# Jaccard Vector Similarity Measure of Bipolar Neutrosophic Set Based on Multi-Criteria Decision Making

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**3 authors:**

Memet Şahin
Gaziantep University


Irfan Deli
Kilis 7 Aralik Üniversitesi


Vakkas Uluçay

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**Mehmet Şahin**
Gaziantep University, Department of Mathematics, Gaziantep 27310-Turkey

**Irfan Deli**
Kilis 7 Aralık University, Muallim Rıfat Faculty of Education, Kilis 79000, Turkey

**Vakkas Uluçay**
Gaziantep University, Department of Mathematics, Gaziantep 27310-Turkey

**ABSTRACT**

The main aim of this study is to present a novel method based on multi-criteria decision making for bipolar neutrosophic sets. Therefore, Jaccard vector similarity and weighted Jaccard vector similarity measure is defined to develop the bipolar neutrosophic decision making method. In addition, the method is applied to a numerical example in order to confirm the practicality and accuracy of the proposed method.

**Keywords:** Neutrosophic set, bipolar neutrosophic set, Jaccard vector similarity measure, multi-criteria decision making.

## 1. Introduction

As generalization of fuzzy set [20] and intuitionistic fuzzy set [1], Smarandache [10,11] initiated the notation of neutrosophic set which has a truth-membership, a indeterminacy membership and a false-membership function in $^{-}[0,1]^{+}$ . After Smarandache, many extensions and examples of neutrosophic sets have been introduced by many researcher such as; single valued neutrosophic sets [13], interval neutrosophic sets [14], single valued neutrosophic multi-sets [5,16], N-valued interval neutrosophic sets [2], neutrosophic soft sets [9], interval neutrosophic soft sets [7], possibility neutrosophic soft sets [8], rough neutrosophic sets [12], and so on. As a significant content in fuzzy sets, the similarity measure between the these sets have received more attention to calculate the degree of similarity measure between proposed the sets in [2,3,4,12,15,17,18,19].

Recently, different a generalization of neutrosophic sets is proposed by Deli et a.[6] is called bipolar neutrosophic sets. The bipolar neutrosophic set can be effectively used to evaluate information during decision making process. Therefore, in this study we present a novel method by extending the Jaccard vector similarity measures of neutrosophic sets to bipolar neutrosophic sets.

## 2. Preliminaries

In the subsection, we give some concepts related to neutrosophic sets and bipolar neutrosophic sets.

**Definition 2.1** [10-11] Let X be a universe of discourse. Then a neutrosophic set N is defined as:

$$N = \{\langle x, F_N(x), T_N(x), I_N(x)\rangle : x \in X\},$$

which is characterized by a truth-membership function $T_N: X \to ]0^-, 1^+[$, an indeterminacy-membership function $I_N: X \to ]0^-, 1^+[$and a falsity-membership function $F_N: X \to ]0^-, 1^+[$.

There is not restriction on the sum of $T_N(x)$, $I_N(x)$ and $F_N(x)$, so $0^- \le \sup T_N(x) \le \sup I_N(x) \le \sup F_N(x) \le 3^+$.

**Definition 2.2** [15] Let X be a universe of discourse. Then a single valued neutrosophic set(SVN-set) is defined as:

$$N = \{\langle x, F_N(x), T_N(x), I_N(x)\rangle : x \in X\},$$

which is characterized by a truth-membership function $T_N: X \to [0,1]$, an indeterminacy-membership function $I_N: X \to [0,1]$and a falsity-membership function $F_N: X \to [0,1]$.

There is not restriction on the sum of $T_N(x)$, $I_N(x)$ and $F_N(x)$, so $0 \le \sup T_N(x) \le \sup I_N(x) \le \sup F_N(x) \le 3$.

**Definition 2.3** [6] Let X be a universe of discourse. A bipolar neutrosophic set $A_{BNS}$ in $X$ is defined as an object of the form

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

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

The positive membership degree $T^+(x), I^+(x), F^+(x)$ denotes the truth membership, indeterminate membership and false membership of an element $x \in X$ corresponding to a bipolar neutrosophic set $A_{BNS}$ and the negative membership degree $T^-(x), I^-(x), F^-(x)$ denotes the truth membership, indeterminate membership and false membership of an element $x \in X$ to some implicit counter-property corresponding to a bipolar neutrosophic set $A_{BNS}$.

Set- theoretic operations, for two bipolar neutrosophic set

$$A_{BNS} = \left\{ \left\langle x, T_1^+(x), I_1^+(x), F_1^+(x), T_1^-(x), I_1^-(x), F_1^-(x) \right\rangle : x \in X \right\}$$

and

$$B_{BNS} = \left\{ \left\langle x, T_2^+(x), I_2^+(x), F_2^+(x), T_2^-(x), I_2^-(x), F_2^-(x) \right\rangle : x \in X \right\}$$ are given as;

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

$$T^+_1(x) \le T_2^+(x) \; I^+_1(x) \le I_2^+(x), F^+_1(x) \ge F_2^+(x),$$

and

$$T^-_1(x) \ge T_2^-(x), \; I^-_1(x) \ge I^-_2(x), \; F_1^-(x) \le F_2^-(x)$$

for all $x \in X$ .

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

$$T^{+}_{1}(x) = T_{2}^{+}(x),\; I^{+}_{1}(x) = I_{2}^{+}(x),\; F^{+}_{1}(x) = F_{2}^{+}(x),$$

and

$$T^{-}_{1}(x) = T_{2}^{-}(x),\; I^{-}_{1}(x) = I^{-}_{2}(x),\; F_{1}^{-}(x) = F_{2}^{-}(x)$$

for all $x \in X$ .

3. The complement of $A_{BNS}$ is denoted by $A^{o}_{BNS}$ and is defined by

$$T_{A^c}^{+}(x) = \{1^{+}\} - T_{A}^{+}(x),\; I_{A^c}^{+}(x) = \{1^{+}\} - I_{A}^{+}(x),\; F_{A^c}^{+}(x) = \{1^{+}\} - F_{A}^{+}(x)$$

and

$$T_{A^c}^{-}(x) = \{1^{-}\} - T_{A}^{-}(x),\; I_{A^c}^{-}(x) = \{1^{-}\} - I_{A}^{-}(x),\; F_{A^c}^{-}(x) = \{1^{-}\} - F_{A}^{-}(x),$$

for all $x \in X$ .

4. The intersection

$$(A_{BNS} \cap B_{BNS})(x) = \left\{ \begin{array}{l} \left\langle x, \min(T_1^{+}(x), T_2^{+}(x)), \dfrac{I_1^{+}(x) + I_2^{+}(x)}{2}, \max((F_1^{+}(x), F_2^{+}(x)), \max(T_1^{-}(x), T_2^{+}(x)), \right. \\ \left. \dfrac{I_1^{-}(x) + I_2^{-}(x)}{2}, \min((F_1^{-}(x), F_2^{-}(x)) \right\rangle : x \in X \end{array} \right\}$$

5. The union

$$(A_{BNS} \cup B_{BNS})(x) = \left\{ \begin{array}{l} \left\langle x, \max(T_1^{+}(x), T_2^{+}(x)), \dfrac{I_1^{+}(x) + I_2^{+}(x)}{2}, \min((F_1^{+}(x), F_2^{+}(x)), \right. \\ \left. \min(T_1^{-}(x), T_2^{+}(x)), \dfrac{I_1^{-}(x) + I_2^{-}(x)}{2}, \max((F_1^{-}(x), F_2^{-}(x)) \right\rangle : x \in X \end{array} \right\}.$$

**Definition 2.3** [19] Let $A = \langle T_A(x_i), I_A(x_i), F_A(x_i) \rangle$ and $B = \langle T_B(x_i), I_B(x_i), F_B(x_i) \rangle$ be two SVNSs in a universe of discourse $X = (x_1, x_2, \dots, x_n)$. Then the Jaccard similarity measure between SVN-sets A and B in the vector space is defined as follows:

$$J(A,B) = \frac{1}{n}\sum_{i=1}^{n} \times \left( \frac{T_A(x_i)T_B(x_i) + I_A(x_i)I_B(x_i) + F_A(x_i)F_B(x_i)}{\left[ \begin{array}{c} \left(T_A(x_i)\right)^2 + \left(I_A(x_i)\right)^2 + \left(F_A(x_i)\right)^2 + \left(T_B(x_i)\right)^2 + \left(I_B(x_i)\right)^2 + \left(F_B(x_i)\right)^2 \\ -\left(T_A(x_i)T_B(x_i) + I_A(x_i)I_B(x_i) + F_A(x_i)F_B(x_i)\right) \end{array} \right]} \right)$$

Then, this similarity measure satisfies the following properties:

1. $0 \le J(A,B) \le 1$,
2. $J(A,B) = J(B,A)$,
3. $J(A,B) = 1$ for $A = B$ i.e. $T_A(x) = T_B(x), I_A(x) = I_B(x), F_A(x) = F_B(x), i = (1,2 \dots, n) \in X$.

## 3. Jaccard vector similarity measure of Bipolar Neutrosophic Set

In this section, we present a Jaccard vector similarity and weighted Jaccard vector similarity measure for bipolar neutrosophic sets by extending the approach of SVN-set [19] to bipolar neutrosophic set.

**Definition 3.1** Let $A = \langle T_A^+(x_i), I_A^+(x_i), F_A^+(x_i), T_A^-(x_i), I_A^-(x_i), F_A^-(x_i)\rangle$ and $B = \langle T_B^+(x_i), I_B^+(x_i), F_B^+(x_i), T_B^-(x_i), I_B^-(x_i), F_B^-(x_i)\rangle$ be two BNSs. Then, Jaccard similarity measure between BNS A and B, denoted $J(A,B)$, is defined as follows:

$$J(A,B) = \frac{1}{n}\sum_{i=1}^{n} \times \frac{1}{2}\left(\frac{\begin{array}{c}T_A^+(x_i)T_B^+(x_i) + I_A^+(x_i)I_B^+(x_i) + F_A^+(x_i)F_B^+(x_i) - \\ (T_A^-(x_i)T_B^-(x_i) + I_A^-(x_i)I_B^-(x_i) + F_A^-(x_i)F_B^-(x_i))\end{array}}{\left[\begin{array}{c}\left(T_A^+(x_i)\right)^2 + \left(I_A^+(x_i)\right)^2 + \left(F_A^+(x_i)\right)^2 + \left(T_B^+(x_i)\right)^2 + \left(I_B^+(x_i)\right)^2 + \left(F_B^+(x_i)\right)^2 + \\ \left(T_A^-(x_i)\right)^2 + \left(I_A^-(x_i)\right)^2 + \left(F_A^-(x_i)\right)^2 + \left(T_B^-(x_i)\right)^2 + \left(I_B^-(x_i)\right)^2 + \left(F_B^-(x_i)\right)^2 \\ -\left(T_A^+(x_i)T_B^+(x_i) + I_A^+(x_i)I_B^+(x_i) + F_A^+(x_i)F_B^+(x_i)\right) \\ -\left(T_A^-(x_i)T_B^-(x_i) + I_A^-(x_i)I_B^-(x_i) + F_A^-(x_i)F_B^-(x_i)\right)\end{array}\right]}\right)$$

**Definition 3.2** Let $A = \langle T_A^+(x_i), I_A^+(x_i), F_A^+(x_i), T_A^-(x_i), I_A^-(x_i), F_A^-(x_i)\rangle$ and $B = \langle T_B^+(x_i), I_B^+(x_i), F_B^+(x_i), T_B^-(x_i), I_B^-(x_i), F_B^-(x_i)\rangle$ be two BNSs and $w_i \in [0,1]$ be the weight of each element $x_i$ for $, i = (1,2 \dots, n)$ such that $\sum_{i=1}^{n} w_i = 1$. Then, weighted Jaccard similarity measure between BNS A and B, denoted $J_w(A,B)$, is defined as follows:

$$J_w(A,B) = \sum_{i=1}^{n} \times \frac{1}{2}\left(\frac{w_i\left[\begin{array}{c}T_A^+(x_i)T_B^+(x_i) + I_A^+(x_i)I_B^+(x_i) + F_A^+(x_i)F_B^+(x_i) - \\ (T_A^-(x_i)T_B^-(x_i) + I_A^-(x_i)I_B^-(x_i) + F_A^-(x_i)F_B^-(x_i))\end{array}\right]}{\left[\begin{array}{c}\left(T_A^+(x_i)\right)^2 + \left(I_A^+(x_i)\right)^2 + \left(F_A^+(x_i)\right)^2 + \left(T_B^+(x_i)\right)^2 + \left(I_B^+(x_i)\right)^2 + \left(F_B^+(x_i)\right)^2 + \\ \left(T_A^-(x_i)\right)^2 + \left(I_A^-(x_i)\right)^2 + \left(F_A^-(x_i)\right)^2 + \left(T_B^-(x_i)\right)^2 + \left(I_B^-(x_i)\right)^2 + \left(F_B^-(x_i)\right)^2 \\ -\left(T_A^+(x_i)T_B^+(x_i) + I_A^+(x_i)I_B^+(x_i) + F_A^+(x_i)F_B^+(x_i)\right) \\ -\left(T_A^-(x_i)T_B^-(x_i) + I_A^-(x_i)I_B^-(x_i) + F_A^-(x_i)F_B^-(x_i)\right)\end{array}\right]}\right)$$

**Proposition 3.3** Let $J_w(A,B)$ be a Jaccard similarity measure between bipolar neutrosophic sets A and B. Then, we have

1. $0 \le J_w(A,B) \le 1$,
2. $J_w(A,B) = J_w(B,A)$,
3. $J_w(A,B) = 1$ for $A = B$ i.e. $T_A^+(x_i) = T_B^+(x_i), I_A^+(x_i) = I_B^+(x_i), F_A^+(x_i) = F_B^+(x_i), T_A^-(x_i) = T_B^-(x_i), I_A^-(x_i) = I_B^-(x_i), F_A^-(x_i) = F_B^-(x_i)$ $i = (1,2 \dots, n) \in X$.

**Proof:**

1. It is clear from Definition 3.2.

2.

$$J_w(A,B) = \sum_{i=1}^{n} \times \frac{1}{2} \left( \frac{w_i \begin{bmatrix} T_A^+(x_i)T_B^+(x_i) + I_A^+(x_i)I_B^+(x_i) + F_A^+(x_i)F_B^+(x_i) - \\ (T_A^-(x_i)T_B^-(x_i) + I_A^-(x_i)I_B^-(x_i) + F_A^-(x_i)F_B^-(x_i)) \end{bmatrix}}{\begin{bmatrix} \left(T_A^+(x_i)\right)^2 + \left(I_A^+(x_i)\right)^2 + \left(F_A^+(x_i)\right)^2 + \left(T_B^+(x_i)\right)^2 + \left(I_B^+(x_i)\right)^2 + \left(F_B^+(x_i)\right)^2 + \\ \left(T_A^-(x_i)\right)^2 + \left(I_A^-(x_i)\right)^2 + \left(F_A^-(x_i)\right)^2 + \left(T_B^-(x_i)\right)^2 + \left(I_B^-(x_i)\right)^2 + \left(F_B^-(x_i)\right)^2 \\ -\left(T_A^+(x_i)T_B^+(x_i) + I_A^+(x_i)I_B^+(x_i) + F_A^+(x_i)F_B^+(x_i)\right) \\ -\left(T_A^-(x_i)T_B^-(x_i) + I_A^-(x_i)I_B^-(x_i) + F_A^-(x_i)F_B^-(x_i)\right) \end{bmatrix}} \right)$$

$$= \sum_{i=1}^{n} \times \frac{1}{2} \left( \frac{w_i \begin{bmatrix} T_B^+(x_i)T_A^+(x_i) + I_B^+(x_i)I_A^+(x_i) + F_B^+(x_i)F_A^+(x_i) - \\ (T_B^-(x_i)T_A^-(x_i) + I_B^-(x_i)I_A^-(x_i) + F_B^-(x_i)F_A^-(x_i)) \end{bmatrix}}{\begin{bmatrix} \left(T_B^+(x_i)\right)^2 + \left(I_B^+(x_i)\right)^2 + \left(F_B^+(x_i)\right)^2 + \left(T_A^+(x_i)\right)^2 + \left(I_A^+(x_i)\right)^2 + \left(F_A^+(x_i)\right)^2 - \\ \left(T_B^-(x_i)\right)^2 + \left(I_B^-(x_i)\right)^2 + \left(F_B^-(x_i)\right)^2 + \left(T_A^-(x_i)\right)^2 + \left(I_A^-(x_i)\right)^2 + \left(F_A^-(x_i)\right)^2 \\ -\left(T_B^+(x_i)T_A^+(x_i) + I_B^+(x_i)I_A^+(x_i) + F_B^+(x_i)F_A^+(x_i)\right) \\ -\left(T_B^-(x_i)T_A^-(x_i) + I_B^-(x_i)I_A^-(x_i) + F_B^-(x_i)F_A^-(x_i)\right) \end{bmatrix}} \right)$$

$$= J_w(B,A).$$

3. Since $T_A^+(x_i) = T_B^+(x_i), I_A^+(x_i) = I_B^+(x_i), F_A^+(x_i) = F_B^+(x_i), T_A^-(x_i) = T_B^-(x_i), I_A^-(x_i) = I_B^-(x_i), F_A^-(x_i) = F_B^-(x_i)$ $i = (1,2 \dots, n) \in X$, we have $J_w(A,B) = 1$.
   The proof is completed.

## 4. BN- Multi-criteria Decision Making Method

In this section, we developed BN- Multi-criteria Decision Making Method based on weighted Jaccard vector similarity for bipolar neutrosophic sets by extending the some definitions of SVN-set [19,21] to bipolar neutrosophic set.

**Definition 4.1** Let $U = (u_1, u_2, \dots, u_m)$ be a set of alternatives, $A = (a_1, a_2, \dots, a_n)$ be the set of criteria, $w = (w_1, w_2, \dots, w_n)^T$ be the weight vector of the $a_j$ $(j = 1,2 \dots, n)$ such that $w_j \geq 0$ and $\sum_{i=1}^{n} w_i = 1$ and $[b_{ij}]_{mxn} = \langle T_{ij}^+, I_{ij}^+, F_{ij}^+, T_{ij}^-, I_{ij}^-, F_{ij}^- \rangle$ be the decision matrix in which the rating values of the alternatives. Then

$$\left[b_{ij}\right]_{m\times n} = \begin{array}{c} \\ u_1 \\ u_2 \\ \vdots \\ u_m \end{array} \begin{array}{c} \begin{array}{cccc} a_1 & a_2 & \cdots & a_n \end{array} \\ \begin{pmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & & \ddots & \vdots \\ b_{m1} & b_{m2} & \cdots & b_{mn} \end{pmatrix} \end{array}$$

is called a BN-multi-attribute decision making matrix of the decision maker.

Also; $b_j^*$ is positive ideal bipolar neutrosophic solution of decision matrix $\left[b_{ij}\right]_{m\times n}$ as form:

$$b_j^* = \langle \max_i\{T_{ij}^+\}, \min_i\{I_{ij}^+\}, \min_i\{F_{ij}^+\}, \min_i\{T_{ij}^-\}, max_i\{I_{ij}^-\}, \max_i\{T_{ij}^-\}\rangle$$

and $\bar{b}_j^*$ is negative ideal bipolar neutrosophic solution of decision matrix $\left[b_{ij}\right]_{m\times n}$ as form:

$$\bar{b}_j^* = \langle \min_i\{T_{ij}^+\}, \max_i\{I_{ij}^+\}, \max_i\{F_{ij}^+\}, \max_i\{T_{ij}^-\}, min_i\{I_{ij}^-\}, \min_i\{T_{ij}^-\}\rangle.$$

**Algorithm:**

**Step1.** Give the decision-making matrix $\left[b_{ij}\right]_{m\times n}$; for decision;

**Step2.** Compute the positive ideal (or negative ideal) bipolar neutrosophic solution $b_j^* = \{b_1^*, b_2^*, \ldots b_n^*\}$ fo r$\left[b_{ij}\right]_{m\times n}$;

**Step3.** Calculate the weighted Jaccard vector similarity measure $S_i$ between positive ideal (or negative ideal) bipolar neutrosophic solution $b_j^*$ and $b_i = \langle T_{ij}^+, I_{ij}^+, F_{ij}^+, T_{ij}^-, I_{ij}^-, F_{ij}^-\rangle$ and $(i = 1,2\ldots,m)$ $(j = 1,2\ldots,n)$ as;

$$S_i = J_w(b_j^*, b_i) = \sum_{j=1}^{n} \times \left( \frac{w_i\left[\begin{array}{c}(T_j^*)^+(T_{ij}^*)^+ + (I_j^*)^+(I_{ij}^*)^+ + (F_j^*)^+(F_{ij}^*)^+ - \\ (T_j^*)^-(T_{ij}^*)^- - (I_j^*)^-(I_{ij}^*)^- - (F_j^*)^-(F_{ij}^*)^-\end{array}\right]}{\left[\begin{array}{c}((T_j^*)^+)^2 + ((I_j^*)^+)^2 + ((F_j^*)^+)^2 + ((T_{ij}^*)^+)^2 + ((I_{ij}^*)^+)^2 + ((F_{ij}^*)^+)^2 + \\ ((T_j^*)^-)^2 + ((I_j^*)^-)^2 + ((F_j^*)^-)^2 + ((T_{ij}^*)^-)^2 + ((I_{ij}^*)^-)^2 + ((F_{ij}^*)^-)^2 \\ -((T_j^*)^+(T_{ij}^*)^+ + (I_j^*)^+(I_{ij}^*)^+ + (F_j^*)^+(F_{ij}^*)^+) \\ -((T_j^*)^-(T_{ij}^*)^- + (I_j^*)^-(I_{ij}^*)^- + (F_j^*)^-(F_{ij}^*)^-)\end{array}\right]} \right)$$

**Step 4.** Determine the nonincreasing order of $S_i = J_w(b_j^*, b_i)$ $(i = 1,2\ldots,m)$ $(j = 1,2\ldots,n)$ and select the best alternative.

Now, we give a numerical example as follows;

**Example 4.2** Let us consider decision making problem adapted from Xu and Cia [21]. We consider Gaziantep hospital who intends to buy bed. Four types of beds (alternatives) $u_i (i = 1,2,3,4)$ are available. The customer takes into account four attributes to evaluate the alternatives; $a_1 =$ air bed; $a_2 =$ moving bed; $a_3 =$ two motorized bed and use the bipolar neutrosophic values to evaluate the four possible alternatives $u_i(i = 1,2,3,4)$ under the above four attributes. Also, the weight vector of the attributes $a_j (j = 1,2,3)$ is $\omega = (0.6,0.3,0.1)^T$. Then,

**Algorithm**

**Step1.** Constructed the decision matrix provided by the Gaziantep hospital as;

**Table 1**: Decision matrix given by Hospital

| | $a_1$ | $a_2$ | $a_3$ |
|---|---|---|---|
| $u_1$ | $\langle 0.5,0.7,0.2,-0.7,-0.3,-0.6\rangle$ | $\langle 0.4,0.4,0.5,-0.7,-0.8,-0.4\rangle$ | $\langle 0.7,0.7,0.5,-0.8,-0.7,-0.6\rangle$ |
| $u_2$ | $\langle 0.9,0.7,0.5,-0.7,-0.7,-0.1\rangle$ | $\langle 0.7,0.6,0.8,-0.7,-0.5,-0.1\rangle$ | $\langle 0.9,0.4,0.6,-0.1,-0.7,-0.5\rangle$ |
| $u_3$ | $\langle 0.3,0.4,0.2,-0.6,-0.3,-0.7\rangle$ | $\langle 0.2,0.2,0.2,-0.4,-0.7,-0.4\rangle$ | $\langle 0.9,0.5,0.5,-0.6,-0.5,-0.2\rangle$ |
| $u_4$ | $\langle 0.9,0.7,0.2,-0.8,-0.6,-0.1\rangle$ | $\langle 0.3,0.5,0.2,-0.5,-0.5,-0.2\rangle$ | $\langle 0.5,0.4,0.5,-0.1,-0.7,-0.2\rangle$ |

**Step2.** Computed the positive ideal bipolar neutrosophic solution as;

$b_j^* = \{\langle 0.9,0.4,0.2,-0.8,-0.3,-0.1\rangle, \langle 0.7,0.2,0.2,-0.7,-0.5,-0.1\rangle, \langle 0.9,0.4,0.5,-0.8,-0.5,-0.2\rangle\}$

**Step3.** Calculated the weighted Jaccard vector similarity measures $S_i = J_w(b_j^*, b_i)$ as;

$$S_1 = 0.03126$$
$$S_2 = 0.05809$$
$$S_3 = 0.05033$$
$$S_4 = 0.30225$$

**Step4**. Rank all the software systems of u (i = 1,2,3,4.) according to the weighted Jaccard vector similarity measure as;

$$S_2 \succ S_3 \succ S_1 \succ S_4$$

and thus $u_2$ is the most desirable alternative.

## 5. Conclusions

In this paper, we developed a multi-criteria decision making for bipolar neutrosophic sets based on Jaccard vector similarity measures and applied to a numerical example in order to confirm the practicality and accuracy of the proposed method. In the future, the method can be extend with different similarity and distance measures in fuzzy set, intuitionistic fuzzy set and neutrosophic set.

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