World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:15, No:10, 2021

Neutrosophic Multiple Criteria Decision Making Analysis Method for Selecting Stealth Fighter Aircraft

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***Abstract*—**In this paper, a neutrosophic multiple criteria decision analysis method is proposed to select stealth fighter aircraft. Neutrosophic multiple criteria decision analysis methods are used to analyze the neutrosophic environment and give results under uncertainty and incompleteness. Linguistic scale variables and neutrosophic numbers are used to evaluate alternatives over a set of decision criteria. Finally, the proposed model is applied to a practical decision problem for selecting stealth fighter aircraft.

***Keywords*—**Neutrosophic sets, multiple criteria decision making analysis, stealth fighter aircraft, aircraft selection, MCDMA.

I. Introduction

Multiple criteria decision making analysis (MCDMA) methods are widely used to rank alternatives or select the optimal one with respect to several concerned decision criteria. However, in some cases, it is difficult for decision makers to explicitly express preference in solving MCDMA problems with uncertain or incomplete information.

Under these circumstances, conventional multiple criteria decision making analysis models require crisp information that may not be permanently accessible in real life applications. Nevertheless, in numerous cases, data are unstable, uncertain, and complicated; therefore, they cannot be accurately measured.

The theory of fuzzy sets was proposed against certain logic [1]. Fuzzy sets deal with fuzziness in terms of degree of truthness or membership within the range of interval [0,1]. Fuzzy sets were considered to be effective in handling uncertain information and decision making processes in an uncertain environment. The idea of fuzzy sets was developed over time, and different variants were introduced to handle different forms of uncertainty. The traditional fuzzy sets are not efficient when the decision makers face more complex problems, and it is difficult to quantify their truth values [1-2].

However, fuzzy sets consider only the membership function and cannot deal with other parameters of vagueness. To overcome this lack of information, an extension of fuzzy sets called intuitionistic fuzzy sets was introduced [3]. Although the theory of intuitionistic fuzzy sets can handle incomplete information for various real life issues, it cannot address all types of uncertainty such as inconsistent and indeterminate evidence. Neutrosophic sets were introduced by defining the truth membership function, indeterminacy function and falsity membership function as independent components by extending fuzzy sets [1] and intuitionistic fuzzy sets [3].Therefore, the neutrosophic sets as a robust overall framework that generalizes classical and all kinds of fuzzy sets (fuzzy sets and intuitionistic fuzzy sets) was established [4-5].

The philosophical idea of neutrosophic sets is formulated from the general concept of fuzzy sets and many real life applications were considered. Neutrosophic sets that has three membership functions namely positive, indeterminate, and negative were introduced to handle uncertain information and decision analysis in uncertain environment [4-5].

Neutrosophic sets can accommodate indeterminate, ambiguous, and conflicting information where the indeterminacy is clearly quantified, and define three kinds of membership function independently. Some versions of neutrosophic sets such as interval neutrosophic sets [6-7], bipolar neutrosophic sets [8-9], single valued neutrosophic sets where each of truth, indeterminacy and falsity membership degree belongs to [0,1] were introduced [10-13], and neutrosophic linguistic sets [14] have been presented. In addition, in the field of neutrosophic sets, logic, measure, probability, statistics, and their applications in multiple areas have been extended [15–18].

In real circumstances, some data in multiple criteria decision making analysis (MCDMA) may be uncertain, indeterminate, and inconsistent, and considering truth, falsity, and indeterminacy membership functions for each attribute in the neutrosophic sets help decision makers to obtain a better interpretation of information.

In addition, by using the neutrosophic sets in MCDMA, analysts can better set their acceptance, indeterminacy, and rejection degrees regarding each datum. Moreover, with neutrosophic sets, a better depiction of reality through seeing all features of the decision making procedure can be obtained. Therefore, the neutrosophic sets can embrace imprecise, vague, incomplete, and inconsistent evidence powerfully and efficiently. Although there are several approaches to solve various problems under neutrosophic environments, there are not many studies that have dealt with MCDMA under neutrosophic sets.

The utilization of neutrosophic logic in MCDMA can improve the decision making process in stealth fighter aircraft selection problem. Therefore, in this paper, an innovative simple model of MCDMA in which all data are triangular single valued neutrosophic numbers (TSVNNs) was designed, and a new efficient strategy to solve it was established. Furthermore, the suggested technique for the performance assessment of three stealth fighter aircraft was

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used.

Aggregating the fuzzy information plays an important role in decision theory and in particular decision making in real life problems. The introduction of neutrosophic sets has transformed the application of fuzzy sets in decision making processes and has been applied to various decision problems in the different fields. Single valued neutrosophic sets are used in the multiple criteria decision making analysis situation of selecting a suitable stealth fighter aircraft for air defense purposes. Also, fuzzy multiple criteria decision analysis was proposed to address the uncertainty in decision making process for the aircraft selection problem.

The reminder of paper unfolds as follows: some basic knowledge, concepts, and arithmetic operations on neutrosophic sets and TSVNNs are discussed in Section 2. In Section 3, mentioned model of MCDMA under the neutrosophic environment was established and a method to solve it was proposed. The suggested model was utilized for a case study of stealth fighter aircraft selection. Lastly, conclusions and future directions are presented in Section 4.

II. Methodology

In this section, some basic definitions related to neutrosophic sets and single valued neutrosophic numbers are presented respectively. An indeterminacy degree of membership as an independent component was proposed in his papers [4-5], and since the principle of excluded middle cannot be applied to new logic, non-standard analysis with three-valued logic, set theory, probability theory, and philosophy was combined. As a result, neutrosophic means neutral thinking knowledge. Given this meaning and the use of the term neutral, along with the components of truth (membership) and falsity (non-membership), its distinction is marked by fuzzy sets and intuitionistic fuzzy sets. Here, it is appropriate to give a brief explanation of the non-standard analysis.

Non-standard analysis as a form of analysis and a branch of logic in which infinitesimals are precisely defined [19]. Formally, x is called an infinitesimal number if and only if for any non-null positive integer *n* we have $|x| \leq \frac{1}{n}$. Let $\varepsilon > 0$ be an infinitesimal number; then, the extended real number set is an extension of the set of real numbers that contains the classes of infinite numbers and the infinitesimal numbers. If we consider non-standard finite numbers $1^{+} = 1 + \varepsilon$ and $-0 = 0 - \varepsilon$ where 0 and 1 are the standard parts and ε is the non-standard part, then $]^{-}0,1^{+}[$ is a non-standard unit interval. It is clear that 0, 1, as well as the non-standard infinitesimal numbers that are less than zero and infinitesimal numbers that are more than one belong to this non-standard unit interval. Now, let us define a neutrosophic set:

Definition 1 ([4-5,15]). A neutrosophic set in universal ε is defined by three membership functions for the truth, indeterminacy, and falsity of *x* in the real non-standard $]^{-}0,1^{+}[$ where the summation of them belongs to [0, 3].

Definition 2 ([7]). A neutrosophic set α over ε is given. If the three membership functions of a neutrosophic sets are singleton in the real standard [0, 1], then a single valued neutrosophic set (SVNS) is denoted by:

$$\alpha = \left\{ (x, T_{\alpha}(x), I_{\alpha}(x), F_{\alpha}(x) \mid x \in \varepsilon \right\} \tag{1}$$

which satisfies the following condition:

$$0 \leq T_{\alpha}(x) + I_{\alpha}(x) + F_{\alpha}(x) \leq 3, \forall x \in \varepsilon \tag{2}$$

Definition 3 ([11]). A triangular single-valued neutrosophic number (TSVNN) $A^{\aleph} = \left\langle (a^{l}, a^{m}, a^{u}), (b^{l}, b^{m}, b^{u}), (c^{l}, c^{m}, c^{u}) \right\rangle$ is defined as a particular single-valued neutrosophic number (SVNN) whose truth membership ($T_{A^{\aleph}}(x)$), indeterminacy ($I_{A^{\aleph}}(x)$), and falsity membership ($F_{A^{\aleph}}(x)$) are presented as follows:

$$T_{A^{\aleph}}(x) = \begin{cases} \dfrac{x - a^{l}}{a^{m} - a^{l}} & a^{l} \leq x < a^{m} \\ 1 & x = a^{m} \\ \dfrac{a^{u} - x}{a^{u} - a^{m}} & a^{m} \leq x < a^{u} \\ 0 & otherwise \end{cases}$$

$$I_{A^{\aleph}}(x) = \begin{cases} \dfrac{b^{m} - x}{b^{m} - b^{l}} & b^{l} \leq x < b^{m} \\ 0 & x = b^{m} \\ \dfrac{x - b^{m}}{b^{u} - b^{m}} & b^{m} \leq x < b^{u} \\ 1 & otherwise \end{cases} \tag{3}$$

$$F_{A_{n}}(x) = \begin{cases} \dfrac{c^{m} - x}{c^{m} - c^{l}} & c^{l} \leq x < c^{m} \\ 0 & x = c^{m} \\ \dfrac{x - c^{m}}{c^{m} - c^{m}} & c^{m} \leq x < c^{u} \\ 1 & otherwise \end{cases}$$

Definition 4 ([4-5,15]). Let ε be a space of points with generic elements in ε denoted by *x*. Then a neutrosophic set α in ε is characterized by a truth membership function, T_{α}, an indeterminacy membership function, I_{α}, and a falsity membership function , F_{α}: The function, $T_{\alpha} : \varepsilon \to [0,1^{+}]$; $I_{\alpha} : \varepsilon \to [0,1^{+}]$; $F_{\alpha} : \varepsilon \to [0,1^{+}]$. It is noted that there is no restriction on the sum of $T_{\alpha}(x), I_{\alpha}(x), F_{\alpha}(x)$, i.e. $0 \leq T_{\alpha}(x) + I_{\alpha}(x) + F_{\alpha}(x) \leq 3^{+}$.

Definition 4 ([4-5,15]). Let ε be a universal space of points with a generic elements of ε denoted by *x*. A single valued neutrosophic set *S* is characterized by a truth membership function $T_{s}(x)$; an indeterminacy membership function $I_{s}(x)$; a falsity membership function $F_{s}(x)$ with $T_{s}(x)$,

$I_s(x)$, $F_s(x) \in [0,1]$ for all x in ε. When ε is continuous a single valued neutrosophic set (SVNS) can be written as:

$$S = \int < T_s(x), F_s(x), I_s(x) > x, \forall x \in \varepsilon \quad (4)$$

When ε is discrete a SVNSs S can be written as:

$$S = \sum < T_s(x), F_s(x), I_s(x) > x, \forall x \in \varepsilon \quad (5)$$

It is noted that for a SVNS,

$$0 \le \sup T_s(x) + \sup I_s(x) + \sup F_s(x) \le 3, \forall x \in \varepsilon \quad (6)$$

Neutroshophic decision analysis algorithm

Step 1. Problem field selection

Consider a multiple attribute decision making problem with m alternatives and n attributes. Triangular single valued neutrosophic set decision matrix is given by:

$$D < d_{ij} >_{mxn} = \begin{pmatrix} a_1 \\ \vdots \\ a_i \end{pmatrix} \begin{pmatrix} \overset{g_1}{d_{11}} & \cdots & \overset{g_j}{d_{1j}} \\ \vdots & \ddots & \vdots \\ d_{i1} & \cdots & d_{ij} \end{pmatrix}_{ixj} \quad (7)$$

where, $d_{ij} (i = 1, 2, ..., m; j = 1, 2, ..., n)$ are all single valued neutrosophic number.

Step 2. Input the triangular single valued neutrosophic fuzzy number as edge weight.

Step 3. Take the coefficient of triangular single valued neutrosophic fuzzy number as Pascal's triangle number taken along the three sides of Pascal's triangle.

Step 4. Add and divide by the total of Pascal's triangle number and call it as Pascal's triangle for triangular single valued neutrosophic fuzzy number.

Let the are two triangular fuzzy numbers, then take the coefficient of fuzzy numbers as Pascal triangular type and apply the simple probability approach. The Pascal's triangle for triangular neutrosophic fuzzy number is given by

$$P_p = \frac{1}{4}\left[a_1 + 2(a_2) + a_3\right] \quad (8)$$

Step 5. Convert triangular neutrosophic single valued fuzzy number into a single valued neutrosophic fuzzy number using the below formula.

$$SVNFN(A_i) = \frac{1}{m}\sum_{r=1}^{m}\left[\frac{2 + T_{rj} - I_{rj} - F_{rj}}{2}\right] \quad (9)$$

Step 6. Selection zone.

Single valued neutrosophic fuzzy value are classified into three zones. These are described as follows.

Highly acceptable zone: $0.50 \le SVNFN(A_i) \le 1$
Tolerable acceptable zone: $0.25 \le SVNFN(A_i) \le 0.50$ (10)
Unacceptable acceptable zone: $0.00 \le SVNFN(A_i) \le 0.25$

Step 7. Ranking of Alternatives

According to the single valued neutrosophic number, a panel of all alternatives can be set up in descending order, and larger number of alternatives can be chosen into the decision making analysis process considering highly acceptable zone and tolerable acceptable zone.

Step 8. End

III. Application

In this section, selection of stealth fighter aircraft using triangular single valued neutrosophic multiple criteria decision making analysis problem is considered as numerical example case study. Consider a multiple attribute decision making problem with m alternatives and n attributes (large numbers of data).

Let $a_i = \{a_1, a_2, ..., a_m\}$ and $g_j = \{g_1, g_2, ..., g_n\}$ denote the alternatives and attributes respectively. In decision making process, a finite but more important attributes from given n attributes must be selected. All attributes are expressed in single valued neutrosophic number.

Military fighter aircraft are developed with stealth characteristics. This means that such a fighter aircraft has a very small σ, or radar cross-sectional area, relative to other aircraft of similar size. It can still be detected by a sufficiently powerful radar or at close enough distances. Because the stealth aircraft is similar in size to other military aircraft, the stealth characteristic is achieved by reducing the amount of radar signal power reflected from the stealth aircraft to the transmitting radar.

There are two basic ways to reduce reflected energy: either absorb the radar signal or deflect it in a different direction from the radar transmitter. Special radar absorbing materials are used in stealth aircraft. The shape and contours of the aircraft greatly affect the effective radar cross section. A concave surface tends to reflect radar waves back to the transmitter in the general direction of their arrival direction. This should be avoided on stealth aircraft.

Examples of concave surfaces include engine intakes, right angles where the wings meet the fuselage, open bomb bays, and even the cockpit if the windshields are transparent to radar signals. Convex surfaces, on the other hand, tend to scatter radar waves in widely separated directions, reducing the amount of energy reflected back to the source. Smaller features, such as engine air intakes, have geometry designed to reflect impinging radar signals in a different direction than illuminating radar.

Stealth technology, also called low observable technology (LO technology), is a sub-discipline of military tactics and passive and active electronic countermeasures, encompassing a range of methods used to make personnel, aircraft, ships, submarines, missiles, satellites. ground vehicles that are less visible (ideally invisible) to radar, infrared, sonar, and other detection methods.

For these parts of the electromagnetic spectrum, it corresponds to military camouflage (i.e., multi-spectral camouflage). The shape of a stealth plane helps deflect radar echoes. Flat surfaces reflect radar most effectively, so aircraft designers avoid having flat parts that might face the direction of the threat radar on the ground or in aircraft up ahead. Stealth fighter aircraft candidates are analyzed by the proposed neutrospophic decision making process.

Step 1. Determining alternatives and attributes

Alternatives are indicated by α_1, α_2, and α_3, a set of stealth fighter aircraft candidates. Attributes, characteristics of stealth fighter aircraft are defined as follows:

g_1 : Maximum takeoff weight (kg)
g_2 : Payload (kg)
g_3 : Avionics
g_4 : Maximum speed (km/h)
g_5 : Range (km)
g_6 : Service ceiling (km)
g_7 : Combat radius (km)
g_8 : Maneuverability
g_9 : Reliability

The direction of optimization for the criteria mentioned above is the maximization of the utility function.

Step 2. The linguistic term set $H = \{h_1, h_2, ..., h_7\}$ = {very poor, poor, slightly poor, fair, sightly good, good, very good} is employed here, and the evaluation information is given in the form of SVNSs.

Linguistic variables can effectively describe qualitative information and SVNSs can flexibly express uncertain, imprecise, incomplete, and inconsistent information that widely exist in scientific and engineering situations.

Step 3. The Pascal's triangle for triangular single valued neutrosophic fuzzy number is given by

$$P_p = \frac{1}{4}\left[a_1 + 2(a_2) + a_3\right]$$

The computed triangular single valued neutrosophic fuzzy numbers for P_{11} values are given as follows:

$$P_{11} = \frac{1}{4}\left[0.6 + 2(0.2) + 0.3\right] = 0,325$$

$$P_{11} = \frac{1}{4}\left[0.6 + 2(0.3) + 0.3\right] = 0,375$$

$$P_{11} = \frac{1}{4}\left[0.6 + 2(0.3) + 0.2\right] = 0,35$$

Table 1. Triangular neutrosophic set decision matrix

	α_1	α_2	α_3
g_1	<0.6,0.2,0.3; 0.6,0.3,0.3; 0.6,0.3,0.2>	<07,0.2,0.1; 0.7,0.1,0.2; 0.7,0.3,0.1>	<0.5,0.4,0.3; 0.5,0.3,0.3; 0.5,0.2,0.1>
g_2	<0.6,0.1,0.2; 0.6,0.2,0.1; 0.6,0.3,0.2>	<0.7,0.3,0.1; 0.7,0.2,0.1; 0.7,0.2,0.0>	<0.5,0.4,0.1; 0.5,0.3,0.2; 0.5,0.4,0.3>
g_3	<0.6,0.3,0.2; 0.6,0.4,0.3; 0.6,0.2,0.1>	<0.7,0.2,0.1; 0.7,0.3,0.5; 0.7,0.4,0.1>	<0.5,0.3,0.2; 0.5,0.4,0.3; 0.5,0.3,0.4>
g_4	<0.6,0.3,0.4; 0.6,0.2,0.1; 0.6,0.4,0.3>	<0.7,0.3,0.1; 0.7,0.3,0.2; 0.7,0.4,0.3>	<0.5,0.3,0.4; 0.5,0.4,0.4; 0.5,0.5,0.2>
g_5	<0.6,0.4,0.3; 0.6,0.3,0.2; 0.6,0.3,0.1>	<0.7,0.2,0.1; 0.7,0.3,0.2; 0.7,0.4,0.3>	<0.5,0.3,0.4; 0.5,0.4,0.2; 0.5,0.3,0.1>
g_6	<0.6,0.2,0.1; 0.6,0.1,0.1; 0.6,0.3,0.2>	<0.7,0.3,0.2; 0.7,0.4,0.3; 0.7,0.5,0.4>	<0.5,0.5,0.3; 0.5,0.6,0.4; 0.5,0.7,0.5>
g_7	<0.6,0.3,0.2; 0.6,0.3,0.1; 0.6,0.2,0.1>	<0.7,0.4,0.3; 0.7,0.3,0.2; 0.7,0.2,0.0>	<0.5,0.4,0.3; 0.5,0.5,0.3; 0.5,0.2,0.3>
g_8	<0.6,0.2,0.3; 0.6,0.2,0.3; 0.6,0.3,0.3>	<0.7,0.3,0.4; 0.7,0.2,0.2; 0.7,0.5,0.4>	<0.5,0.3,0.4; 0.5,0.5,0.3; 0.5,0.5,0.4>
g_9	<0.6,0.3,0.1; 0.6,0.2,0.1; 0.6,0.1,0.1>	<0.7,0.3,0.3; 0.7,0.4,0.2; 0.7,0.3,0.3>	<0.5,0.3,0.4; 0.5,0.3,0.0; 0.5,0.2,0.1>

Step 4. Similarly, all the triangular neutrosophic fuzzy numbers are converted into neutrosophic fuzzy numbers. The Table 2 below shows the triangular neutrosophic fuzzy numbers.

Table 2. Triangular neutrosophic fuzzy numbers

	α_1	α_2	α_3
g_1	< 0.325,0.375, 0.35 >	< 0.3, 0.275, 0.35 >	< 0.4, 0.35, 0.25 >
g_2	< 0.25, 0.275, 0.35 >	< 0,35, 0,3, 0.275 >	< 0.35, 0.325, 0.4 >
g_3	< 0.35, 0.425, 0.275 >	< 0.3, 0.45, 0.4 >	< 0.325,0.4, 0.375 >
g_4	< 0.4, 0.275, 0.425 >	< 0.35, 0.375, 0.45 >	< 0.375,0.425, 0.425 >
g_5	< 0.425,0.35, 0.325 >	< 0.3, 0.375, 0.45 >	< 0.375,0.375, 0.3 >
g_6	< 0,275, 0,225, 0,35 >	< 0.375, 0.45. 0.525 >	< 0.45, 0.525, 0,6 >
g_7	< 0,35, 0,325, 0,275 >	< 0.45, 0.375, 0.275 >	< 0.4, 0.45, 0.3 >
g_8	< 0,325, 0,3, 0,375 >	< 0.425,0.325, 0.525 >	< 0.375,0.45, 0.475>
g_9	< 0,325, 0,275, 0,225 >	< 0.4, 0.425, 0.4 >	< 0.375,0.275, 0.25 >

Step 5. Convert triangular neutrosophic fuzzy number into a single valued neutrosophic fuzzy number (SVNFN):

$$SVNFN(A_i) = \frac{1}{m}\sum_{i=1}^{m}\left[\frac{2+T_{rj}-I_{rj}-F_{rj}}{2}\right]$$

$$SVNFN(A_1) = \frac{1}{9}\left[\frac{2+0.325-0.375-0.35}{3}+...+\frac{2+0.325-0.275-0.225}{3}\right]$$

$SVNFN(A_1)$ =0.565

$$SVNFN(A_2) = \frac{1}{9}\left[\frac{2+0.3-0275-0.35}{3}+...+\frac{2+0.4-0.425-0.4}{3}\right]$$

$SVNFN(A_2)$ =0.528

$$SVNFN(A_3) = \frac{1}{9}\left[\frac{2+0.4-035-0.25}{3}+...+\frac{2+0.375-0.275-0.25}{3}\right]$$

$SVNFN(A_3)$ =0.536

Step 6. 0.565, 0.528, 0.536 are highly acceptable zone.

Step 7. Ranking of the alternatives

$SVNFN(A_i)$ ranking order: $0.565 \succ 0.536 \succ 0.528$

$A_1 \succ A_3 \succ A_2$ is best stealth fighter aircraft

A_1 : Stealth fighter aircraft is the best for the Air Force.

So, alternatives corresponding to single valued neutrosophic score values (highly acceptable and tolerance zone) can be chosen as important candidates for decision making process.

Step 8. End

IV. Conclusion

In this paper, multiple criteria decision making analysis in a single valued neutrosophic environment is presented. The advantages of this study are that the approach can accommodate situations where decision making problems involve qualitative variables. It has been shown that neutrosophic logic can play an important role in multiple criteria decision making analysis method. A single valued neutrosophic score function (SVNSF) was defined to collect the attribute values of each alternative.

An approach for analysis of multiple decision making with single valued neutrosophic information, and a numerical example for the proposed approach are also proposed. The best stealth fighter selection problem was analyzed with a single-valued neutrosophic fuzzy set, triangular univalent neutrosophic numbers, and a triangular neutrosophic fuzzy number for Pascal's triangle. From the above neutrosophic decision analysis results, it was concluded that A_1 stealth fighter aircraft was selected as the best aircraft for the Air Force.

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