ Z and (G, B) = G(α) for all $\alpha \in \mathrm{B} \subseteq$ Z. Now , due to the commutative and associative properties of SVNSES, it follows that by definition 4.10 and 4.11, it follows that:

$$
\begin{aligned}
(F,\mathrm{A})^c \mathbin{\tilde{\cap}} (G,\mathrm{B})^c &= (F(\alpha))^c \mathbin{\tilde{\cap}} (G(\alpha))^c \\
&= (\tilde{c}\ (\mathrm{F}(\alpha))) \mathbin{\tilde{\cap}} (\tilde{c}\ (\mathrm{G}(\alpha)) \\
&= (\tilde{c}\ (\mathrm{F}(\alpha) \mathbin{\tilde{\cap}} \mathrm{G}(\alpha)) \\
&= ((F,\mathrm{A}) \mathbin{\tilde{\cup}} (G,\mathrm{B}))^c.
\end{aligned}
$$

(ii) The proof is similar to the proof of part (i) and is therefore omitted

Definition 4.10 Let (F,A) and (G,B) be any two SVNSES over a soft universe (U, Z). Then "(F,A) AND (G,B) " denoted $(F,\mathrm{A}) \mathbin{\tilde{\wedge}} (G,\mathrm{B})$ is a defined by:

$$(F,\mathrm{A}) \mathbin{\tilde{\wedge}} (G,\mathrm{B}) = (H,\mathrm{A}\times\mathrm{B})$$

Where $(H,\mathrm{A}\times\mathrm{B})$ = $\mathrm{H}(\alpha,\beta)$, such that $\mathrm{H}(\alpha,\beta)$ = $\mathrm{F}(\alpha) \cap \mathrm{G}(\beta)$, for all $(\alpha,\beta) \in \mathrm{A}\times\mathrm{B}$. and $\cap$ represent the basic intersection.

Definition 4.11 Let (F,A) and (G,B) be any twoSVNSES over a soft universe (U, Z). Then "(F,A) OR (G,B) " denoted $(F,\mathrm{A}) \mathbin{\tilde{\vee}} (G,\mathrm{B})$ is a defined by:

$$(F,\mathrm{A}) \mathbin{\tilde{\vee}} (G,\mathrm{B}) = (H,\mathrm{A}\times\mathrm{B})$$

Where $(H,\mathrm{A}\times\mathrm{B})$ = $\mathrm{H}(\alpha,\beta)$ such that $\mathrm{H}(\alpha,\beta)$ = $\mathrm{F}(\alpha) \cup \mathrm{G}(\beta)$, for all $(\alpha,\beta) \in \mathrm{A}\times\mathrm{B}$. and $\cup$ represent the basic union.

Proposition 4.12 If(F,A), (G,B) and (H,C) are three SVNSES over a soft universe (U, Z). Then,

i. $(F,\mathrm{A}) \mathbin{\tilde{\wedge}} ((G,\mathrm{B}) \mathbin{\tilde{\wedge}} (H,\mathrm{C})) = ((F,\mathrm{A}) \mathbin{\tilde{\wedge}} (G,\mathrm{B})) \mathbin{\tilde{\wedge}} (H,\mathrm{C})$
ii. $(F,\mathrm{A}) \mathbin{\tilde{\vee}} ((G,\mathrm{B}) \mathbin{\tilde{\vee}} (H,\mathrm{C})) = ((F,\mathrm{A}) \mathbin{\tilde{\vee}} (G,\mathrm{B})) \mathbin{\tilde{\vee}} (H,\mathrm{C})$
iii. $(F,\mathrm{A}) \mathbin{\tilde{\vee}} ((G,\mathrm{B}) \mathbin{\tilde{\wedge}} (H,\mathrm{C})) = ((F,\mathrm{A}) \mathbin{\tilde{\vee}} (G,\mathrm{B})) \mathbin{\tilde{\wedge}} ((F,\mathrm{A}) \mathbin{\tilde{\vee}} (H,\mathrm{C}))$
iv. $(F,\mathrm{A}) \mathbin{\tilde{\wedge}} ((G,\mathrm{B}) \mathbin{\tilde{\vee}} (H,\mathrm{C})) = ((F,\mathrm{A}) \mathbin{\tilde{\wedge}} (G,\mathrm{B})) \mathbin{\tilde{\vee}} ((F,\mathrm{A}) \mathbin{\tilde{\wedge}} (H,\mathrm{C}))$

Proof. The proofs are straightforward by definitions 4.10 and 4.11 and is therefore omitted.

Note: The "AND" and "OR" operations are not commutative since generally A $\times$B$\neq$B$\times$A.

Proposition 4.13 If (F,A) and (G,B) are two SVNSES over a soft universe (U, Z).Then,

i. $((F,\mathrm{A}) \mathbin{\tilde{\wedge}} (G,\mathrm{B}))^c = (F,\mathrm{A})^c \mathbin{\tilde{\vee}} (G,\mathrm{B})^c$.
ii. $((F,\mathrm{A}) \mathbin{\tilde{\vee}} (G,\mathrm{B}))^c = (F,\mathrm{A})^c \mathbin{\tilde{\wedge}} (G,\mathrm{B})^c$.

Proof. (i) suppose that (F,A) and (G,B) be SVNSES over a soft universe (U, Z) defined as:

(F,A) = $\mathrm{F}(\alpha)$ for all $\alpha \in \mathrm{A} \subseteq \mathrm{Z}$ and (G,B)= $\mathrm{G}(\beta)$ for all $\beta \in \mathrm{B} \subseteq$ Z. Then by Definition 4.10 and 4.11, it follows that:

$$
\begin{aligned}
((F,\mathrm{A}) \mathbin{\tilde{\wedge}} (G,\mathrm{B}))^c &= ((F(\alpha) \mathbin{\tilde{\wedge}} G(\beta))^c \\
&= (F(\alpha) \cap G(\beta))^c
\end{aligned}
$$

$= (\tilde{c}(\mathrm{F}(\alpha) \cap \mathrm{G}(\beta))$
$= (\tilde{c}(\mathrm{F}(\alpha)) \cup \tilde{c}(\mathrm{G}(\beta)))$
$= (F(\alpha))^c \,\tilde{\vee}\, (G(\beta))^c$
$= (F, \mathrm{A})^{\mathrm{c}} \,\tilde{\vee}\, (G, \mathrm{B})^{\mathrm{c}}$.

(ii) The proof is similar to that of part (i) and is therefore omitted.

5. Application of Single Valued Neutrosophic Soft Expert Sets in a Decision Making Problem.

In this section, we introduce a generalized algorithm which will be applied to the SVNSES model introduced in Section 3 and used to solve a hypothetical decision making problem.

Suppose that company Y is looking to hire a person to fill in the vacancy for a position in their company. Out of all the people who applied for the position, three candidates were shortlisted and these three candidates form the universe of elements, U= $\{u_1, u_2, u_3\}$ The hiring committee consists of the hiring manager, head of department and the HR director of the company and this committee is represented by the set {p,q,r }(a set of experts) while the set O= {1=agree, 0=disagree } represents the set of opinions of the hiring committee members. The hiring committee considers a set of parameters, E={ e_1,e_3,e_3,e_4} where the parameters e_i represent the characteristics or qualities that the candidates are assessed on, namely "relevant job experience", "excellent academic qualifications in the relevant field", "attitude and level of professionalism" and "technical knowledge" respectively. After interviewing all the three candidates and going through their certificates and other supporting documents, the hiring committee constructs the following SVNSES.

(F, Z) ={ $(e_1, p, 1)$ = $\{(\frac{u_1}{<0.2,0.8,0.4>}), (\frac{u_2}{<0.3,0.2,0.4>}), (\frac{u_3}{<0.4,0.7,0.2>})\}\}$,

$\{(e_2, p, 1) = \{(\frac{u_1}{<0.3,0.2,0.23>}), (\frac{u_2}{<0.25,0.2,0.3>}), (\frac{u_3}{<0.3,0.5,0.6>})\}\}$,

$\{(e_3, p, 1) = \{(\frac{u_1}{<0.3,0.2,0.7>}), (\frac{u_2}{<0.4,0.3,0.3>}), (\frac{u_3}{<0.1,0.6,0.2>})\}\}$,

$\{(e_4, p, 1) = \{(\frac{u_1}{<0.2,0.2,0.6>}), (\frac{u_2}{<0.7,0.3,0.2>}), (\frac{u_3}{<0.3,0.1,0.5>})\}\}$,

$\{(e_1, q, 1) = \{(\frac{u_1}{<0.4,0.6,0.3>}), (\frac{u_2}{<0.1,0.3,0.7>}), (\frac{u_3}{<0.6,0.3,0.7>})\}\}$,

$\{(e_2, q, 1) = \{(\frac{u_1}{<0.3,0.3,0.5>}), (\frac{u_2}{<0.6,0.9,0.1>}), (\frac{u_3}{<0.1,0.2,0.7>})\}\}$,

$\{(e_3, q, 1) = \{(\frac{u_1}{<0.1,0.4,0.7>}), (\frac{u_2}{<0.4,0.6,0.2>}), (\frac{u_3}{<0.6,0.2,0.4>})\}\}$.

$\{(e_4, q, 1) = \{(\frac{u_1}{<0.6,0.5,0.3>}), (\frac{u_2}{<0.7,0.8,0.2>}), (\frac{u_3}{<0.3,0.4,0.6>})\}\}$.

$\{(e_1,r,1) = \{(\frac{u_1}{<0.4,0.5,0.7>}),(\frac{u_2}{<0.3,0.8,0.4>}),(\frac{u_3}{<0.6,0.2,0.4>})\}\}.$

$\{(e_2,r,1) = \{(\frac{u_1}{<0.3,0.7,0.1>},(\frac{u_2}{<0.7,0.3,0.2>}),(\frac{u_3}{<0.8,0.2,0.2>})\}\}.$

$\{(e_3,r,1) = \{(\frac{u_1}{<0.6,0.5,0.2>}),(\frac{u_2}{<0.5,0.1,0.6>}),(\frac{u_3}{<0.3,0.2,0.1>})\}\}.$

$\{(e_1,p,0) = \{(\frac{u_1}{<0.1,0.4,0.3>}),(\frac{u_2}{<0.3,0.8,0.2>}),(\frac{u_3}{<0.6,0.2,0.4>})\}\}.$

$\{(e_3,p,0) = \{(\frac{u_1}{<0.6,0.3,0.2>}),(\frac{u_2}{<0.2,0.7,0.4>}),(\frac{u_3}{<0.3,0.1,0.6>})\}\}.$

$\{(e_4,p,0) = \{(\frac{u_1}{<0.3,0.2,0.5>}),(\frac{u_2}{<0.6,0.4,0.5>}),(\frac{u_3}{<0.5,0.4,0.3>})\}\}.$

$\{(e_1,q,0) = \{(\frac{u_1}{<0.2,0.4,0.7>}),(\frac{u_2}{<0.1,0.9,0.2>}),(\frac{u_3}{<0.1,0.2,0.5>})\}\},$

$\{\ (e_2,q,0) = \{(\frac{u_1}{<0.3,0.4,0.6>}),(\frac{u_2}{<0.2,0.7,0.6>}),(\frac{u_3}{<0.4,0.5,0.3>})\}\},$

$\{(e_3,q,0) = \{(\frac{u_1}{<0.2,0.8,0.4>}),(\frac{u_2}{<0.1,0.2,0.5>}),(\frac{u_3}{<0.7,0.6,0.3>})\}\},$

$\{(e_4,q,0) = \{(\frac{u_1}{<0.9,0.4,0.7>}),(\frac{u_2}{<0.5,0.6,0.2>}),(\frac{u_3}{<0.6,0.3,0.4>})\}\}.$

$\{(e_1,r,0) = \{(\frac{u_1}{<0.3,0.4,0.5>}),(\frac{u_2}{<0.3,0.6,0.2>}),(\frac{u_3}{<0.25,0.2,0.4>})\}\}.$

$\{(e_2,r,0) = \{(\frac{u_1}{<0.4,0.6,0.7>}),(\frac{u_2}{<0.6,0.4,0.2>}),(\frac{u_3}{<0.6,0.4,0.3>})\}\}.$

$\{(e_3,r,0) = \{(\frac{u_1}{<0.4,0.3,0.2>}),(\frac{u_2}{<0.3,0.5,0.7>}),(\frac{u_3}{<0.7,0.5,0.6>})\}\}.$

Next the SVNSES (F, Z) is used together with a generalized algorithm to solve the decision making problem stated at the beginning of this section. The algorithm given below is employed by the hiring committee to determine the best or most suitable candidate to be hired for the position. This algorithm is a generalization of the algorithm introduced by Alkhazaleh and Salleh [37] which is used in the context of the SVNSES model that is introduced in this paper. The generalized algorithm is as follows:

Algorithm

1. Input the SVNSES (F, Z)

2. Find the values of $\mu_{F(Z_i)}(u_i)$ - $\nu_{F(Z_i)}(u_i)$ -$\omega_{F(Z_i)}(u_i)$ for each element $u_i \in$ U where $\mu_{F(Z_i)}(u_i)$, $\nu_{F(Z_i)}(u_i)$ and $\omega_{F(Z_i)}(u_i)$ are the membership function, indeterminacy function and non-membership function of each of the elements $u_i \in$ U respectively.

3. Find the highest numerical grade for the agree-SVNSES and disagree-SVNSES.

4. Compute the score of each element $u_i \in$ U by taking the sum of the products of the numerical grade of each element for the agree-SVNSES and disagree SVNSES, denoted by A_i and D_i respectively.

5. Find the values of the score r_i= A_i-D_i for each element $u_i \in$ U.

6. Determine the value of the highest score, s = $\max_{u_i} \{r_i\}$. Then the decision is to choose element as the optimal or best solution to the problem. If there are more than one element with the highest r_i. score, then any one of those elements can be chosen as the optimal solution.

Then we can conclude that the optimal choice for the hiring committee is to hire candidate u_i to fill the vacant position

Table I gives the values of $\mu_{F(Z_i)}(u_i)$ - $\nu_{F(Z_i)}(u_i)$ -$\omega_{F(Z_i)}(u_i)$ for each element $u_i \in$ U.

The notation a ,b gives the values of $\mu_{F(Z_i)}(u_i)$ - $\nu_{F(Z_i)}(u_i)$ -$\omega_{F(Z_i)}(u_i)$.

Table I. Values of $\mu_{F(Z_i)}(u_i)$ - $\nu_{F(Z_i)}(u_i)$ -$\omega_{F(Z_i)}(u_i)$ for all $u_i \in$ U.

	u_1	u_2	u_3		u_1	u_2	u_3
$(e_1, p, 1)$	-1	-0.3	-0.5	$(e_3, p, 0)$	0.1	-0.9	-0.4
$(e_2, p, 1)$	-0.13	-0.25	-0.8	$(e_4, p, 0)$	-0.4	-0.3	-0.2
$(e_3, p, 1)$	-0.6	-0.2	-0.7	$(e_1, q, 0)$	-0.9	-1	-0.6
$(e_4, p, 1)$	-0.6	0.2	-0.3	$(e_2, q, 0)$	-0.7	-1.1	-0.4
$(e_1, q, 1)$	-0.5	-0.9	-0.4	$(e_3, q, 0)$	-1	-0.6	-0.2
$(e_2, q, 1)$	-0.5	-0.4	-0.5	$(e_4, q, 0)$	-0.2	-0.3	-0.1
$(e_3, q, 1)$	-1	-0.4	0	$(e_1, r, 0)$	-0.6	-0.5	0.35
$(e_4,q, 1)$	-0.2	-0.3	-0.5	$(e_2, r, 0)$	-0.9	0	-0.1
$(e_1, r, 1)$	-0.8	-0.9	0	$(e_4, r, 0)$	-0.1	-0.9	-0.4
$(e_2, r, 1)$	-0.5	0.2	0.4				
$(e_3, r, 1)$	-0.1	-0.2	0				
$(e_1, p, 0)$	-0.6	-0.7	0				

In Table II and Table III, we gives the highest numerical grade for the elements in the agree-SVNSES and disagree SVNSES respectively.

Table II. Numerical Grade for Agree-SVNSES

	u_i	Highest Numeric Grade
$(e_1, p, 1)$	u_2	-0.3
$(e_2, p, 1)$	u_1	-0.13
$(e_3, p, 1)$	u_2	-0.2
$(e_4, p, 1)$	u_2	0.2
$(e_1, q, 1)$	u_3	-0.4
$(e_2, q, 1)$	u_2	-0.4
$(e_3, q, 1)$	u_3	0
$(e_4,q, 1)$	u_1	-0. 2
$(e_1, r, 1)$	u_3	0
$(e_2, r, 1)$	u_3	0.4
$(e_3, r, 1)$	u_3	0

Score (u_1) = -0.13 + -0.2 = -0.23

Score (u_2) = -0.3 + -0.2 + -0.2 + -0.4 = -0.11

Score (u_3) =-0.4 +0+ 0 +0.4 + 0

Table III. Numerical Grade for Disagree-SVNSE

	u_i	Highest Numeric Grade
$(e_1,p, 0)$	u_3	0
$(e_3,p, 0)$	u_1	0.1
$(e_4,p, 0)$	u_3	-0.2
$(e_1,q, 0)$	u_3	-0.6
$(e_2,q, 0)$	u_3	-0.4
$(e_3,q, 0)$	u_3	-0.2
$(e_4,q, 0)$	u_3	-0.1
$(e_1,r, 0)$	u_3	-0.35
$(e_2,r, 0)$	u_2	0
$(e_4,r, 0)$	u_1	-0.1

Score (u_1) = 0.1 + -0.1 = 0
Score (u_2) = 0
Score (u_3) = 0 -0.2 + -0.6 + -0.4 + -0.2 +-0.1 + -0.35 = - 1.85

Let A_i and D_i represent the score of each numerical grade for the agree-SVNSES and disagree-SVNSES respectively. These values are given in Table IV.

Table IV. The score $r_i = A_i - D_i$

A_i	D_i	r_i
Score (u_1) = - 0.23	Score (u_1) = 0	**-0.23**
Score (u_2) = -0.11	Score (u_2) = 0	**-0.11**
Score (u_3) = 0	Score (u_3) = -1.85	**1.85**

Then s $= \max_{u_i} \{r_i\} = r_3$, the hiring committee should hire candidate u_3 to fill in the vacant position.

6. Conclusion

In this paper we have introduced the concept of single valued neutrosophic soft expert soft set and studied some related properties with supporting proofs. The complement, union, intersection, AND or OR operations have been defined on the single valued neutrosophic soft expert set. Finally, an application of this concept is given in solving a decision making problem. This new extension will provide a significant addition to existing theories for handling indeterminacy, and lead to potential areas of further research and pertinent applications.

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