A MATLAB TOOLBOX FOR INTERVAL VALUED NEUTROSOPHIC MATRICES FOR COMPUTER APPLICATIONS

Said BROUMI
Laboratory of Information Processing, Faculty of Science Ben M'Sik, University Hassan II
broumisaid78@gmail.com

Prof.Dr. Assia BAKALI
Ecole Royale Navale, Boulevard Sour Jdid
assiabakali@yahoo.fr

Dr. Mohamed TALEA
Laboratory of Information Processing, Faculty of Science Ben M'Sik, University Hassan II
taleamohamed@yahoo.fr

Prof.Dr. Florentin SMARANDACHE
Department of Mathematics, University of New Mexico
smarand@unm.edu

Abstract

The concept of interval valued neutrosophic matrices is a generalized structure of fuzzy matrices, intuitionistic fuzzy matrices, interval fuzzy matrices and single valued neutrosophic matrices. Recently many studies have focused on interval valued neutrosophic matrices, In this paper, a variety of operations on interval valued neutrosophic matrices are presented using a new Matlab' package. This package contains some essential functions which could help the researchers to do computations on interval valued neutrosophic matrices quickly.

Keywords: Neutrosophic sets, interval valued neutrosophic matrices, matlab package.

Geliş Tarihi / Received: 02.12.2017
Kabul Tarihi / Accepted: 21.12.2017

I. INTRODUCTION

Smarandache (1998) first defined the concept of neutrosophic set (NS) considering the triplet neutrosophic components (T, I, F), which are independent and their values belong to real standard or nonstandard unit interval]−0, 1+[. To apply the concept of neutrosophic sets (NS) in science and engineering applications, Smarandache (1998) introduced for the first time, the single valued neutrosophic set (SVNS). Later on, Wang et all.(2010) studied some properties related to single valued neutrosophic sets. The neutrosophic set model is an important tool for dealing with real scientific and engineering applications because it can handle not only incomplete information but also the inconsistent information and indeterminate information. Single valued neutrosophic sets were extended to interval valued neutrosophic sets by Zhang et al. (2014) to represent the degree of membership, indeterminacy-membership and falsity membership of an element by interval rather than crisp real number For other works on neutrosophic set and their extensions, see (Garg H. 2017; Tian, et all 2016; Venkatesan and Sriram, 2017).

The interval valued neutrosophic sets has enriched its potentiality since its introduction by Zhang et all. (2014). In some real-life situations, the INS, as a particular case of an NS, can be more flexible in assessing objections than an SVNS. Recently, more studies relating to INSs have been increased rapidly.

Reddy et al. (2016) proposed a new hybrid method which combines AHP and TOPSIS to find best supplier suited for present practical scenario. In Bausys and Zavadskas (2015) proposed a novel extension of VIKOR method for the solution of the multicriteria decision making problems, namely VIKOR-IVNS. In Huang et all (2017) extended the VIKOR method to multiple attribute group decision-making with INNs. Şahin (2017) defined the concept of interval neutrosophic cross-entropy based on two extension, one based on fuzzy cross-entropy and the other based on single-valued neutrosophic cross-entropy.The same author proposed two methods converting an interval neutrosophic set into a fuzzy set and a single-valued neutrosophic set. Sun et al. (2015) combined the Choquet integral and the interval neutrosophic set theory and then gave an application to multi-criteria decision making problem. In Ye J. (2016a, 2014a, 2014b, 2015, 2016b), proposed a series of papers related to application of interval valued neutrosophic set in multicriteria decision making problems. Ma et al.(2017) developed an interval neutrosophic linguistic multi-criteria group decision-making method and applied it toa practical treatment selection method. Garg (2016) developed a new ranking approach by modifying an existing ranking approach for comparing single valued neutrosophic numbers and interval valued neutrosophic numbers, and applied them to handle MCDM problems. The same author (2017) proposed the non-linear programming method for multi-criteria decision making problems under interval neutrosophic set environment. Tian et al. (2016) presented the cross-entropy of interval neutrosophic sets and then applied it to interval valued neutrosophic multi-criteria decision-making problems. In Şahin M. et all (2017) the authors proposed some new operations of (α,β,γ) interval cut set of interval valued neutrosophic sets. Deli (2017) combined interval valued neutrosophicsets with soft set and studied some of their related properties with application in decision making problem. Broumi et al. (2016, 2016, 2016, 2017) applied the concept of interval valued neutrosophic sets on graph theory and studied some interesting results.

Matrices play an important role in the broad area of science and engineering. However, the classical matrix theory sometimes fails to solve the problems involving uncertainties. So for this reason, many works on fuzzy matrices and their extension including triangular fuzzy matrices,type-2 triangular fuzzy matrices, interval valued fuzzy matrices, intuitionistic fuzzy matrices, interval valued intuitionistic fuzzy matrices are carried out by a number of several researchers (Anand and Anand, 2015; Jaisankar and Mani, 2017; Jaisankar et all,2016;Dinagar and Latha,2013; Pal et all,2002; Venkatesan and Sriram,2017; Pal and Pal,2010; Pushpalatha, 2017). In Zahariev (2009), developed a software package and API in MATLAB for working with fuzzy algebras. Peeva and

Kyosev (2004) developed a fuzzy relational calculus toolbox for solving problems in intuitionistic fuzzy relational calculus. Later on, in Karunambigai and Kalaivani (2016) proposed some computing procedures in Matlab for intuitionistic fuzzy operational matrices with suitable examples. The fuzzy and intuitionistic fuzzy toolbox Matlab described above cannot deal with matrices in neutrosophic environment. So, for this reason, Broumi et al. (submitted) developed a Matlab toolbox for computing operational matrices in single valued neutrosophic environments.

To do best of our knowledge there is no study on developing library in Matlab environment for computing the operations on interval valued neutrosophic matrices. So there is a need to this.

The rest of the paper is organized as follows. Section 2 discuss some definitions regarding neutrosophic sets, single valued neutrosophic sets, interval valued neutrosophic sets, the set-theoretic operators on the interval neutrosophic set and interval valued neutrosophic matrix. Section 3 presents some matlab programs for computing operations on interval valued neutrosophic matrices. Section 4 provides some numerical examples in workspace Matlab. Section 5, illustrates the application of interval valued neutrosophic Toolbox Matlab, lastly, section 6 conclude the paper.

II. BACKGROUND AND INTERVAL VALUED NEUTROSOPHIC SETS

In this section, we will discuss some definitions regarding neutrosophic sets, single valued neutrosophic sets, interval valued neutrosophic sets, the set-theoretic operators on the interval neutrosophic set and interval valued neutrosophic matrix, which will be used in the rest of the paper. However, for details on the interval valued neutrosophic sets, one can see (Zhang et all., 2014).

Definition 2.1 [1] Le ξ be an universal set. The neutrosophic set A on the universal set ξ categorized in to three membership functions called the true T_A(x), indeterminate I_A(x) and false F_A(x) contained in real standard or non-standard subset of $]^-0, 1^+[$ respectively.

$$^-0 \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+ \qquad (1)$$

Definition 2.2 [2] Let ξ be a universal set. The single valued neutrosophic sets (SVNs) A on the universal ξ is denoted as following

$$A = \{< x: T_A(x), I_A(x), F_A(x) > x \in \xi\} \qquad (2)$$

The functions $T_A(x) \in [0.\ 1]$, $I_A(x) \in [0.\ 1]$ and $F_A(x) \in [0.\ 1]$ are named "degree of truth, indeterminacy and falsity membership of x in A", satisfy the following condition:

$$0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3 \qquad (3)$$

Definition 2.3 [3] Let ξ be a space of points (objects)with a generic element in ξ denoted by x. An interval valued neutrosophic set (IVNS) A in ξ is characterized by truth-membership function T_A, indeterminacy-membershipfunction I_A, and falsity-membership function F_A. For each point $x \in \xi$, $T_A(x)$, $I_A(x)$, $F_A(x) \subseteq [0, 1]$.

$$A_{\text{IVNS}} = \{\langle [T_A^L(x), T_A^U(x)], [I_A^L(x), I_A^U(x)], [F_A^L(x), F_A^U(x)] \rangle : x \in \xi\}$$

with $0 \leq T_A^U(x) + I_A^U(x) + F_A^U(x) \leq 3 \qquad (4)$

Definition 2.4: [3] Given two interval valued neutrosophic sets

$$A_{\text{IVNS}} = \{\langle [T_A^L(x), T_A^U(x)], [I_A^L(x), I_A^U(x)], [F_A^L(x), F_A^U(x)] \rangle : x \in \xi\}$$

and

$$B_{\mathrm{IVNS}} = \{\langle [\, T_A^L(x), T_A^U(x)], [\, I_A^L(x), I_A^U(x)], [\, F_A^L(x), F_A^U(x)] \rangle : \mathrm{x} \in \xi\}$$

the set-theoretic operators on the interval neutrosophic set are defined as follow.

1. An interval valued neutrosophic set A is contained in another interval valued neutrosophic set B, $\mathrm{A_{IVNS}} \subseteq \mathrm{B_{IVNS}}$, if and only if

$$T_A^L(x) \le T_B^L(x), T_A^U(x) \le T_B^U(x),$$
$$I_A^L(x) \ge I_B^L(x), I_A^U(x) \ge I_B^U(x),$$
$$F_A^L(x) \ge F_B^L(x), F_A^U(x) \ge F_B^U(x), \text{ for all } x \in \xi.$$

2. Two interval valued neutrosophic sets A and B are equal, written as $A_{\mathrm{IVNS}} = B_{\mathrm{IVNS}}$, if and only if A $\subseteq$ B and B $\subseteq$ A, i.e.

$$T_A^L(x) = T_B^L(x), T_A^U(x) = T_B^U(x),$$
$$I_A^L(x) = I_B^L(x), I_A^U(x) = I_B^U(x),$$
$$F_A^L(x) = F_B^L(x), F_A^U(x) = F_B^U(x),$$

for all x ∈ ξ.

3. An interval neutrosophic set A is empty if and only if

$$T_A^L(x) = T_A^U(x) = 0,$$
$$I_A^L(x) = I_A^U(x) = 1 \text{ and}$$
$$F_A^L(x) = F_A^U(x) = 0,$$

for all x ∈ ξ.

4. The complement of an interval neutrosophic set A is denoted by A^c and is defined by

$$A_{\mathrm{IVNS}^c} = \left\{\begin{matrix} x, [F_A^L(x), F_A^U(x)], \\ [1 - I_A^U(x), 1 - I_A^L(x)], : \mathrm{x} \in \mathrm{X} \\ [T_A^L(x), F_A^U(x)] \end{matrix}\right\},$$

for all x in ξ.

5. The intersection of two interval valued neutrosophic sets A and B is an interval valued neutrosophic set $A \cap B$, whose truth-membership, indeterminacy-membership and falsity-membership functions are related to those of A and B by

$$A_{IVNS} \cap B_{IVNS} = \left\{\begin{matrix} x, [T_A^L(x) \wedge T_B^U(x), T_A^U(x) \wedge T_B^U(x)], \\ \langle \quad [I_A^L(x) \vee I_B^U(x), I_A^U(x) \vee I_B^U(x)], \quad \rangle : x \in \xi \\ [F_A^L(x) \vee F_B^U(x), F_A^U(x) \vee F_B^U(x) \end{matrix}\right\},$$

for all x in ξ.

6. The union of two interval neutrosophic sets A and B is an interval neutrosophic set $A_{\mathrm{IVNS}} \cup B_{\mathrm{IVNS}}$, whose truth-membership, indeterminacy-membership and false-membership are related to those of A and B by

$$A_{IVNS} \cup B_{IVNS} = \left\{ \left\langle \begin{matrix} x, [T_A^L(x) \vee T_B^L(x), T_A^U(x) \vee T_B^U(x)], \\ [I_A^L(x) \wedge I_B^L(x), I_A^U(x) \wedge I_B^U(x)], \\ [F_A^L(x) \wedge F_B^L(x), F_A^U(x) \wedge F_B^U(x)] \end{matrix} \right\rangle : x \in \xi \right\},$$

for all x in ξ.

7. The difference of two interval neutrosophic sets A and B is an interval neutrosophic set $A_{\mathrm{IVNS}} \ominus B_{\mathrm{IVNS}}$, whose truth-membership, indeterminacy-membership and falsity-membership functions are related to those of A and B by

$$\mathrm{A}\ominus\mathrm{B}=<[T_{\mathrm{A}\ominus\mathrm{B}}^L, T_{\mathrm{A}\ominus\mathrm{B}}^U], [I_{\mathrm{A}\ominus\mathrm{B}}^L, I_{\mathrm{A}\ominus\mathrm{B}}^U], [F_{\mathrm{A}\ominus\mathrm{B}}^L, F_{\mathrm{A}\ominus\mathrm{B}}^U]> \quad (5)$$

where

$T_{\mathrm{A}\ominus\mathrm{B}}^L=\min(T_A^L(x), F_B^L(x))$, $\quad T_{\mathrm{A}\ominus_2\mathrm{B}}^U=\min(T_A^U(x), F_B^U(x))$

$I_{\mathrm{A}\ominus_2\mathrm{B}}^L= \max(I_A^L(x), 1 - I_B^U(x))$, $\quad I_{\mathrm{A}\ominus_2\mathrm{B}}^U= \max(I_B^U(x), 1 - I_B^L(x))$

$F_{\mathrm{A}\ominus_2\mathrm{B}}^L=\max(F_A^L(x), T_B^L(x))$, $\quad F_{\mathrm{A}\ominus_2\mathrm{B}}^U=\max(F_A^U(x), T_B^U(x))$

In another paper, Karaşan and Kahraman (2017) developed another new difference operation for the interval-valued neutrosophic sets as follow:

$$\mathrm{A}\ominus_2\mathrm{B}=<[T_{\mathrm{A}\ominus_2\mathrm{B}}^L, T_{\mathrm{A}\ominus_2\mathrm{B}}^U], [I_{\mathrm{A}\ominus_2\mathrm{B}}^L, I_{\mathrm{A}\ominus_2\mathrm{B}}^U], [F_{\mathrm{A}\ominus_2\mathrm{B}}^L, F_{\mathrm{A}\ominus_2\mathrm{B}}^U]> \quad (6)$$

Where

$T_{\mathrm{A}\ominus_2\mathrm{B}}^L=T_A^L(x) - F_B^U(x)$, $\quad T_{\mathrm{A}\ominus_2\mathrm{B}}^U=T_A^U(x) - F_B^L(\mathrm{x})$

$I_{\mathrm{A}\ominus_2\mathrm{B}}^L= \max(I_A^L(x), I_B^L(x))$, $\quad I_{\mathrm{A}\ominus_2\mathrm{B}}^U= \max(I_A^U(x), I_B^U(x))$

$F_{\mathrm{A}\ominus_2\mathrm{B}}^L=F_A^L(x) - T_B^U(x)$, $\quad F_{\mathrm{A}\ominus_2\mathrm{B}}^U=F_A^U(x) - T_B^L(\mathrm{x})$

for all x in ξ.

8. The scalar multiplication of interval neutrosophic set A is $A_{\mathrm{IVNS}}.a$, whose truth-membership, indeterminacy-membership and falsity-membership functions are related to those of A by

$$A_{\mathrm{IVNS}}.a = \left\{ \left\langle \begin{matrix} x, [\min(T_A^L(x).a,1), \min(T_A^U(x).a,1)], \\ [\min(I_A^L(x).a,1), \min(I_A^U(x).a,1)], \\ [\min(F_A^L(x).a,1), \min(F_A^U(x).a,1)] \end{matrix} \right\rangle : x \in \xi \right\}$$

for all x $\in \xi$, $a \in \mathrm{R}^+$.

9. The scalar division of interval neutrosophic set A is A_{IVNS}/a, whose truth-membership, indeterminacy-membership and falsity-membership functions are related to those of A by

$$A_{\mathrm{IVNS}}/a == \left\{ \left\langle \begin{matrix} x, [\min(T_A^L(x)/a,1), \min(T_A^U(x)/a,1)], \\ [\min(I_A^L(x)/a,1), \min(I_A^U(x)/a,1)], \\ [\min(F_A^L(x)/a,1), \min(F_A^U(x)/a,1)] \end{matrix} \right\rangle : x \in \xi \right\}$$

for all x $\in \xi$, $a \in R^+$

The score function of an interval valued neutrosophic number is calculated as below:

Definition 2.5 [8, 37,16] Let A be an interval neutrosophic number A_{IVNS}=([$T_A^L(x)$,$T_A^U(x)$], [$I_A^L(x)$,$I_A^U(x)$], [$F_A^L(x)$,$F_A^U(x)$]), the score function of

$$\tilde{S}_{Ridvan}(x)=\frac{T_A^L(x)+T_A^U(x)+4-I_A^L(x)-I_A^U(x)-F_A^L(x)-F_A^U(x)}{6} \quad (7)$$

$$\tilde{S}_{Karasan}(x)=\frac{T_A^L+T_A^U+(1-F_A^L)+(1-F_A^U)}{6}\times(2-I_A^L-I_A^U) \quad (8)$$

$$\tilde{S}_{Nancy}(x)=\frac{4+(T_A^L+T_A^U-2I_A^L-2I_A^U-F_A^L-F_A^U)(4-T_A^L+T_A^U-F_A^L-F_A^U)}{8} \quad (9)$$

Definition 2.6 [21]: An interval valued neutrosophic matrix(IVNM) of order m× n is defined as

$A_{\text{IVNM}}=\left[< a_{ij}, [a_{ij_T}^L, a_{ij_T}^U], [a_{ij_I}^L, a_{ij_I}^U], [a_{ij_F}^L, a_{ij_F}^U] >\right]_{m\times n}$ where

$a_{ij_T}^L$ is the lower membership value of element a_{ij} in A.

$a_{ij_T}^L$ is the upper membership value of element a_{ij} in A.

$a_{ij_T}^L$ is the lower indeterminate-membership value of element a_{ij} in A.

$a_{ij_T}^L$ is the upper indeterminate-membership value of element a_{ij} in A.

$a_{ij_T}^L$ is the lower non- membership value of element a_{ij} in A.

$a_{ij_T}^L$ is the upper non-membership value of element a_{ij} in A.

For simplicity, we write A as

$$A_{\text{IVNM}}=\left[< [a_{ij_T}^L, a_{ij_T}^U], [a_{ij_I}^L, a_{ij_I}^U], [a_{ij_F}^L, a_{ij_F}^U] >\right]_{m\times n} \quad (10)$$

III. COMPUTING THE INTERVAL-VALUED NEUTROSOPHIC MATRIX

To generate the MATLAB program for inputting the interval valued neutrosophic matrices. The procedure is described as follows

```
Function ivnm_out=ivnm(varargin);
% intervalvalued neutrosophic matrix class constructor.
%   mi = ivnm (Aml,Amu,Ail,Aiu,AnlAnu) creates an interval valued valued neutrosophic matrix
%   with interval membership degrees from matrix Am
%  interval indeterminate membership degrees from matrix Ai
%   and interval non-membership degreesfrom Matrix An.
% If the new matrix is not interval valued neutrosophic i.e. Amu(i,j)+Aiu(i,j)+Anu(i,j)>3
% appears warning message, but the new object will be constructed.
if length(varargin)==6
Aml = varargin{1}; % Cell array indexing
Amu = varargin{2};
Ail = varargin{3};
Aiu = varargin{4};
Anl = varargin{5};
Anu = varargin{6} ;
```

```
end
ivnm_.ml=Aml;
```

```
ivnm_.mu=Amu;
ivnm_.il=Ail;
ivnm_.iu=Aiu;
ivnm_.nl=Anl;
ivnm_.nu=Anu;
ivnm_out=class(ivnm_,'ivnm');
if ~checknm(ivnm_out)
disp('Warning! The created new object is NOT an interval valued neutrosophic matrix')
end
```

3.2. Determining complement of an interval-valued neutrosophic matrix

The complement of an interval-valued neutrosophic is defined as follow:

$$A^c = \left[< [a_{ij_F}^L, a_{ij_F}^U], [1-a_{ij_I}^U, 1-a_{ij_I}^L], [a_{ij_T}^L, a_{ij_T}^U] >\right]_{m\times n} \qquad (11)$$

To generate the MATLAB program for finding complement of an interval-valued neutrosophic matrix, simple call of the function named “complement.m” is defined as follow:

```
Function At=complement(A);
% complement of an interval valued neutrosophic matrix A
% "A" have to be interval valued neutrosophic  matrix - "ivnm" object:
a.ml=A.nl;
a.mu=A.nu;
a.il=1-A.iu;
a.iu=1-A.il;
a.nl=A.ml;
a.nu=A.mu;
At=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
```

3.3. Determining the score matrix of an interval-valued neutrosophic matrix

To generate the MATLAB program for obtaining the score matrix of an interval-valued neutrosophic matrix, simple call of the function named “scorefunction.m” is defined as follow:

```
function z=scorefunction(A);
% Score function of an interval valued neutrosophic matrix A in the sense of [8]
% "A" have to be interval valued neutrosophic  matrix - "ivnm" object:
a.ml=A.ml;
a.mu=A.mu;
a.il=A.il;
a.iu=A.iu;
a.nl=A.nl;
a.nu=A.nu;
z=((2+a.ml-a.il-a.nl)+(2+a.mu-a.iu-a.nu))./6
```

3.4. Computing union of two interval-valued neutrosophic matrices

The union of two interval valued neutrosophic matrices A and is defined as follow:

$$A \cup B = C = \left[< [c^L_{ij_T}, c^U_{ij_T}], [c^L_{ij_I}, c^U_{ij_I}], [c^L_{ij_F}, c^U_{ij_F}] >\right]_{m\times n} \quad (12)$$

where

$$c^L_{ij_T} = a^L_{ij_T} \vee b^L_{ij_T},\ c^U_{ij_T} = a^U_{ij_T} \vee b^U_{ij_T}$$
$$c^L_{ij_I} = a^L_{ij_I} \wedge b^L_{ij_I},\ c^U_{ij_I} = a^U_{ij_I} \wedge b^U_{ij_I}$$
$$c^L_{ij_F} = a^L_{ij_F} \wedge b^L_{ij_F},\ c^U_{ij_F} = a^U_{ij_F} \wedge b^U_{ij_F}$$

To generate the MATLAB program for finding the union of two interval valued neutrosophic matrices, simple call of the following function named "union.m" is defined as follow:

```
Function At=union(A,B);
% union of two interval valued neutrosophic matrix A and B
% "A" have to be interval valued neutrosophic  matrix - "ivnm" object:
%"B" have to be interval valued neutrosophic  matrix - "ivnm" object:
a.ml=max(A.ml,B.ml);
a.mu=max(A.mu,B.mu);
a.il=min(A.il,B.il);
a.iu=min(A.iu,B.iu);
a.nl=min(A.nl,B.nl);
a.nu=min(A.nu,B.nu);
At=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
```

3.5. Computing intersection of two interval-valued neutrosophic matrices

The union of two interval valued neutrosophic matrices A and B is defined as follow:

$$A \cap B = D = \left[< [d^L_{ij_T}, d^U_{ij_T}], [d^L_{ij_I}, d^U_{ij_I}], [d^L_{ij_F}, d^U_{ij_F}] >\right]_{m\times n} \quad (13)$$

where

$$d^L_{ij_T} = a^L_{ij_T} \vee b^L_{ij_T},\ d^U_{ij_T} = a^U_{ij_T} \vee b^U_{ij_T}$$
$$d^L_{ij_I} = a^L_{ij_I} \wedge b^L_{ij_I},\ d^U_{ij_I} = a^U_{ij_I} \wedge b^U_{ij_I}$$
$$d^L_{ij_F} = a^L_{ij_F} \wedge b^L_{ij_F},\ d^U_{ij_F} = a^U_{ij_F} \wedge b^U_{ij_F}$$

To generate the MATLAB program forfinding the intersection of two interval-valued neutrosophic matrices, simple call of the function named "intersection.m" is defined as follow:

```
Function At=intersection(A,B);
% intersection of two interval valued neutrosophic matrix A and B
% "A" have to be interval valued neutrosophic  matrix - "ivnm" object:
%"B" have to be interval valued neutrosophic  matrix - "ivnm" object:
a.ml=min(A.ml,B.ml);
a.mu=min(A.mu,B.mu);
a.il=max(A.il,B.il);
a.iu=max(A.iu,B.iu);
a.nl=max(A.nl,B.nl);
a.nu=max(A.nu,B.nu);
```

```
At=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
```

3.6 Computing power of an interval-valued neutrosophic matrix

To generate the MATLAB program for finding the power of interval-valued neutrosophic matrix, simple call of the function named “power.m” is defined as follow:

```
Function At=power(A,k);
%power of an interval valued neutrosophic matrix A
% "A" have to be an interval valued neutrosophic  matrix - "ivnm" object:
for i =2 :k
a.ml=(A.ml).^k;
a.mu=(A.mu).^k;
a.il=(A.il).^k;
a.iu=(A.iu).^k;
a.nl=(A.nl).^k;
a.nu=(A.nu).^k;
At=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
end
```

3.7. Computing addition operation of two interval-valued neutrosophic matrices.

The addition of two interval valued neutrosophic matrices A and B is defined as follow:

$$A \oplus B = S = \left[< [s^L_{ij_T}, s^U_{ij_T}], [s^L_{ij_I}, s^U_{ij_I}], [s^L_{ij_F}, s^U_{ij_F}] >\right]_{\mathrm{m}\times \mathrm{n}} \quad (14)$$

where

$$s^L_{ij_T} = a^L_{ij_T} + b^L_{ij_T} - a^L_{ij_T}.b^L_{ij_T},\ s^U_{ij_T} = a^U_{ij_T} + b^U_{ij_T} - a^U_{ij_T}.b^U_{ij_T}$$

$$s^L_{ij_I} = a^L_{ij_I}.b^L_{ij_I},\ s^U_{ij_I} = a^U_{ij_I}.b^U_{ij_I}$$

$$s^L_{ij_F} = a^L_{ij_F}.b^L_{ij_F},\ s^U_{ij_F} = a^U_{ij_F}.b^U_{ij_F}$$

To generate the MATLAB program for obtaining the addition of two interval-valued neutrosophic matrices, simple call of the function named “addition .m” is defined as follow:

```
Function At=addition(A,B);
% addition operation of two interval valued neutrosophic matrix A and B
% "A" have to be interval valued neutrosophic  matrix - "ivnm" object:
a.ml=A.ml+B.ml-(A.ml).*(B.ml);
a.mu=A.mu+B.mu-(A.mu).*(B.mu);
a.il= (A.il).*(B.il);
a.iu= (A.iu).*(B.iu);
a.nl=(A.nl).*(B.nl);
a.nu=(A.nu).*(B.nu);


At=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
```

3.8. Computing product of two interval-valued neutrosophic matrices

The product of two interval valued neutrosophic matrices A and B is defined as follow:

$$A \odot B = R = \left[< [r_{ij_T}^L, r_{ij_T}^U], [r_{ij_I}^L, r_{ij_I}^U], [r_{ij_F}^L, r_{ij_F}^U] >\right]_{m\times n} \quad (15)$$

where

$$r_{ij_T}^L = a_{ij_T}^L . b_{ij_T}^L,\ r_{ij_T}^U = a_{ij_T}^U . b_{ij_T}^U$$

$$r_{ij_I}^L = a_{ij_I}^L + b_{ij_I}^L - a_{ij_I}^L . b_{ij_I}^L,\ r_{ij_I}^U = a_{ij_I}^U + b_{ij_I}^U - a_{ij_I}^U . b_{ij_I}^U$$

$$r_{ij_F}^L = a_{ij_F}^L + b_{ij_F}^L - a_{ij_F}^L . b_{ij_F}^L,\ r_{ij_F}^U = a_{ij_F}^U + b_{ij_F}^U - a_{ij_F}^U . b_{ij_F}^U$$

To generate the MATLAB program for finding the product operation of two interval-valued neutrosophic matrices, simple call of the function named “product.m” is defined as follow:

```
Function At=product(A,B);
% product operation of two interval valued neutrosophic  matrix A and B
% "A" have to be an interval valued neutrosophic  matrix - "ivnm" object:
a.ml=(A.ml).*(B.ml);
a.mu=(A.mu).*(B.mu);
a.il= A.il+B.il-(A.il).*(B.il);
a.iu=A.iu+B.iu-(A.iu).*(B.iu);
a.nl=A.nl+B.nl-(A.nl).*(B.nl);
a.nu=A.nu+B.nu-(A.nu).*(B.nu);
At=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
```

3.9. Computing transpose of an interval-valued neutrosophic matrix

To generate the MATLAB program for finding the transpose of interval-valued neutrosophic matrix, simple call of the function named “transpose.m” is defined as follow:

```
Function At=transpose(A);
% transpose of an interval valued neutrosophic matrix A
% "A" have to be an interval valued neutrosophic matrix - "ivnm" object:
a.ml=(A.ml)';
a.mu=(A.mu)';
a.il=(A.il)';
a.iu=(A.iu)';
a.nl=(A.nl)';
a.nu=(A.nu)';
At=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
```

3.10. Computing difference of two interval-valued neutrosophic matrices

The difference of two interval valued neutrosophic matrices A and B is defined as follow:

$$A \ominus_2 B = K = \left[< [k_{ij_T}^L, k_{ij_T}^U], [k_{ij_I}^L, k_{ij_I}^U], [k_{ij_F}^L, k_{ij_F}^U] >\right]_{m\times n} \quad (16)$$

where

$$k_{ij_T}^L = a_{ij_T}^L - b_{ij_F}^U,\ k_{ij_T}^U = a_{ij_T}^U - b_{ij_F}^L$$

$$k_{ij_I}^L = \max(a_{ij_I}^L, b_{ij_I}^L),\ k_{ij_I}^U = \max(a_{ij_I}^U, b_{ij_I}^U)$$

$$k_{ij_F}^L = a_{ij_F}^L - b_{ij_T}^U,\ k_{ij_F}^U = a_{ij_F}^U - b_{ij_T}^L$$

To generate the MATLAB program for finding the subtraction operation of two interval-valued neutrosophic matrices, simple call of the function named “diffrence.m” or “diffrence2.m” is defined as follow:

```
Function st=difference(A,B);
% difference operation of two interval valued neutrosophic  matrix A and B refereed to [37]
% "A" have to be an interval valued neutrosophic  matrix - "ivnm" object:
a.ml=A.ml-B.nu;
a.mu=A.mu-B.nl;
a.il=max(A.il,B.il);
a.iu=max(A.iu,B.iu);
a.nl=A.nl-B.mu;
a.nu=A.nu-B.ml;
st=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
```

```
Function st= difference2(A,B);
% difference operation of two interval valued neutrosophic  matrix A and B refereed to [3]
% "A" have to be an interval valued neutrosophic  matrix - "ivnm" object:
c.ml=min(A.ml,B.nl);
c.mu=min(A.mu,B.nu);
c.il=max(A.il,1-B.iu);
c.iu=max(A.iu,1-B.il);
c.nl=max(A.nl,B.ml);
c.nu=max(A.nu,B.mu);
At=ivnm(c.ml,c.mu,c.il,c.iu,c.nl,c.nu);
```

3.11 Computing scalar of an interval-valued neutrosophic matrix

To generate the MATLAB program for obtaining the scalar of interval-valued neutrosophic matrix, simple call of the function named “scalar.m” is defined as follow:

```
function At=scalar (A,k);
%scalar of interval valued neutrosophic matrix A
% "A" have to be an interval valued neutrosophic  matrix - "ivnm" object:
a.ml=(A.ml).*k;
a.mu=(A.mu).*k;
a.il=(A.il).*k;
a.iu=(A.iu).*k;
a.nl=(A.nl).*k;
a.nu=(A.nu).*k;
At=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
```

3.13. Computing scalar multiplication of an interval-valued neutrosophic matrix

The scalar multiplication of an interval neutrosophic matrix A is $A_{\mathrm{IVNM}}.z$ is defined as follow:

$$A_{\mathrm{IVNM}}.z = P = \left[< [p_{ij_T}^L, p_{ij_T}^U], [p_{ij_I}^L, p_{ij_I}^U], [p_{ij_F}^L, p_{ij_F}^U] >\right]_{\mathrm{m}\times\mathrm{n}} \quad (16)$$

where

$p^L_{ij_T} = \min(a^L_{ij_T}.z, 1)$, $p^U_{ij_T} = \min(a^U_{ij_T}.z, 1)$

$p^L_{ij_I} = \min(a^L_{ij_I}.z, 1)$, $p^U_{ij_I} = \min(a^U_{ij_I}.z, 1)$

$p^L_{ij_F} = \min(a^L_{ij_F}.\mathrm{z}, 1)$, $p^U_{ij_F} = \min(a^U_{ij_F}.z, 1)$

To generate the MATLAB program for finding scalar multiplication of interval-valued neutrosophic matrix, simple call of the function named “scalarmult.m” is defined as follow:

```
function At=scalarmult (A,k);
%scalar multiplication of interval valued neutrosophic matrix A
% "A" have to be an interval valued neutrosophic  matrix - "ivnm" object:
a.ml=min((A.ml).*k,1);
a.mu=min((A.mu).*k,1);
a.il=min((A.il).*k,1);
a.iu=min((A.iu).*k,1);
a.nl=min((A.nl).*k,1);
a.nu=min((A.nu).*k,1);
At=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
```

3.14. Computing scalar division of an interval-valued neutrosophic matrix

The scalar division of an interval neutrosophic matrix A is A_{IVNM}/z is defined as follow:

$$A_{\mathrm{IVNM}}.z = P = \left[< [p^L_{ij_T}, p^U_{ij_T}], [p^L_{ij_I}, p^U_{ij_I}], [p^L_{ij_F}, p^U_{ij_F}] >\right]_{\mathrm{m}\times \mathrm{n}} \quad (17)$$

where

$p^L_{ij_T} = \min(a^L_{ij_T}/ z, 1)$, $p^U_{ij_T} = \min(a^U_{ij_T}/ z, 1)$

$p^L_{ij_I} = \min(a^L_{ij_I}/ z, 1)$, $p^U_{ij_I} = \min(a^U_{ij_I}/ z, 1)$

$p^L_{ij_F} = \min(a^L_{ij_F}/\mathrm{z}, 1)$, $p^U_{ij_F} = \min(a^U_{ij_F}/ z, 1)$

To generate the MATLAB program for finding scalar division of interval-valued neutrosophic matrix, simple call of the function named “scalardiv.m” is defined as follow:

```
function At=scalardiv (A,k);
%scalar division of interval valued neutrosophic matrix A
% "A" have to be an interval valued neutrosophic  matrix - "ivnm" object:
a.ml=min((A.ml).*k,1);
a.mu=min((A.mu).*k,1);
a.il=min((A.il).*k,1);
a.iu=min((A.iu).*k,1);
a.nl=min((A.nl).*k,1);
a.nu=min((A.nu).*k,1);
At=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu);
```

IV. NUMERICAL EXAMPLES

In this section, we evaluate some numerical examples using the proposed Matlab procedures defined in pervious section

Example 1. Input an interval valued neutrosophic matrix by a given structure in the toolbox.

```
%Enter the degree of lower membership of A in the variable a.ml
>> a.ml= [.1  .3 ;.2 .1; .4 .5; .5 .2];

%Enter the degree of upper membership of A in the variable a.mu
>> a.mu = [.5  .4 ;.3 .7; .5 .8; .6 .5];

%Enter the degree of lower indeterminate-membership of A in the variable a.il
>>a.il = [.3  .2 ;.1 .3; .2 .1; .3 .4];

%Enter the degree of upper indeterminate-membership of A in the variable a.iu
>>a.iu = [.4  .6 ;.3 .4; .3 .2; .4 .6];
%Enter the degree of lower non-membership of A in the variable a.nl
>>a.nl = [.2  .2 ;.4 .5; .1 .4; .4 .3];
%Enter the degree of upper non-membership of A in the variable a.nu
>>a.nu=[.5  .4 ;.7 .6; .3 .7; .5 .8];

%Enter the degree of lower membership of B in the variable b.ml
>> b.ml= [.3  .4 ;.4 .2; .1 .2; .3 .1];

%Enter the degree of upper membership of B in the variable b.mu
>> b.mu = [.4  .6 ;.7 .3; .3 .6; .4 .2];

%Enter the degree of lower indeterminate-membership of B in the variable b.il
>>b.il = [.2  .3 ;.2 .3; .2 .3; .2 .1];

%Enter the degree of upper indeterminate-membership of B in the variable b.iu
>>b.iu = [.6  .4 ;.6 .4; .4 .5; .3 .4];
%Enter the degree of lower non-membership of B in the variable b.nl
>>b.nl = [.1  .3 ;.4 .4; .2 .3; .3 .2];
%Enter the degree of upper non-membership of B in the variable b.nu
>>b.nu=[.3  .5 ;.5 .7; .3 .6; .5 .6];

>>A=ivnm(a.ml,a.mu,a.il,a.iu,a.nl,a.nu)

%This command returns a matrix A with interval degree of membership [a.ml, a.mu] ,interval degree of indeterminate-membership [a.il, a.iu]  and interval degree of non-membership [a.nl, anu] %
```

A =

$$\begin{matrix} <[.1,.5],[.3,.4],[.2,.5]> & <[.3,.4],[.2,.6],[.2,.4]> \\ <[.2,.3],[.1,.3],[.4,.7]> & <[.1,.7],[.3,.4],[.5,.6]> \\ <[.4,.5],[.2,.3],[.1,.3]> & <[.5,.8],[.1,.2],[.4,.7]> \\ <[.5,.6],[.3,.4],[.4,.5]> & <[.2,.5],[.4,.6],[.3,.8]> \end{matrix}$$

>>**B=ivnm(b.ml,b.mu,b.il,b.iu,b.nl,b.nu)**

% This command returns a matrix B with interval degree of membership [b.ml, b.mu] ,interval degree of indeterminate-membership [b.il, b.iu] and interval degree of non-membership [b.nl, b.nu] %

B =

$$\begin{matrix} <[.3,.4],[.2,.6],[.1,.3]> & <[.4,.6],[.3,.4],[.3,.5]> \\ <[.4,.7],[.2,.6],[.4,.5]> & <[.2,.3],[.3,.4],[.4,.7]> \\ <[.1,.3],[.2,.4],[.2,.3]> & <[.2,.6],[.3,.5],[.3,.6]> \\ <[.3,.4],[.2,.3],[.3,.5]> & <[.1,.2],[.1,.4],[.2,.6]> \end{matrix}$$

Example 2. Generate the complement of the interval valued neutrosophic matrix:

A=

$$\begin{pmatrix} <[.1,.5],[.3,.4],[.2,.5]> & <[.3,.4],[.2,.6],[.2,.4]> \\ <[.2,.3],[.1,.3],[.4,.7]> & <[.1,.7],[.3,.4],[.5,.6]> \\ <[.4,.5],[.2,.3],[.1,.3]> & <[.5,.8],[.1,.2],[.4,.7]> \\ <[.5,.6],[.3,.4],[.4,.5]> & <[.2,.5],[.4,.6],[.3,.8]> \end{pmatrix}$$

>>**complement(A)**

% This command returns the complement of interval valued neutrosophic matrix A .

ans =

$$\begin{matrix} <[.2,.5],[.6,.7],[.1,.5]> & <[.2,.4],[.4,.8],[.3,.4]> \\ <[.4,.7],[.7,.9],[.2,.3]> & <[.5,.6],[.6,.7],[.1,.7]> \\ <[.1,.3],[.7,.8],[.4,.5]> & <[.4,.7],[.8,.9],[.5,.8]> \\ <[.4,.5],[.6,.7],[.5,.6]> & <[.3,.8],[.4,.6],[.2,.5]> \end{matrix}$$

Example 3 . Evaluate the intersection , union and division of these matrices:

A=

$$\begin{pmatrix} <[.1,.5],[.3,.4],[.2,.5]> & <[.3,.4],[.2,.6],[.2,.4]> \\ <[.2,.3],[.1,.3],[.4,.7]> & <[.1,.7],[.3,.4],[.5,.6]> \\ <[.4,.5],[.2,.3],[.1,.3]> & <[.5,.8],[.1,.2],[.4,.7]> \\ <[.5,.6],[.3,.4],[.4,.5]> & <[.2,.5],[.4,.6],[.3,.8]> \end{pmatrix}$$

B=

$$\begin{pmatrix} <[.3,.4],[.2,.6],[.1,.3]> & <[.4,.6],[.3,.4],[.3,.5]> \\ <[.4,.7],[.2,.6],[.4,.5]> & <[.2,.3],[.3,.4],[.4,.7]> \\ <[.1,.3],[.2,.4],[.2,.3]> & <[.2,.6],[.3,.5],[.3,.6]> \\ <[.3,.4],[.2,.3],[.3,.5]> & <[.1,.2],[.1,.4],[.2,.6]> \end{pmatrix}$$

```
>>intersection(A,B)
 % This command returns the intersection of two interval valued neutrosophic matrices
ans =
```

$$\begin{matrix} <[.1,.4],[.3,.6],[.2,.5]> & <[.3,.4],[.3,.6],[.3,.5]> \\ <[.2,.3],[.2,.6],[.4,.7]> & <[.1,.3],[.3,.4],[.5,.7]> \\ <[.1,.3],[.2,.4],[.2,.3]> & <[.2,.6],[.3,.5],[.4,.7]> \\ <[.3,.4],[.3,.4],[.4,.5]> & <[.1,.2],[.4,.6],[.3,.8]> \end{matrix}$$

```
>>union(A,B)
 % This command returns the union of two interval valued neutrosophic matrices
ans =
```

$$\begin{matrix} <[.3,.5],[.2,.4],[.1,.3]> & <[.4,.6],[.2,.4],[.2,.4]> \\ <[.4,.7],[.1,.3],[.4,.5]> & <[.2,.7],[.3,.4],[.4,.6]> \\ <[.4,.5],[.2,.3],[.1,.3]> & <[.5,.8],[.1,.2],[.3,.6]> \\ <[.5,.6],[.2,.3],[.3,.5]> & <[.2,.5],[.1,.4],[.2,.6]> \end{matrix}$$

```
>>division(A,B)
% This command returns the division  of interval valued neutrosophic  matrices A and B .
ans =
```

$$\begin{pmatrix} <[.29,.17],[1.5,.67],[1.67,.2]> & <[.3,.4],[.2,1.5],[.67,.8]> \\ <[.33,1.33],[.5,.5],[.4,.7]> & <[.1,.7],[.3,.4],[1.25,.86]> \\ <[.33,.29],[1,.75],[.5,1]> & <[.5,.8],[.1,.2],[1.33,1.17]> \\ <[.29,.33],[1.5,1.33],[1,.1.33]> & <[.2,.5],[.4,.6],[1.5,1.33]> \end{pmatrix}$$

Example 4. Evaluate the addition $A \oplus B$ and product $A \odot B$ operations of the matrices in Example 3

```
>>addition(A,B)
% This command returns the addition of two interval valued neutrosophic matrices A and B
ans =
```

$$\begin{matrix} <[.37,.70],[.06,.24],[.02,.15]> & <[.58,.76],[.06,.24],[.06,.20]> \\ <[.52,.79],[.02,.18],[.16,.35]> & <[.28,.79],[.09,.16],[.20,.42]> \\ <[.46,.65],[.04,.12],[.02,.09]> & <[.60,.92],[.03,.10],[.12,.42]> \\ <[.65,.76],[.06,.12],[.12,.25]> & <[.28,.60],[.04,.24],[.06,.48]> \end{matrix}$$

>>product(A,B)

% This command returns the product of two interval valued neutrosophic matrices A and B

ans =

$$\begin{matrix} <[.03,.20],[.44,.76],[.28,.65]> & <[.12,.24],[.44,.76],[.44,.70]> \\ <[.08,.21],[.28,.72],[.64,.85]> & <[.02,.21],[.51,.64],[.70,.88]> \\ <[.04,.15],[.36,.58],[.25,.51]> & <[.10,.48],[.37,.60],[.58,.88]> \\ <[.15,.24],[.44,.58],[.58,.75]> & <[.02,.10],[.46,.76],[.44,.92]> \end{matrix}$$

Example 5. Evaluate the difference operations of the matrices in Example 3

>>difference (A,B)

% This command returns the diffrence of two interval valued neutrosophic matrices A and B

ans =

$$\begin{matrix} <[-.2,.4],[.3,.6],[-.2,.2]> & <[-.2,.1],[.3,.6],[-.4,.0]> \\ <[-.3,-.1],[.2,.6],[-.3,.3]> & <[-.6,.3],[.3,.4],[.2,.4]> \\ <[.1,.3],[.2,.4],[-.2,.2]> & <[-.1,.5],[.3,.5],[-.2,.5]> \\ <[0,.3],[.3,.4],[0,.2]> & <[-.4,.3],[.4,.6],[.1,.7]> \end{matrix}$$

>>diffrence2(A,B)

% This command returns the diffrence2 of two interval valued neutrosophic matrices A and B

ans =

$$\begin{matrix} <[.1,.3],[.4,.8],[.3,.5]> & <[.3,.4],[.6,.7],[.4,.6]> \\ <[.2,.3],[.4,.8],[.4,.7]> & <[.1,.7],[.6,.7],[.5,.6]> \\ <[.2,.3],[.6,.8],[.1,.3]> & <[.3,.6],[.5,.7],[.4,.7]> \\ <[.3,.5],[.7,.8],[.4,.5]> & <[.2,.5],[.6,.9],[.3,.8]> \end{matrix}$$

Example 6. Return the power of the matrix below:

A=

$$\begin{pmatrix} <[.1,.5],[.3,.4],[.2,.5]> & <[.3,.4],[.2,.6],[.2,.4]> \\ <[.2,.3],[.1,.3],[.4,.7]> & <[.1,.7],[.3,.4],[.5,.6]> \\ <[.4,.5],[.2,.3],[.1,.3]> & <[.5,.8],[.1,.2],[.4,.7]> \\ <[.5,.6],[.3,.4],[.4,.5]> & <[.2,.5],[.4,.6],[.3,.8]> \end{pmatrix}$$

>>**power(A,2)**

% This command returns the power of matrix A .

ans =

$$\begin{matrix} <[.01,.25],[.09,.16],[.04,.25]> & <[.09,.16],[.4,.36],[.04,.16]> \\ <[.04,.09],[.01,.09],[.16,.49]> & <[.01,.49],[.9,.16],[.25,.36]> \\ <[.16,.25],[.04,.09],[.01,.09]> & <[.25,.64],[.1,.04],[.16,.49]> \\ <[.25,.36],[.09,.16],[.16,.25]> & <[.04,.25],[.16,.36],[.09,.64]> \end{matrix}$$

Example 7. Generate the scalar division of the interval valued neutrosophic matrix:

A=

$$\begin{pmatrix} <[.1,.5],[.3,.4],[.2,.5]> & <[.3,.4],[.2,.6],[.2,.4]> \\ <[.2,.3],[.1,.3],[.4,.7]> & <[.1,.7],[.3,.4],[.5,.6]> \\ <[.4,.5],[.2,.3],[.1,.3]> & <[.5,.8],[.1,.2],[.4,.7]> \\ <[.5,.6],[.3,.4],[.4,.5]> & <[.2,.5],[.4,.6],[.3,.8]> \end{pmatrix}$$

```
>>scalardivsion(A, 2)
% This command returns the scalar division of interval valued neutrosophic matrix A .

ans =
```

$$\begin{matrix} <[.05,.25],[.10,.15],[.25,.35]> & <[.15,.20],[.10,.30],[.10,.20]> \\ <[.10,.15],[.05,.15],[.20,.35]> & <[.05,.35],[.15,.20],[.25,.30]> \\ <[.20,.25],[.10,.15],[.05,.15]> & <[.25,.40],[.05,.10],[.20,.35]> \\ <[.25,.30],[.15,.20],[.20,.25]> & <[.10,.25],[.20,.30],[.15,.40]> \end{matrix}$$

Example 8. Generate the scalar multiplication of the interval valued neutrosophic matrix:

A=

$$\begin{pmatrix} <[.1,.5],[.3,.4],[.2,.5]> & <[.3,.4],[.2,.6],[.2,.4]> \\ <[.2,.3],[.1,.3],[.4,.7]> & <[.1,.7],[.3,.4],[.5,.6]> \\ <[.4,.5],[.2,.3],[.1,.3]> & <[.5,.8],[.1,.2],[.4,.7]> \\ <[.5,.6],[.3,.4],[.4,.5]> & <[.2,.5],[.4,.6],[.3,.8]> \end{pmatrix}$$

```
>>scalarmult(A,2)
```

>>scalarmult(A,2)

```
% This command returns the scalar multiplicationof interval valued neutrosophic matrix A .

ans =
```

$$\begin{matrix} <[.2,1.0],[.6,.8],[.4,1.0]> & <[.6,.8],[.4,1.0],[.4,.8]> \\ <[.4,.6],[.2,.6],[.8,1.0]> & <[.2,1.0],[.6,.7],[1.0,1.0]> \\ <[.8,.4],[.4,.6],[.2,.6]> & <[1.0,1.0],[.2,.4],[.8,1.0]> \\ <[1.0,.1.0],[.6,.8],[.8,1.0]> & <[.4,1.0],[.8,1.0],[.6,1.0]> \end{matrix}$$

Example 9. Generate the score matrix of the following the interval valued neutrosophic matrix:

A=

$$\begin{pmatrix} <[.1,.5],[.3,.4],[.2,.5]> & <[.3,.4],[.2,.6],[.2,.4]> \\ <[.2,.3],[.1,.3],[.4,.7]> & <[.1,.7],[.3,.4],[.5,.6]> \\ <[.4,.5],[.2,.3],[.1,.3]> & <[.5,.8],[.1,.2],[.4,.7]> \\ <[.5,.6],[.3,.4],[.4,.5]> & <[.2,.5],[.4,.6],[.3,.8]> \end{pmatrix}$$

```
>>score function A
% This command returns the score matrix of interval valued neutrosophic matrx A .

ans =

   0.5333    0.5500
   0.5000    0.5000
   0.6667    0.6500
   0.5833    0.4333
```

V. APPLICATION OF INTERVAL VALUED NEUTROSOPHIC TOOLBOX MATLAB

It is known that interval-valued neutrosophic matrices constitute a generalization of the notion of fuzzy matrices, single valued neutrosophic matrices, interval valued fuzzy matrices and interval valued intuitionistic fuzzy matrices. The interval valued neutrosophic matrices models give more precision, flexibility, and compatibility to the system as compared to the classical and fuzzy models. In this paper, we have developed the interval valued neutrosophic toolbox Matlab. We plan to apply this software package in the

following areas:

• Decision making problems.

•Networking

VI. CONCLUSION

This paper proposed some new Matlab program for set-theoretic operations on the interval valued neutrosophic matrices. The package provides some programs such as complement, transpose, scalar multiplication of matrix, scalar division of matrix, computing the union, intersection addition, product, difference and division operations of the proposed neutrosophic matrices. The interval neutrosophic software package gives the ability for easy calculation of operations in associated problems and can be used for large order interval valued neutrosophic matrices. The proposed software package can be used for computing other operations such as:

-Computing Laplacian eigenvalues of interval valued neutrosophic matrix

-Energy of graph

In future works, We plan to extended this software package for computing other kind of matrices including, bipolar neutrosophic matrices, interval valued bipolar neutrosophic matrices and interval complex neutrosophic matrices.

VII. ACKNOWLEDGMENT

The authors are very grateful to the chief editor and reviewers for their comments and suggestions, which is helpful in improving the paper.

REFERENCES

Anand, M.C.J. and Anand, M.E.,(2015) Eigenvaluesand eigen vectors for fuzzy matrix, International Journal of Engineering Research and General Science Volume 3, Issue 1, 2015, pp.878- 890

Bausys, R., & Zavadskas, E. K. (2015). Multıcrıterıa Decısıon Makıng Approach By Vıkor Under Interval Neutrosophıc Set Envıronment. Economic Computation & Economic Cybernetics Studies & Research, 49(4).

Broumi, S. , M. Talea, A. Bakali, F. Smarandache, (2016). Interval Valued Neutrosophic Graphs, Critical Review, XII, 2016. pp.5-33.

Broumi, S., A.Bakali, M.Talea, F.Smarandache, R.Verma,(2017) Computing Minimum Spanning Tree In Interval Valued Bipolar Neutrosophic Environment,International Journal of Modeling and Optimization, Vol. 7, No. 5, 2017, pp300-304.

Broumi, S., Le Hoang, F. Smarandache, A. Bakali, M.Talea, G.Selvachandran, Kishore Kumar.P.K, Computing Operational Matrices in Neutrosophic Environments: A Matlab toolbox, submitted

Broumi, S., Smarandache, F., Talea, M., & Bakali, A. (2016). Operations on interval valued neutrosophic graphs. Infinite Study. Graphs, chapter in book- New Trends in Neutrosophic Theory and Applications- FlorentinSmarandache and SurpatiPramanik (Editors), pp. 231-254. ISBN 978-1-59973-498-9

Broumi, S., Talea, M., Smarandache, F., & Bakali, A. (2016, December). Decision-making method based on the interval valued neutrosophic graph. In Future Technologies Conference (FTC) (pp. 44-50). IEEE.

C.Jaisankar, S.Arunvasan and R.Mani.,(2016) On Hessenberg of Triangular fuzzy matrices, IJSRET, V-5(12), 2016,pp.586-591

Deli, I. (2017). Interval-valued neutrosophic soft sets and its decision making. International Journal of Machine Learning and Cybernetics, 8(2), 665-676.

Dinagar, D. S., & Latha, K. (2013). Some types of type-2 triangular fuzzy matrices. International Journal of Pure and Applied Mathematics, 82(1), 21-32.

Garg, H. (2016). An improved score function for ranking neutrosophic sets and its application to decision-making process. International Journal for Uncertainty Quantification, 6(5).

Garg, H. (2017). Non-linear programming method for multi-criteria decision making problems under interval neutrosophic set environment. Applied Intelligence, 1-15.

Huang, Y. H., Wei, G. W., & Wei, C. (2017). VIKOR method for interval neutrosophic multiple attribute group decision-making. Information, 8(4), 144. doi:10.3390/info8040144

Jaisankar, C., and Mani, R., (2017) Some Properties of Determinant of Trapezoidal Fuzzy Number Matrices, International Journal Of Modern Engineering Research, Vol. 7 ,Iss. 1 , 2017 ,pp70-78

Karaşan, A., & Kahraman, C. (2017). Interval-Valued Neutrosophic Extension of EDAS Method. In Advances in Fuzzy Logic and Technology 2017 (pp. 343-357). Springer, Cham. DOI 10.1007/978-3-319-66824-6_3

Karunambigai, M. G., and Kalaivani, O. K., (2016). Software development in intuitionistic Fuzzy Relational Calculus. International Journal of Scientific and research Publication, 6(7), 2016,pp.311-331.

Ma, Y. X., Wang, J. Q., Wang, J., & Wu, X. H. (2017). An interval neutrosophic linguistic multi-criteria group decision-making method and its application in selecting medical treatment options. Neural Computing and Applications, 28(9), 2745-2765. DOI 10.1007/s00521-016-2203-1.

Pal, A., & Pal, M. (2010, December). Some results on interval-valued fuzzy matrices. In The 2010 International Conference on E-Business Intelligence, Org. by Tsinghua University, Kunming, China, Atlantis Press (pp. 554-559).

Pal, M., Khan, S. K., & Shyamal, A. K. (2002). Intuitionistic fuzzy matrices. Notes on Intuitionistic fuzzy sets, 8(2), 51-62.

Peeva, K., & Kyosev, Y. (2004) Solving problems in intuitionistic fuzzy relational calculus with fuzzy relational calculus toolbox. In Eight International Conference on IFSs, Varna (pp. 37-43).

Pushpalatha, V.,(2017). α-Cuts Of Interval-Valued Fuzzy Matrices With Interval-Valued Fuzzy Rows And Columns, IOSR Journal of Mathematics, Volume 13, Issue 3 Ver. II ,2017, pp.55-62

Reddy, R., Reddy, D., & Krishnaiah, G. (2016). Lean Supplier Selection based on Hybrid MCGDM Approach using Interval Valued Neutrosophic Sets: A Case Study. International Journal of Innovative Research and Development, 5(4). pp.291-296.

Smarandache, F. (1998). Neutrosophy. neutrosophic probability, set, and logic, ProQuest information and learning. Ann Arbor, Michigan, USA, 105.

Sun, H. X., Yang, H. X., Wu, J. Z., & Ouyang, Y. (2015). Interval neutrosophic numbers Choquet integral operator for multi-criteria decision making. Journal of Intelligent & Fuzzy Systems, 28(6), 2443-2455.

Şahin, M., Ulucay V., and Menekşe, M., (2017). (α,β,ϒ) Interval Cut Set Of Interval Valued Neutrosophic Sets, International Conference on Mathematics and Mathematics Education (ICMME-2017), Harran University, Şanlıurfa, 11-13 May 2017

Şahin, R. (2017). Cross-entropy measure on interval neutrosophic sets and its applications in multicriteria decision making. Neural Computing and Applications, 28(5), 1177-1187

Tian, Z. P., Zhang, H. Y., Wang, J., Wang, J. Q., & Chen, X. H. (2016). Multi-criteria decision-making method based on a cross-entropy with interval neutrosophic sets. International Journal of Systems Science, 47(15), 3598-3608.

Venkatesan, D. and Sriram, S. (2017). Multiplicative Operations of Intuitionistic Fuzzy Matrices, Annals of Pure and Applied Mathematics Vol. 14, No. 1, 2017, pp.173-181

Venkatesan, D. and Sriram, S. (2017). Multiplicative Operations of Intuitionistic Fuzzy Matrices, Annals of Pure and Applied Mathematics Vol. 14, No. 1, 2017, pp.173-181

Wang, H., Smarandache, F., Zhang, Y., & Sunderraman, R. (2010). Single valued neutrosophic sets. Review of the Air Force Academy, (1), 10. pp. 410-413.

Ye, J. (2014a). Similarity measures between interval neutrosophic sets and their applications in multicriteria decision-making. Journal of Intelligent & Fuzzy Systems, 26(1), 165-172.

Ye, J. (2014b). A multicriteria decision-making method using aggregation operators for simplified neutrosophic sets. Journal of Intelligent & Fuzzy Systems, 26(5), 2459-2466.

Ye, J. (2015). Multiple attribute decision-making method based on the possibility degree ranking method and ordered weighted aggregation operators of interval neutrosophic numbers. Journal of Intelligent & Fuzzy Systems, 28(3), 1307-1317.

Ye, J. (2016a). Interval neutrosophic multiple attribute decision-making method with credibility information. International Journal of Fuzzy Systems, 18(5), 914-923. DOI 10.1007/s40815-015-0122-4.

Ye, J. (2016b). Exponential operations and aggregation operators of interval neutrosophic sets and their decision making methods. SpringerPlus, 5(1), 1488.

Zahariev, Z. (2009, November). Software package and API in MATLAB for working with fuzzy algebras. In AIP Conference Proceedings (Vol. 1184, No. 1, pp. 341-348). AIP.

Zhang, H. Y., Wang, J. Q., & Chen, X. H. (2014). Interval neutrosophic sets and their application in multicriteria decision making problems. The Scientific World Journal, 2014. doi:10.1155/2014/645953.