Bipolar Neutrosophic Soft Expert Set Theory

Mehmet Şahin[1], Vakkas Uluçay[1*], and Said Broumi[3]

[1] Department of Mathematics, Gaziantep University, Gaziantep27310-Turkey
E-mail: mesahin@gantep.edu.tr, vulucay27@gmail.com
[2] Laboratory of Information processing, Faculty of Science Ben M'Sik, University Hassan II, B.P 7955, Sidi Othman, Casablanca, Morocco.
E-mail: broumisaid78@gmail.com

ABSTRACT

In this paper, we introduce for the first time the concept of bipolar neutrosophic soft expert set and its some operations. Also, the concept of bipolar neutrosophic soft expert set and its basic operations, namely complement, union and intersection. We give examples for these concepts.

KEYWORDS: Soft expert set, neutrosophic soft set, neutrosophic soft expert set, bipolar neutrosophic soft expert set.

Section1. Introduction

In some real life problems in expert system, belief system, information fusion and so on, we must consider the truth-membership as well as the falsity- membership for proper description of an object in uncertain, ambiguous environment. Intuitionistic fuzzy sets introduced by Atanassov (1986). After Atanassov's work, Smarandache (1998) introduced the concept of neutrosophic set which is a mathematical tool for handling problems involving imprecise, indeterminacy and inconsistent data. These sets models have been studied by many authors; on application (Molodtsov1999, Maji 2003, Cheng 2008, Gua 2009, Kharal 2013, Kang 2012, Liu 2014, Liu 2015, Majumdar 2014, Peng 2015, Sahin 2014, Broumi, & Smarandache 2015a, 2015b, Broumi, Ali & Smarandache 2015; Broumi, Talea, Bakali, & Smarandache 2016a,2016b; Broumi, Smarandache, Talea, & Bakali, 2016; Broumi, Talea, Smarandache, & Bakali 2016; Karaaslan 2016, Guo 2015), and so on.

Bosc and Pivert (2013) said that "Bipolarity refers to the propensity of the human mind to reason and make decisions on the basis of positive and negative effects. Positive information states what is possible, satisfactory, permitted, desired, or considered as being acceptable. On the other hand, negative statements express what is impossible, rejected, or forbidden. Negative preferences correspond to constraints, since they specify which values or objects have to be rejected (i.e., those that do not satisfy the constraints), while positive preferences correspond to wishes, as they specify which objects are more desirable than others (i.e., satisfy user wishes) without rejecting those that do not meet the wishes." Therefore, Lee (Lee 2000,2009) introduced the concept of bipolar fuzzy sets which is a generalization of the fuzzy sets. Recently, bipolar fuzzy models have been studied by many authors on algebraic structures such as; Majumder (2012) proposed bipolar valued fuzzy subsemigroup, bipolar valued fuzzy bi-ideal, bipolar valued fuzzy (1, 2) - ideal and bipolar valued fuzzy ideal. Manemaran and Chellappa (2010) gave some applications of bipolar fuzzy sets in groups are called the bipolar fuzzy groups, fuzzy d-ideals of groups under

(T-S) norm. Chen et al. (2014) studied of m-polar fuzzy set and illustrates how many concepts have been defined based on bipolar fuzzy sets.
Alkhazaleh et al. (2011) where the mapping in which the approximate function is defined from fuzzy parameters set, and gave an application of this concept in decision making. Alkhazaleh and Salleh (2011) introduced the concept soft expert sets where user can know the opinion of all expert sets. Sahin et al. (2015) firstly proposed neutrosophic soft expert sets with operations. Until now, there is no study on soft experts in bipolar neutrosophic environment, so there is a need to develop a new mathematical tool called "bipolar neutrosophic soft expert sets. So motivated by the work of Sahin in et al. (2015) and Deli et al (2015), we introduced the concept of bipolar neutrosophic soft expert sets which is an extension of the fuzzy soft expert sets, bipolar fuzzy soft expert sets, intuitionistic fuzzy sets soft expert and neutrosophic soft expert sets.

The paper is organized as follows. In section2, we first recall the necessary background on neutrosophic sets, single valued neutrosophic sets, neutrosophic soft expert sets and bipolar neutrosophic soft set. In section3, we introduce the concept of bipolar neutrosophic soft expert set and its basic operations, namely complement, union and intersection. Finally, we conclude the paper.

Section 2. Preliminaries

In this section we recall some related definitions.

Definition 2.1: (Smarandache 1998) Let U be a space of points (objects), with a generic element in U denoted by u. A neutrosophic sets(N-sets) A in U is characterized by atruth-membership function T_A, a indeterminacy-membership function $I_A$and a falsity-membership function F_A. T_A(u); I_A(u) and F_A(u) are real standard or nonstandard subsets of [0, 1]. It can be written as
A = {< u, (T_A(u), I_A(u), F_A(u)) >: u ∈U, T_A(u), I_A(u), F_A(u) ∈[0, 1]}.There is no restriction on the sum of T_A(u); I_A(u) and F_A(u), so

$$0 \leq \sup T_A(u) + \sup I_A(u) + \sup F_A(u) \leq 3.$$

Definition 2.2: (Maji, 2013) A neutrosophic set A is contained in another neutrosophic set B i.e.

$$A \subseteq B \text{ if } \forall x \in X \ , T_A(x) \leq T_B(x),\ I_A(x) \leq I_B(x),\ F_A(x) \geq F_B(x).$$

Let U be a universe, E a set of parameters, and X a soft experts (agents). Let O be a set of opinion, $Z = E \times X \times O$ and $A \subseteq Z$.

Definition 2.3: (Sahin et al., 2015) A pair (F, A) is called a neutrosophic soft expert set over U, where F is mapping given by

$F: A \rightarrow P(U)$

Where $P(U)$ denotes the power neutrosophic set of U.

Set- theoretic operations, for two neutrosophic soft expert sets,

A_{NSE} = {<x, $T_{F(e)}(x)$, $I_{F(e)}(x)$, $F_{F(e)}(x)$> | $\forall e \in A, x \in U$ } and B_{NSE} = {<x, $T_{G(e)}(x)$, $I_{G(e)}(x)$, $F_{G(e)}(x)$> | $\forall e \in A, x \in U$ } are given as;

1. The subset; $A_{NSE} \subseteq B_{NSE}$ if and only if

$$T_{F(e)}(x) \tilde{\leq} T_{G(e)}(x),\ I_{F(e)}(x) \tilde{\leq} I_{G(e)}(x),\ F_{F(e)}(x) \tilde{\geq} F_{G(e)}(x) \forall e \in A, x \in U.$$

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

$$T_{F(e)}(x) = T_{G(e)}(x),\ I_{F(e)}(x) = I_{G(e)}(x),\ F_{F(e)}(x) = F_{G(e)}(x) \forall e \in A, x \in U.$$

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

$$A_{NSE}^c = \{<x,\ T_{F^c(x)} = F_{F(x)},\ I_{F^c(x)} = I_{F(x)},\ F_{F^c(x)} = T_{F(x)} | x \in X\}$$

4. The intersection

$$A_{NSE} \cap B_{NSE} = \{<x, \min\{T_{F(e)}(x), T_{G(e)}(x)\}, \max\{I_{F(e)}(x), I_{G(e)}(x)\}, \max\{F_{F(e)}(x), F_{G(e)}(x)\}>: x \in X\}$$

5. The union

$$A_{NSE} \cup B_{NSE} = \{<x, \max\{T_{F(e)}(x), T_{G(e)}(x)\}, \min\{I_{F(e)}(x), I_{G(e)}(x)\}, \min\{F_{F(e)}(x), F_{G(e)}(x)\}>: x \in X\}$$

Definition 2.4: [Deli et a., 2015] A bipolar neutrosophic set A in X is defined as an object of the form

$$A = \left\{\left\langle x, T^+(x), I^+(x), F^+(x), T^-(x), I^-(x), F^-(x)\right\rangle : x \in X\right\},$$

where $T^+, I^+, F^+ : X \to [1,0]$ and $T^-, I^-, F^- : X \to [-1,0]$.

Definition 2.5: (Deli et al. 2015) Let $\tilde{a}_1 = \langle T_1^+, I_1^+, F_1^+, T_1^-, I_1^-, F_1^- \rangle$ and $\tilde{a}_2 = \langle T_2^+, I_2^+, F_2^+, T_2^-, I_2^-, F_2^- \rangle$ be two bipolar neutrosophic number . Then the operations for NNs are defined as below;

i. $\lambda\tilde{a}_1 = \langle 1-(1-T_1^+)^\lambda, (I_1^+)^\lambda, (F_1^+)^\lambda, -(-T_1^-)^\lambda, -(-I_1^-)^\lambda, -(1-(1-(-F_1^-))^\lambda) \rangle$
ii. $\tilde{a}_1^\lambda = \langle (T_1^+)^\lambda, 1-(1-I_1^+)^\lambda, 1-(1-F_1^+)^\lambda, -(1-(1-(-T_1^-))^\lambda), -(-I_1^-)^\lambda, -(-F_1^-)^\lambda \rangle$
iii. $\tilde{a}_1 + \tilde{a}_2 = \langle T_1^+ + T_2^+ - T_1^+T_2^+, I_1^+I_2^+, F_1^+F_2^+, -T_1^-T_2^-, -(-I_1^- - I_2^- - I_1^-I_2^-), -(-F_1^- - F_2^- - F_1^-F_2^-) \rangle$
iv. $\tilde{a}_1.\tilde{a}_2 = \langle T_1^+T_2^+, I_1^+ + I_2^+ - I_1^+I_2^+, F_1^+ + F_2^+ - F_1^+F_2^+, -(-T_1^- - T_2^- - T_2^-T_2^-), -I_1^-I_2^-, -F_1^-F_2^- \rangle$

where $\lambda > 0$.

Definition 2.6: (Deli et al. 2015) Let $\tilde{a}_1 = \langle T_1^+, I_1^+, F_1^+, T_1^-, I_1^-, F_1^- \rangle$ be a bipolar neutrosophic number. Then, the score function s($\tilde{a}_1$), accuracy function a($\tilde{a}_1$) and certainty function c($\tilde{a}_1$) of an NBN are defined as follows:

i. $\tilde{s}(\tilde{a}_1) = (T_1^+ + 1 - I_1^+ + 1 - F_1^+ + 1 + T_1^- - I_1^- - F_1^-)/6$
ii. $\tilde{a}(\tilde{a}_1) = T_1^+ - F_1^+ + T_1^- - F_1^-$

iii. $\tilde{c}(\tilde{a}_1) = T_1^+ - F_1^-$

Definition 2.7: (Deli et al. 2015) $\tilde{a}_1 = \langle T_1^+, I_1^+, F_1^+, T_1^-, I_1^-, F_1^- \rangle$and $\tilde{a}_2 = \langle T_2^+, I_2^+, F_2^+, T_2^-, I_2^-, F_2^- \rangle$ be two bipolar neutrosophic number. The comparison method can be defined as follows:

i. if $\tilde{s}(\tilde{a}_1) > \tilde{s}(\tilde{a}_2)$, then $\tilde{a}_1$is greater than $\tilde{a}_2$, that is, $\tilde{a}_1$is superior to $\tilde{a}_2$, denoted by $a_1 > \tilde{a}_2$

ii. $\tilde{s}(\tilde{a}_1) = \tilde{s}(\tilde{a}_2)$ and $\tilde{a}(\tilde{a}_1) > \tilde{a}(\tilde{a}_2)$, then $\tilde{a}_1$is greater than $\tilde{a}_2$, that is, $\tilde{a}_1$is superior to $\tilde{a}_2$, denoted by $\tilde{a}_1 < \tilde{a}_2$;

iii. if $\tilde{s}(\tilde{a}_1) = \tilde{s}(\tilde{a}_2)$, $\tilde{a}(\tilde{a}_1) = \tilde{a}(\tilde{a}_1)$ and $\tilde{c}(\tilde{a}_1) > \tilde{c}(\tilde{a}_2)$, then $\tilde{a}_1$is greater than $\tilde{a}_2$, that is, $\tilde{a}_1$is superior to $\tilde{a}_2$, denoted by $\tilde{a}_1 > \tilde{a}_2$;

iv. if $\tilde{s}(\tilde{a}_1) = \tilde{s}(\tilde{a}_2)$, $\tilde{a}(\tilde{a}_1) = \tilde{a}(\tilde{a}_2))$ and $\tilde{c}(\tilde{a}_1) = \tilde{c}(\tilde{a}_2)$, then $\tilde{a}_1$is equal to $\tilde{a}_2$, that is, $\tilde{a}_1$is indifferent to $\tilde{a}_2$, denoted by $\tilde{a}_1 = \tilde{a}_2$.

Section 3. Bipolar Neutrosophic Soft Expert Set

In this section, using the concept of bipolar neutrosophic set now we introduce the concept of bipolar neutrosophic soft expert set and we also give basic properties of this concept.

Let U be a universe, E a set of parameters, X a set of experts (agents), and $O = \{1 = agree, 0 = disagree\}$a set of opinions. Let $Z = E \times X \times O$ and $\bar{A} \subseteq Z$.

Definition 3.1:A pair $(H, \bar{A})$ is called a bipolar neutrosophic soft expert set over U, where H is mapping given by

$H: \bar{A} \to P(U)$

where$P(U)$ denotes the power bipolar neutrosophic set of U and

$$\left(H, \bar{A}\right) = \left\{ \left\langle u, T^+_{H(e)}(u), I^+_{H(e)}(u), F^+_{H(e)}(u), T^-_{H(e)}(u), I^-_{H(e)}(u), F^-_{H(e)}(u) \right\rangle : \forall e \in A, u \in U \right\},$$

where $T^+_{H(e)}, I^+_{H(e)}, F^+_{H(e)} : U \to [1,0]$ and $T^-_{H(e)}, I^-_{H(e)}, F^-_{H(e)} : U \to [-1,0]$.

For definition we consider an example.

Example 3.2: Suppose the following U is the set of notebook under consideration E is the set of parameters. Each parameter is a neutrosophic word or sentence involving neutrosophic words.

$E = \{\text{cheap}; \text{expensive}\} = \{e_1, e_2\}$

$X = \{p, q, r\}$be a set of experts. Suppose that

$H(e_1, p, 1) = \{< u_1, 0.3, 0.5, 0.7, -0.2, -0.3, -0.4 >, < u_3, 0.5, 0.6, 0.3, -0.3, -0.4, -0.1 >\}$

$H(e_1, q, 1) = \{< u_2, 0.8, 0.2, 0.3, -0.1, -0.3, -0.5 >, < u_3, 0.9, 0.5, 0.7, -0.4, -0.1, -0.2 >\}$

$H(e_1, r, 1) = \{< u_1, 0.4, 0.7, 0.6, -0.6, -0.2, -0.4 >\}$

$H(e_2, p, 1) = \{< u_1, 0.4, 0.2, 0.3, -0.2, -0.3, -0.1 >, < u_2, 0.7, 0.1, 0.3, -0.3, -0.2, -0.5 >\}$

$H(e_2,q,1) = \{< u_3, 0.3,0.4,0.2, -0.5, -0.1, -0.4 >\}$

$H(e_2,r,1) = \{< u_2, 0.3,0.4,0.9, -0.4, -0.3, -0.1 >\}$

$H(e_1,p,0) = \{< u_2, 0.5,0.2,0.3, -0.5, -0.2, -0.3 >\}$

$H(e_1,q,0) = \{< u_1, 0.6,0.3,0.5, -0.4, -0.2, -0.6 >\}$

$H(e_1,r,0) = \{< u_2, 0.7,0.6,0.4, -0.3, -0.4, -0.5 >, < u_3, 0.9,0.5,0.7, -0.2, -0.3, -0.5 >\}$

$H(e_2,p,0) = \{< u_3, 0.7,0.9,0.6, -0.2, -0.3, -0.4 >\}$

$H(e_2,q,0) = \{< u_1, 0.7,0.3,0.6, -0.3, -0.2, -0.4 >, < u_2, 0.6,0.2,0.5, -0.3, -0.1, -0.4 >\}$

$H(e_2,r,0) = \{< u_1, 0.6,0.2,0.5, -0.5, -0.3, -0.2 >, < u_3, 0.7,0.2,0.8, -0.6, -0.2, -0.1 >\}$

The bipolar neutrosophic soft expert set $(H, \bar{Z})$ is a parameterized family $\{H(e_i), i = 1,2,3, \ldots\}$ of all neutrosophic sets of U and describes a collection of approximation of an object.

Definition 3.3: Let $(H, \bar{A})$ and $(G, \bar{B})$be two bipolar neutrosophic soft expert sets over the common universe U. $(H, \bar{A})$is said to be bipolar neutrosophic soft expert subset of$(G, \bar{B})$, if $(H, \bar{A}) \tilde{\subseteq} (G, \bar{B})$ if and only if

$$T^+_{H(e)}(u) \le T^+_{G(e)}(u)\ I^+_{H(e)}(u) \le I^+_{G(e)}(u)\ , F^+_{H(e)}(u) \ge F^+_{G(e)}(u)\ ,$$

and

$$T^-_{H(e)}(u) \ge T^-_{G(e)}(u)\ ,\ I^-_{H(e)}(u) \ge I^-_{G(e)}(u)\ ,\ F^-_{H(e)}(u) \le F^-_{G(e)}(u)$$

$\forall e \in A, u \in U.$

$(H, \bar{A})$is said to be bipolar neutrosophic soft expert superset of $(G, \bar{B})$ if $(G, \bar{B})$is a neutrosophic soft expert subset of $(H, \bar{A})$. We denote by$(H, \bar{A}) \tilde{\supseteq} (G, \bar{B})$.

Example 3.4: Suppose that a company produced new types of its products and wishes to take the opinion of some experts about price of these products. Let $U = \{u_1, u_2, u_3\}$ be a set of product, $E = \{e_1, e_2\}$ a set of decision parameters where $e_i (i = 1,2)$ denotes the decision "cheap ", "expensive" respectively and let $X = \{p, q, r\}$ be a set of experts. Suppose $(H, \bar{A})$ and $(G, \bar{B})$be defined as follows:

$(H, \bar{A}) =$

$\{[(e_1,p,1), < u_1, 0.3,0.5,0.6, -0.2, -0.3, -0.4 >, < u_2, 0.5,0.2,0.3, -0.4, -0.2, -0.5 >],$

$[(e_2,p,0), < u_2, 0.2,0.4,0.7, -0.5, -0.4, -0.3 >],$

$[(e_1,q,1), < u_1, 0.6,0.3,0.5, -0.6, -0.2, -0.5 >, < u_2, 0.6,0.2,0.3, -0.5, -0.4, -0.3 >],$

$[(e_1,r,0), < u_1, 0.2,0.7,0.3, -0.4, -0.3, -0.5 >],$

$[(e_2,r,1), < u_2, 0.3,0.4,0.9, -0.3, -0.2, -0.4 >, < u_3, 0.7,0.2,0.8, -0.5, -0.3, -0.6 >]\}.$

$(G, \bar{B}) =$

$\{[(e_1, p, 1), < u_1, 0.3, 0.5, 0.7, -0.2, -0.3, -0.6 >, < u_2, 0.5, 0.2, 0.3, -0.1, -0.2, -0.7 >],$

$[(e_2, p, 0), < u_2, 0.2, 0.4, 0.7, -0.2, -0.4, -0.5 >],$

$[(e_1, q, 1), < u_1, 0.6, 0.3, 0.5, -0.1, -0.2, -0.8 >, < u_2, 0.6, 0.2, 0.3, -0.3 - 0.1, -0.4 >]\}.$

Therefore

$$(H, \bar{A}) \tilde{\supseteq} (G, \bar{B}).$$

Definition 3.5: Let $(H, \bar{A})$ and $(G, \bar{B})$be two bipolar neutrosophic soft expert sets over the common universe U. $(H, \bar{A})$ is said to be bipolar neutrosophic soft expert equal(G, B), if $(H, \bar{A}) = (G, \bar{B})$if and only if

$$T^{+}_{H(e)}(u) = T^{+}_{G(e)}(u)\ I^{+}_{H(e)}(u) = I^{+}_{G(e)}(u), F^{+}_{H(e)}(u) = F^{+}_{G(e)}(u),$$

and

$$T^{-}_{H(e)}(u) = T^{-}_{G(e)}(u),\ I^{-}_{H(e)}(u) = I^{-}_{G(e)}(u),\ F^{-}_{H(e)}(u) = F^{-}_{G(e)}(u)$$

$\forall e \in A, u \in U.$

Definition 3.6: NOT set of set parameters. Let $E = \{e_1, e_2, \dots, e_n\}$ be a set of parameters. The NOT set of E is denoted by$\neg$E = $\{\neg e_1, \neg e_2, \dots, \neg e_n\}$where $\neg e_i$= not e_i, $\forall i=1,2,\dots,n$.

Example 3.7: Consider example 3.2. Here $\neg$E={not cheap, not expensive}

Definition 3.8: Complement of a bipolar neutrosophic soft expert set. The complement of a bipolar neutrosophic soft expert set $(H, \bar{A})$ denoted by $(H, \bar{A})^c$ and is defined as $(H, \bar{A})^c$=$(H^c, \neg \bar{A})$ where $H^c = \neg \bar{A} \to P(U)$ is mapping given by $H^c(u)$= neutrosophic soft expert complement with

$$T^{+}_{H^c(u)} = F^{+}_{H(u)}, I^{+}_{H^c(u)} = I^{+}_{H(u)}, F^{+}_{H^c(u)} = T^{+}_{H(u)}$$

and

$T^{-}_{H^c(u)} = F^{-}_{H(u)}, I^{-}_{H^c(u)} = I^{-}_{H(u)}, F^{-}_{H^c(u)} = T^{-}_{H(u)}$

Example 3.9: Consider the Example 3.2. Then $(H, \bar{Z})^c$ describes the “not price of the notebook” we have

$(H, \bar{Z})^c = \{(\neg e_1, p, 1), [< u_2, 0.3, 0.2, 0.5, -0.3, -0.2, -0.5 >]$

$[(\neg e_1, q, 1), < u_1, 0.5, 0.3, 0.6, -0.4, -0.1, -0.3 >],$

$[(\neg e_1, r, 1), < u_2, 0.4, 0.6, 0.7, -0.3, -0.4, -0.2 >, < u_3, 0.7, 0.5, 0.9, -0.1, -0.2, -0.3 >],$

$[(\neg e_2, p, 1), < u_3, 0.6, 0.9, 0.7, -0.4, -0.3, -0.2 >],$

$[(\neg e_2, q, 1), < u_1, 0.6, 0.3, 0.7, -0.5, -0.1, -0.3 >, < u_2, 0.5, 0.2, 0.6, -0.3, -0.5, -0.6 >],$

$[(\neg e_2, r, 1), < u_1, 0.5, 0.2, 0.6 - 0.6, -0.2, -0.4 >, < u_3, 0.8, 0.2, 0.7, -0.3, -0.4, -0.1 >],$

$[(\neg e_1, p, 0), < u_1, 0.7, 0.5, 0.3, -0.4, -0.2, -0.3 >, < u_3, 0.3, 0.6, 0.5, -0.6, -0.3, -0.5 >],$

$[(\neg e_1, q, 0), < u_2, 03, 0.2, 0.8, -0.3, -0.2, -0.7 >, < u_3, 0.9, 0.5, 0.7, -0.7, -0.3, -0.5 >],$

$[(\neg e_1, r, 0), < u_1, 0.6, 0.7, 0.4, -0.4, -0.3, -0.5 >],$

$[(\neg e_2, p, 0), < u_1, 0.3, 0.2, 0.4, -0.3, -0.5, -0.4 >, < u_2, 0.3, 0.1, 0.7, -0.6, -0.5, -0.1 >],$

$[(\neg e_2, q, 0), < u_3, 0.2, 0.4, 0.3, -0.7, -0.4, -0.3 >],$

$[(\neg e_2, r, 0), < u_2, 0.9, 0.4, 0.3, -0.8, -0.3, -0.5 >]\}.$

Definition 3.10: Empty or Null bipolar neutrosophic soft expert set with respect to parameter. A bipolar neutrosophic soft expert set $(H, \bar{A})$over the universe U is termed to be empty or null bipolar neutrosophic soft expert set with respect to the parameter $\bar{A}$ if

$$T^+_{H(e)}(u) = T^+_{G(e)}(u) = 0 \; I^+_{H(e)}(u) = I^+_{G(e)}(u) = 0 \,, F^+_{H(e)}(u) = F^+_{G(e)}(u) = 0 \,,$$

and

$$T^-_{H(e)}(u) = T^-_{G(e)}(u) = 0 \,,\; I^-_{H(e)}(u) = I^-_{G(e)}(u) = 0 \,,\; F^-_{H(e)}(u) = F^-_{G(e)}(u) = 0$$

$\forall e \in \bar{A}, u \in U.$

In this case the null bipolar neutrosophic soft expert set (NBNSES) is denoted by$\phi_{\breve{A}}$.

Example 3.11: Let $U = \{u_1, u_2, u_3\}$ the set of three handbags be considered as universal set $E = \{quality\} = \{e_1\}$be the set of parameters that characterizes the handbag and let $X = \{p, q\}$ be a set of experts.

$\Phi_{\breve{A}} = \text{(NBNSES)} = \{[(e_1, p, 1), < u_1, 0,0,0,0,0,0 >, < u_2, 0,0,0,0,0,0 >],$

$[(e_1, q, 1), < u_1, 0,0,0,0,0,0 >, < u_2, 0,0,0,0,0,0 >],$

$[(e_1, p, 0), < u_3, 0,0,0,0,0,0 >],$

$[(e_1, q, 0), < u_3, 0,0,0,0,0,0 >]\}.$

Here the (NBNSES) (H,$\bar{A}$) is the null bipolar neutrosophic soft expert sets.

Definition 3.12: An agree-bipolar neutrosophic soft expert set $(H, \bar{A})_1$ over U is a bipolar neutrosophic soft expert subset of $(H, \bar{A})$defined as follow

$$(H, \bar{A})_1 = \{H_1(u) : u \in E \times X \times \{1\}\}.$$

Example 3.13: Consider Example 3.2. Then the agree-bipolar neutrosophic soft expert set $(H, \bar{A})_1$ over U is
$(H, \bar{A})_1 =$
$\{[(e_1, p, 1), < u_1, 0.3, 0.5, 0.7, -0.2, -0.3, -0.4 >, < u_3, 0.5, 0.6, 0.3, -0.3, -0.4, -0.1 >],$

$[(e_1, q, 1), < u_2, 0.8, 0.2, 0.3, -0.1, -0.3, -0.5 >, < u_3, 0.9, 0.5, 0.7, -0.4, -0.1, -0.2 >],$

$$[(e_1, r, 1), < u_1, 0.4, 0.7, 0.6, -0.6, -0.2, -0.4 >],$$
$$[(e_2, p, 1), < u_1, 0.4, 0.2, 0.3, -0.2, -0.3, -0.1 >, < u_2, 0.7, 0.1, 0.3, -0.3, -0.2, -0.5 >],$$
$$[(e_2, q, 1), < u_3, 0.3, 0.4, 0.2, -0.5, -0.1, -0.4 >],$$
$$[(e_2, r, 1), < u_2, 0.3, 0.4, 0.9, -0.4, -0.3, -0.1 >]\}.$$

Definition 3.14: A disagree-bipolar neutrosophic soft expert set $(H, \bar{A})_0$ over U is a bipolar neutrosophic soft expert subset of $(H, \bar{A})$defined as follow

$$(H, \bar{A})_0 = \{F_0(u): u \in E \times X \times \{0\}\}.$$

Example 3.15: Consider Example 3.2. Then the disagree-bipolar neutrosophic soft expert set $(H, \bar{A})_0$ over U is
$(H, \bar{A})_0 = \{[(e_1, p, 0), < u_2, 0.5, 0.2, 0.3, -0.5, -0.2, -0.3 >],$

$$[(e_1, q, 0), < u_1, 0.6, 0.3, 0.5, -0.4, -0.2, -0.6 >],$$
$$[(e_1, r, 0), < u_2, 0.7, 0.6, 0.4, -0.3, -0.4, -0.5 >, < u_3, 0.9, 0.5, 0.7, -0.2, -0.3, -0.5 >],$$
$$[(e_2, p, 0), < u_3, 0.7, 0.9, 0.6, -0.2, -0.3, -0.4 >],$$
$$[(e_2, q, 0), < u_1, 0.7, 0.3, 0.6, -0.3, -0.2, -0.4 >, < u_2, 0.6, 0.2, 0.5, -0.3, -0.1, -0.4 >],$$
$$[(e_2, r, 0), < u_1, 0.6, 0.2, 0.5, -0.5, -0.3, -0.2 >, < u_3, 0.7, 0.2, 0.8, -0.6, -0.2, -0.1 >]\}.$$

Definition 3.16: Union of two bipolar neutrosophic soft expert sets. Let

$\left(H, \bar{A}\right) = \left\{\left\langle u, T^+_{H(e)}(u), I^+_{H(e)}(u), F^+_{H(e)}(u), T^-_{H(e)}(u), I^-_{H(e)}(u), F^-_{H(e)}(u)\right\rangle : \forall e \in A, u \in U\right\}$ and $\left(G, \bar{B}\right) = \left\{\left\langle u, T^+_{G(e)}(u), I^+_{G(e)}(u), F^+_{G(e)}(u), T^-_{G(e)}(u), I^-_{G(e)}(u), F^-_{G(e)}(u)\right\rangle : \forall e \in B, u \in U\right\}$ be two bipolar neutrosophic soft expert sets. Then their union is defined as:

$$((H, \bar{A}) \tilde{\cup} (G, \bar{B}))(u) = \left(\begin{array}{l} \max(T^+_{H(e)}(u), T^+_{G(e)}(u)), \dfrac{I^+_{H(e)}(u) + I^+_{G(e)}(u)}{2}, \min((F^+_{H(e)}(u), F^+_{G(e)}(u)), \\ \min(T^-_{H(e)}(u), T^-_{G(e)}(u)), \dfrac{I^-_{H(e)}(u) + I^-_{G(e)}(u)}{2}, \max((F^-_{H(e)}(u), F^-_{G(e)}(u)) \end{array} \right)$$

$\forall e \in A, u \in U.$

Example 3.17: Let $(H, \bar{A})$ and $(G, \bar{B})$ be two BNSESs over the common universe U

$(H, \bar{A}) = \{[(e_1, p, 1), < u_1, 0.2, 0.5, 0.8, -0.4, -0.3, -0.5 >, < u_3, 0.2, 0.6, 0.5, -0.2, -0.1, -0.4 >], [(e_1, q, 1), < u_1, 0.5, 0.3, 0.6, -0.2, -0.1, -0.3 >, < u_2, 0.8, 0.2, 0.3, -0.2, -0.3, -0.1 >]\}$

$(G, \bar{B})$

$= \{(e_1, p, 1), < u_1, 0.1, 0.6, 0.2, -0.3, -0.1, -0.4 >, < u_2, 0.4, 0.5, 0.8, -0.1, -0.3, -0.5 >\}$

Therefore$(H,\bar{A})\tilde{\cup}(G,\bar{B}) = (R,\bar{C})$

$$(R,\bar{C}) = \left\{\begin{bmatrix} (e_1,p,1), < u_1, 0.2, 0.55, 0.2, -0.4, -0.2, -0.4 >, \\ < u_2, 0.4, 0.5, 0.8 - 0.1, -0.3, -0.5 >, < u_3, 0.2, 0.6, 0.5, -0.2, -0.1, -0.4 > \end{bmatrix},\right.$$

$$[(e_1, q, 1), < u_1, 0.5, 0.3, 0.6, -0.2, -0.1, -0.3 >, < u_2, 0.4, 0.5, 0.8, -0.1, -0.3, -0,5 >]\}.$$

Definition 3.18: Intersection of two bipolar neutrosophic soft expert sets. $(H,\bar{A}) = \left\{\left\langle u, T^+_{H(e)}(u), I^+_{H(e)}(u), F^+_{H(e)}(u), T^-_{H(e)}(u), I^-_{H(e)}(u), F^-_{H(e)}(u)\right\rangle : \forall e \in A, u \in U\right\}$ and $(G,\bar{B}) = \left\{\left\langle u, T^+_{G(e)}(u), I^+_{G(e)}(u), F^+_{G(e)}(u), T^-_{G(e)}(u), I^-_{G(e)}(u), F^-_{G(e)}(u)\right\rangle : \forall e \in B, u \in U\right\}$ be two bipolar neutrosophic soft expert sets. Then their intersection is defined as:

$$((H,\bar{A})\tilde{\cap}(G,\bar{B}))(u) = \begin{pmatrix} \min(T^+_{H(e)}(u), T^+_{G(e)}(u)), \dfrac{I^+_{H(e)}(u) + I^+_{G(e)}(u)}{2}, \max((F^+_{H(e)}(u), F^+_{G(e)}(u)), \\ \max(T^-_{H(e)}(u), T^-_{G(e)}(u)), \dfrac{I^-_{H(e)}(u) + I^-_{G(e)}(u)}{2}, \min((F^-_{H(e)}(u), F^-_{G(e)}(u)) \end{pmatrix}$$

$\forall e \in A, u \in U$.

Example 3.19: Let$(H,\bar{A})$ and $(G,\bar{B})$ be two BNSESs over the common universe U

$$(H,\bar{A}) = \{[(e_1,p,1), < u_1, 0.2, 0.5, 0.8, -0.4, -0.3, -0.5 >, < u_3, 0.2, 0.6, 0.5, -0.2, -0.1, -0.4 >], [(e_1, q, 1), < u_1, 0.5, 0.3, 0.6, -0.2, -0.1, -0.3 >, < u_2, 0.8, 0.2, 0.3, -0.2, -0.3, -0.1 >]\}$$

$$(G,\bar{B}) = \{(e_1,p,1), < u_1, 0.1, 0.6, 0.2, -0.3, -0.1, -0.4 >, < u_2, 0.4, 0.5, 0.8, -0.1, -0.3, -0.5 >\}$$

Therefore$(H,\bar{A})\tilde{\cap}(G,\bar{B}) = (R,\bar{C})$

$(R,\bar{C}) = \{[(e_1,p,1), < u_1, 0.1, 0.55, 0.8, -0.3, -0.2, -0.5 >]\}$.

Proposition 3.20: If $(H,\bar{A})$ and (G,B) are bipolar neutrosophic soft expert sets over U. Then

i.$(H,\bar{A})\tilde{\cup}(G,\bar{B}) = (G,\bar{B})\tilde{\cup}(H,\bar{A})$

ii.$(H,\bar{A})\tilde{\cap}(G,\bar{B}) = (G,\bar{B})\tilde{\cap}(H,\bar{A})$

iii.$((H,\bar{A})^c)^c = (H,\bar{A})$

iv.$(H,\bar{A})\tilde{\cup}\phi = (H,\bar{A}),\ (H,\bar{A})\tilde{\cap}\phi = \phi$

Proof: The proof is straightforward.

4. AN APPLICATION OF BIPOLAR NEUTROSOPHIC SOFT EXPERT SET

In this section, we present an application of bipolar neutrosophic soft expert set theory in a decision-making problem which demonstrates that this method can be successfully applied to problems of many fields that contain uncertainty. We suggest the following algorithm to solving bipolar neutrosophic soft expert based decision making method as follows:

1. Input the bipolar neutrosophic soft expert set (F, Z).
2. Find an agree-multibipolarneutrosophicsoftexpert set and a disagree-bipolarneutrosophicsoftexpert set.
3. Now calculate the bipolar neutrosophic soft expert set [27] the score function s$(u_i) = (T_1^+ + 1 - I_1^+ + 1 - F_1^+ + 1 + T_1^- - I_1^- - F_1^-)/6$ of agree (u_i) and $C_j = \sum_i (u)_{ij}$ for agree- bipolar neutrosophic soft expert set.

4. Now calculate the bipolar neutrosophic soft expert set the score function s$(u_i) = (T_1^+ + 1 - I_1^+ + 1 - F_1^+ + 1 + T_1^- - I_1^- - F_1^-)/6$ of disagree $(u_i)$and$K_j = \sum_i (u)_{ij}$ for disagree- bipolar neutrosophic soft expert set.
5. Find $s_j = c_j - k_j$.
6. Find u, for which $s(u)$ = maxu_j, where $s(u)$ is the optimal choice object. If u has more than one value, then any one of them could be chosen by the school using its option.

Assume that a School wants to fill a position to be chosen by an expert committee. There are three alternatives $U = \{u_1, u_2, u_3\}$,and there are three parameters $E = \{e_1, e_2, e_3\}$ where the parameters e_i $(i = 1,2,3)$ stand for "education," "age," and "experience" respectively. Let $X = \{p, q\}$ be the set of two expert committee members. From those findings we can find the most suitable choice for the decision. After a serious discussion, the experts construct the following bipolar neutrosophic soft expert set:

Step1-

$$(F, Z) = \left\{\left[(e_1, p, 1), \left(\frac{u_1}{\langle 0.9,0.3,0.4,-0.4,-0.2,-0.7\rangle}, \frac{u_2}{\langle 0.8,0.2,0.6,-0.6,-0.3,-0.1\rangle}, \frac{u_3}{\langle 0.6,0.3,0.5,-0.4,-0.2,-0.3\rangle}\right)\right],\right.$$

$$\left[(e_1, q, 1), \left(\frac{u_1}{\langle 0.8,0.1,0.4,-0.6,-0.2,-0.4\rangle}, \frac{u_2}{\langle 0.2,0.1,0.5,-0.7,-0.2,-0.5\rangle}, \frac{u_3}{\langle 0.4,0.2,0.3,-0.3,-0.1,-0.4\rangle}\right)\right],$$

$$\left[(e_2, p, 1), \left(\frac{u_1}{\langle 0.6,0.2,0.3,-0.3,-0.1,-0.2\rangle}, \frac{u_2}{\langle 0.4,0.2,0.5,-0.1,-0.2,-0.2\rangle}, \frac{u_3}{\langle 0.7,0.3,0.6,-0.5,-0.2,-0.3\rangle}\right)\right],$$

$$\left[(e_2, q, 1), \left(\frac{u_1}{\langle 0.6,0.3,0.1,-0.2,-0.1,-0.3\rangle}, \frac{u_2}{\langle 0.7,0.3,0.1,-0.3,-0.1,-0.4\rangle}, \frac{u_3}{\langle 0.6,0.2,0.5,-0.1,-0.2,-0.1\rangle}\right)\right],$$

$$\left[(e_3, p, 1), \left(\frac{u_1}{\langle 0.9,0.4,0.6,-0.4,-0.3,-0.2\rangle}, \frac{u_2}{\langle 0.8,0.4,0.2,-0.2,-0.2,-0.4\rangle}, \frac{u_3}{\langle 0.7,0.3,0.4,-0.4,-0.3,-0.1\rangle}\right)\right],$$

$$\left[(e_3, q, 1), \left(\frac{u_1}{\langle 0.8,0.2,0.4,-0.6,-0.2,-0.3\rangle}, \frac{u_2}{\langle 0.6,0.2,0.3,-0.2,-0.3,-0.1\rangle}, \frac{u_3}{\langle 0.5,0.3,0.1,-0.1,-0.5,-0.3\rangle}\right)\right],$$

$$\left[(e_1, p, 0), \left(\frac{u_1}{\langle 0.2,0.3,0.4,-0.4,-0.1,-0.1\rangle}, \frac{u_2}{\langle 0.8,0.2,0.6,-0.6,-0.3,-0.1\rangle}, \frac{u_3}{\langle 0.6,0.3,0.5,-0.4,-0.2,-0.3\rangle}\right)\right],$$

$$\left[(e_1, q, 0), \left(\frac{u_1}{\langle 0.6,0.2,0.3,-0.5,-0.2,-0.3\rangle}, \frac{u_2}{\langle 0.5,0.2,0.3,-0.6,-0.1,-0.3\rangle}, \frac{u_3}{\langle 0.4,0.1,0.2,-0.2,-0.3,-0.1\rangle}\right)\right],$$

$$\left[(e_2, p, 0), \left(\frac{u_1}{\langle 0.7,0.1,0.5,-0.4,-0.3,-0.2\rangle}, \frac{u_2}{\langle 0.9,0.2,0.4,-0.4,-0.2,-0.1\rangle}, \frac{u_3}{\langle 0.7,0.3,0.1,-0.1,-0.2,-0.5\rangle}\right)\right],$$

$$\left[(e_2,q,0),\left(\frac{u_1}{\langle 0.4,0.3,0.1,-0.2,-0.1,-0.3\rangle},\frac{u_2}{\langle 0.7,0.3,0.1,-0.3,-0.1,-0.4\rangle},\frac{u_3}{\langle 0.6,0.1,0.3,-0.2,-0.1,-0.3\rangle}\right)\right],$$
$$\left[(e_3,p,0),\left(\frac{u_1}{\langle 0.9,0.2,0.4,-0.4,-0.3,-0.2\rangle},\frac{u_2}{\langle 0.8,0.4,0.2,-0.3,-0.1,-0.4\rangle},\frac{u_3}{\langle 0.5,0.3,0.4,-0.4,-0.3,-0.1\rangle}\right)\right],$$
$$\left[(e_3,q,0),\left(\frac{u_1}{\langle 0.7,0.1,0.3,-0.2,-0.1,-0.3\rangle},\frac{u_2}{\langle 0.7,0.2,0.1,-0.2,-0.3,-0.1\rangle},\frac{u_3}{\langle 0.8,0.3,0.2,-0.3,-0.1,-0.2\rangle}\right)\right]\}.$$

Step 2-Construct the bipolar neutrosophic soft expert tables for each opinion (agree, disagree) of expert.

Table 1. Agree-bipolar neutrosophic soft expert set.

	u_1	u_2	u_3
$(e_1,p,1)$	$\langle 0.9,0.3,0.4,-0.4,-0.2,-0.7\rangle$	$\langle 0.8,0.2,0.6,-0.6,-0.3,-0.1\rangle$	$\langle 0.6,0.3,0.5,-0.4,-0.2,-0.3\rangle$
$(e_2,p,1)$	$\langle 0.6,0.2,0.3,-0.3,-0.1,-0.2\rangle$	$\langle 0.4,0.2,0.5,-0.1,-0.2,-0.2\rangle$	$\langle 0.7,0.3,0.6,-0.5,-0.2,-0.3\rangle$
$(e_3,p,1)$	$\langle 0.9,0.4,0.6,-0.4,-0.3,-0.2\rangle$	$\langle 0.8,0.4,0.2,-0.2,-0.2,-0.4\rangle$	$\langle 0.7,0.3,0.4,-0.4,-0.3,-0.1\rangle$
$(e_1,q,1)$	$\langle 0.8,0.1,0.4,-0.6,-0.2,-0.4\rangle$	$\langle 0.2,0.1,0.5,-0.7,-0.2,-0.5\rangle$	$\langle 0.4,0.2,0.3,-0.3,-0.1,-0.4\rangle$
$(e_2,q,1)$	$\langle 0.6,0.3,0.1,-0.2,-0.1,-0.3\rangle$	$\langle 0.7,0.3,0.1,-0.3,-0.1,-0.4\rangle$	$\langle 0.6,0.2,0.5,-0.1,-0.2,-0.1\rangle$
$(e_3,q,1)$	$\langle 0.8,0.2,0.4,-0.6,-0.2,-0.3\rangle$	$\langle 0.6,0.2,0.3,-0.2,-0.3,-0.1\rangle$	$\langle 0.5,0.3,0.1,-0.1,-0.5,-0.3\rangle$

Table 2. Disagree-bipolar neutrosophic soft expert set.

	u_1	u_2	u_3
$(e_1,p,0)$	$\langle 0.2,0.3,0.4,-0.4,-0.1,-0.1\rangle$	$\langle 0.8,0.2,0.6,-0.6,-0.3,-0.1\rangle$	$\langle 0.6,0.3,0.5,-0.4,-0.2,-0.3\rangle$
$(e_2,p,0)$	$\langle 0.7,0.1,0.5,-0.4,-0.3,-0.2\rangle$	$\langle 0.9,0.2,0.4,-0.4,-0.2,-0.1\rangle$	$\langle 0.7,0.3,0.1,-0.1,-0.2,-0.5\rangle$
$(e_3,p,0)$	$\langle 0.9,0.2,0.4,-0.4,-0.3,-0.2\rangle$	$\langle 0.8,0.4,0.2,-0.3,-0.1,-0.4\rangle$	$\langle 0.5,0.3,0.4,-0.4,-0.3,-0.1\rangle$
$(e_1,q,0)$	$\langle 0.6,0.2,0.3,-0.5,-0.2,-0.3\rangle$	$\langle 0.5,0.2,0.3,-0.6,-0.1,-0.3\rangle$	$\langle 0.4,0.1,0.2,-0.2,-0.3,-0.1\rangle$
$(e_2,q,0)$	$\langle 0.4,0.3,0.1,-0.2,-0.1,-0.3\rangle$	$\langle 0.7,0.3,0.1,-0.3,-0.1,-0.4\rangle$	$\langle 0.6,0.1,0.3,-0.2,-0.1,-0.3\rangle$
$(e_3,q,0)$	$\langle 0.7,0.1,0.3,-0.2,-0.1,-0.3\rangle$	$\langle 0.7,0.2,0.1,-0.2,-0.3,-0.1\rangle$	$\langle 0.8,0.3,0.2,-0.3,-0.1,-0.2\rangle$

Step3-Now calculate the scores of agree (u_i) by using the data in Table 1 to obtain values in Table 3.

$$S(u_1)=\frac{[0.9+1-0.3+1-0.4+1+(-0{,}4)-(-0.2)-(-0.7)]}{6}=0.6167$$

Table 3: Agree-bipolar neutrosophic soft expert set.

U	(u_1)	(u_2)	(u_3)
$(e_1,p,1)$	0.6167	0.4667	0.4833
$(e_2,p,1)$	0.5167	0.5167	0.4667
$(e_3,p,1)$	0.5	0.6	0.5
$(e_1,q,1)$	0.55	0.4333	0.5167
$(e_2,q,1)$	0.5667	0.5833	0.5167
$(e_3,q,1)$	0.5167	0.55	0.6333
$C_j=\sum_i (u)_{ij}$	$c_1=3.2667$	$c_2=3.15$	$c_3=3.1166$

Step4-Now calculate the scores of disagree (u_i) by using the data in Table 2 to obtain values in Table 4.

$$S(u_1) = \frac{[0.2 + 1 - 0.3 + 1 - 0.4 + 1 + (-0{,}4) - (-0.1) - (-0.1)]}{6} = 0.3833$$

Table 4: Disagree-bipolar neutrosophic soft expert set.

U	(u_1)	(u_2)	(u_3)
$(e_1, p, 0)$	0.3833	0.4667	0.4833
$(e_2, p, 0)$	0.5333	0.5333	0.65
$(e_3, p, 0)$	0.55	0.5667	0.4667
$(e_1, q, 0)$	0.5167	0.4667	0.55
$(e_2, q, 0)$	0.5333	0.5833	0.5667
$(e_3, q, 0)$	0.5833	0.6	0.55
$k_j = \sum_i (u)_{ij}$	$k_1 = 3.1$	$k_2 = 3.2167$	$k_3 =$3.2667

Step5-

Table 5:$u_j = c_j - k_j$

j	U	c_j	k_j	s_j
1	(u_1)	3.2667	3.1	0.1667
2	(u_2)	3.15	3.2167	-0.0667
3	(u_3)	3.1166	3.2667	-0.15

From Tables 3and 4 we are able to calculate the values of $u_j = c_j - k_j$ as in Table 5.

Step 6- Clearly, the maximum score is the score 0.1667, shown in the above for the u_1. Hence the best decision for experts are to selectu_1, followed by u_2.

4. FUTURE RESEARCH DIRECTIONS

In this paper, we have introduced the concept of bipolar neutrosophic soft expert set and its basic operations, namely complement, union and intersection of them has been explained with example which has wider application in the field of modern sciences and technology, especially in research areas of computer science including database theory, data mining, neural networks, expert systems, cluster analysis, control theory, and image capturing. Using this concept, we can extend our work in (1) bipolar interval-valued neutrosophic soft expert set (2) On mapping bipolar neutrosophic soft expert sets.

5. CONCLUSION

In this paper, we have introduced the concept of bipolar neutrosophic soft expert set which is more effective and useful and studied some of its properties. Also the basic operations on neutrosophic soft expert set namely complement, union and intersection have been defined.

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REFERENCES

Atanassov, K. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets and Systems*, 20, 87–96.

Alkhazaleh, S., A. R. Salleh & N. Hassan, (2011). Fuzzy parameterized interval- valued fuzzy soft set. *Applied Mathematical Sciences,* 5(67), 3335-3346.

Alkhazaleh S. & A. R. Salleh, (2011). Soft expert sets, *Advances in Decision Sciences*, Article ID 757868, 12 pages. doi:10.1155/2011/75786815-28.

Bosc, P., & Pivert, O. (2013). On a fuzzy bipolar relational algebra, *Information Sciences*, 219, 1–16.

Broumi, S., & Smarandache, F. (2015a). Single valued neutrosophic soft expert sets and their application in decision making. *Journal of New Theory*, *3*, 67-88.

Broumi, S., & Smarandache, F. (2015b). Possibility single valued neutrosophic soft expert sets and its application in decision making. *Journal of New Theory*, *4*, 06-29.

Broumi, S., Ali, M., & Smarandache, F. (2015). Mappings on neutrosophic soft expert sets. *Journal of New Theory*, *5*, 26-42.

Broumi, S, Talea, M, Bakali, A., & Smarandache, F. (2016a). Single valued neutrosophic graphs. *Journal of New Theory,* 10, 86-101.

Broumi, S, Talea, M, Bakali, A., & Smarandache, F. (2016b). On bipolar single valued neutrosophic graphs. *Journal of New Theory*,11, 84-102.

Broumi, S, Talea, M, Bakali, A., & Smarandache, F. (2016c). Isolated single valued neutrosophic graphs. *Neutrosophic Sets and Systems*, 11, 74-78.

Broumi, S, Smarandache, F., Talea, M., & Bakali, A. (2016). An introduction to bipolar single valued neutrosophic graph theory. *Applied Mechanics and Materials*,.841, 184-191.

Broumi, S, Talea, M., Smarandache, F. & Bakali, A. (2016). Single valued neutrosophic graphs: degree, order and size. IEEE World Congress on Computational Intelligence, 2444-2451.

Chen, J., S. Li, S. Ma, & X. Wang, (2014). m-Polar fuzzy sets: An extension of bipolar fuzzy sets, *The Scientific World Journal*. http://dx.doi.org/10.1155/2014/416530.

Cheng H. D. & Guo, Y. (2008). A new neutrosophic approach to image thresholding, *New Mathematics and Natural Computation,* 4(3) 291–308.

Deli, I., Ali, M., & Smarandache, F. (2015). Bipolar neutrosophic sets and their application based on multi-criteria decision making problems. In Advanced Mechatronic Systems (ICAMechS), 2015 International Conference on (pp. 249-254). IEEE.

Guo Y. & Cheng, H. D. (2009). New neutrosophic approach to image segmentation. *Pattern Recognition*, 42, 587–595.

Guo, Y., & Sengur, A. (2015). A novel 3D skeleton algorithm based on neutrosophic cost function, *Applied Soft Computing*, 36, 210-217.

Karaaslan, F. (2016). Possibility neutrosophic soft sets and PNS-decision making method. *Applied Soft Computing.* doi:10.1016/j.asoc.2016.07.013.

Kang, M. K., & Kang, J. G. (2012). Bipolar fuzzy set theory applied to sub-semigroups with operators in semigroups. *The Pure and Applied Mathematics*, *19*(1), 23-35.

Kharal, A. (2014). A neutrosophic multi-criteria decision making method. *New Mathematics and Natural*

Computation, *10*(02), 143-162.

Lee, K. M., (2000). Bipolar-valued fuzzy sets and their operations. Proc. Int. Conf. on Intelligent Technologies, Bangkok, Thailand, 307-312.

Lee, K. J. (2009). Bipolar fuzzy subalgebras and bipolar fuzzy ideals of BCK/BCI-algebras. *Bulletin of the Malaysian Mathematical Sciences Society*, 32/3, 361-373.

Liu P. & Wang, Y. (2014). Multiple attribute decision-making method based on single-valued neutrosophic normalized weighted Bonferroni mean. *Neural Computing and Applications*, 25 7/8, 2001-2010.

Liu P., & Shi, L. (2015). The generalized hybrid weighted average operator based on interval neutrosophic hesitant set and its application to multiple attribute decision making, *Neural Computing and Applications*, 26 /2, 457-471.

Maji, P. K., Roy, A. R. & Biswas, R. (2003) Soft set theory. *Computers and Mathematics with Applications*, 45(4-5): 555 – 562.

Maji, P.K., (2013). Neutrosophic soft set. *Computers and Mathematics with Applications*, 45, 555-562

Majumdar P. & Samanta, S. K. (2014). On similarity and entropy of neutrosophic sets. *Journal of Intelligent &* Fuzzy *Systems*, 26/3,1245–1252.

Majumder, S.K. (2012). Bipolar valued fuzzy sets in Γ-semigroups, *Mathematica Aeterna*, 2/3, 203 – 213.

Manemaran, S. V., & Chellappa, B. (2010). Structures on bipolar fuzzy groups and bipolar fuzzy D-ideals under (T, S) norms. *International Journal of Computer Applications*, *9*(12), 7-10.

Molodtsov, D.A. (1999). Soft set theory-first results. *Computers and Mathematics with Applications*, 37 19-31.

Peng, J. J., Wang, J. Q., Wang, J., Zhang, H. Y., & Chen, X. H. (2016). Simplified neutrosophic sets and their applications in multi-criteria group decision-making problems. *International Journal of Systems Science*, *47*(10), 2342-2358. doi:10.1080/00207721.2014.994050.

Şahin, M., Alkhazaleh, S., & Uluçay, V. (2015). Neutrosophic soft expert sets. *Applied Mathematics*, 6(01), 116.

Sahin R. and A. Kucuk, (2014). Subsethood measure for single valued neutrosophic sets, *Journal of Intelligent and Fuzzy Systems,* DOI: 10.3233/IFS-141304.

Smarandache, F. (1999). A unifying field in logics. Neutrosophy: Neutrosophic probability, set and logic. Rehoboth: American Research Press.

Abdel-Basset, M., Mohamed, M., Smarandache, F., & Chang, V. (2018). Neutrosophic Association Rule Mining Algorithm for Big Data Analysis. *Symmetry*, *10*(4), 106.

Abdel-Basset, M., & Mohamed, M. (2018). The Role of Single Valued Neutrosophic Sets and Rough Sets in Smart City: Imperfect and Incomplete Information Systems. Measurement. Volume 124, August 2018, Pages 47-55

Abdel-Basset, M., Gunasekaran, M., Mohamed, M., & Smarandache, F. A novel method for solving the fully neutrosophic linear programming problems. *Neural Computing and Applications*, 1-11.

Abdel-Basset, M., Manogaran, G., Gamal, A., & Smarandache, F. (2018). A hybrid approach of neutrosophic sets and DEMATEL method for developing supplier selection criteria. *Design Automation for Embedded Systems*, 1-22.

Abdel-Basset, M., Mohamed, M., & Chang, V. (2018). NMCDA: A framework for evaluating cloud computing services. *Future Generation Computer Systems*, *86*, 12-29.

Abdel-Basset, M., Mohamed, M., Zhou, Y., & Hezam, I. (2017). Multi-criteria group decision making based on neutrosophic analytic hierarchy process. *Journal of Intelligent & Fuzzy Systems*, *33*(6), 4055-4066.

Abdel-Basset, M.; Mohamed, M.; Smarandache, F. An Extension of Neutrosophic AHP–SWOT Analysis for Strategic Planning and Decision-Making. *Symmetry* 2018, *10*, 116.