Triple Refined Indeterminate Neutrosophic Sets for Personality Classification

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***Abstract*—Personality tests are most commonly objective type, where the users rate their behaviour. Instead of providing a single forced choice, they can be provided with more options. A person may not be in general capable to judge his/her behaviour very precisely and categorize it into a single category. Since it is self rating there is a lot of uncertain and indeterminate feelings involved. The results of the test depend a lot on the circumstances under which the test is taken, the amount of time that is spent, the past experience of the person, the emotion the person is feeling and the person's self image at that time and so on.**

In this paper Triple Refined Indeterminate Neutrosophic Set (TRINS) which is a type of the refined neutrosophic set is introduced. It provides the additional possibility to represent with sensitivity and accuracy the imprecise, uncertain, inconsistent and incomplete information which are available in real world. More precision is provided in handling indeterminacy; by classifying indeterminacy (I) into three, based on membership; as indeterminacy leaning towards truth membership (I_T), indeterminacy membership (I) and indeterminacy leaning towards false membership (I_F). This kind of classification of indeterminacy is not feasible with the existing Single Valued Neutrosophic Set (SVNS), but it is a particular category of the refined neutrosophic set (where each T, I, F can be refined into $T_1, T_2, \dots$; $I_1, I_2, \dots$; F_1, F_2, $\dots$). TRINS is better equipped at dealing indeterminate and inconsistent information, with more accuracy than SVNS and Double Refined Indeterminate Neutrosophic Set (DRINS), which fuzzy sets and Intuitionistic Fuzzy Sets (IFS) are incapable of. TRINS can be used in any place where the Likert scale is used. Personality test usually make use of the Likert scale. In this paper a indeterminacy based personality test is introduced for the first time. Here personality classification is made based on the Open Extended Jung Type Scale test and TRINS.

I. Introduction

Carl Jung in his collected work [1] had theorized the eight psychological types based on two main attitude types: extroversion and introversion, two observing functions: intuition and sensation and two judging functions: feeling and thinking. Psychological types are Extraverted sensation, Introverted sensation, Extraverted intuition, Introverted intuition, Extraverted thinking, Introverted thinking, Extraverted feeling and Introverted feeling. The MyersBriggs Type Indicator (MBTI) [2], is based on the theory given by Carl Jung. The psychological variations are sorted into four contrary pairs, or "dichotomies", that provides 16 feasible psychological types. The MBTI is a reflective self-analytic questionnaire designed to find the psychological inclinations of people's view of the world and their decision making. These personality tests are mostly objective in nature, where the test taker is forced to select a dominant choice. Quoting Carl Jung himself *"There is no such thing as a pure extrovert or a pure introvert. Such a man would be in the lunatic asylum."*, it is clear that there are degrees of variations, no person fits into a category 100%. Since it is not feasible for a person to put down his answer as single choice in reality, without ignoring the other degrees of variation. It necessitates a tool which can give more than one choice to represent their personality. The choice also depends highly on the situation and circumstance the individual faces at that time,

Fuzzy set theory introduced by Zadeh (1965) [3] proposes a constructive analytic method for soft division of sets. Zadeh's fuzzy set theory [3] was extended to intuitionistic fuzzy set (A-IFS), in which every entity is assigned a non-membership degree and a membership degree by Atanassov (1986) [4]. A-IFS is more suitable than fuzzy set in dealing with data that has fuzziness and uncertainty. A-IFS was further generalized into the concept of interval valued intuitionistic fuzzy set (IVIFS) by Atanassov and Gargov (1989) [5].

To characterize inconsistent, imprecise, uncertain, and incomplete information which are existing in real world, the notion of neutrosophic set from philosophical angle was given by Smarandache [6]. The neutrosophic set is a existing framework that generalizes the notion of the tautological set, fuzzy set, paraconsistent set, interval valued fuzzy set, intuitionistic fuzzy set, paradoxist set, interval valued intuitionistic fuzzy set and classic set. The neutrosophic set articulates independently truth, indeterminacy and falsity memberships. From the philosophical angle the aforesaid sets are generalized by the neutrosophic set. Its functions $T_A(x), I_A(x)$, and $F_A(x)$ are real standard or nonstandard subsets of $]^-0, 1^+[$, that is, $T_A(x) : X \to]^-0, 1^+[$, $I_A(x) : X \to]^-0, 1^+[$, and $F_A(x) : X \to]^-0, 1^+[$, respectively with the condition $^-0 \leq supT_A(x) + supI_A(x) + supF_A(x) \leq 3^+$.

It is challenging to adapt neutrosophic set in this structure in engineering fields and scientific research. To overcome this difficulty, Wang et al. [7] introduced a Single Valued Neutrosophic Set (SVNS), which is another form of a neutrosophic set. Fuzzy sets and intuitionistic fuzzy sets cannot deal with inconsistent and indeterminate information, which SVNS is capable of.

Owing to the fuzziness, uncertainty and indeterminate na-

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ture of many practical problems in the real world, neutrosophy has found application in various fields including Social Network Analysis (Salama et al [8]), Decision-making problems (Ye [9], [10], [11], [12]), Image Processing (Cheng and Guo[13], Sengur and Guo[14], Zhang et al [15]), Social problems (Vasantha and Smarandache [16], [17]) etc.

To provide more accuracy and precision to indeterminacy, the value of indeterminacy present in the neutrosophic set has been classified into two; based on membership; as indeterminacy leaning towards truth membership and as indeterminacy leaning towards false membership. They make the indeterminacy involved in the scenario to be more accurate and precise. This modified refined neutrosophic set was defined as Double Refined Indeterminacy Neutrosophic Set (DRINS) alias Double Valued Neutrosophic Set (DVNS) by Kandasamy [18] and Kandasamy and Smarandache [19].

To increase the accuracy, precision and to fit in the Likert's scale which is usually used in personality test; here the indeterminacy concept is divided into three, as indeterminacy leaning towards truth, indeterminacy and indeterminacy leaning towards false. This refined neutrosophic set is known as the Triple Refined Indeterminate Neutrosophic Sets (TRINS).

Consider an example from a personality test "You tend to sympathize with others". The person need not be forced to opt for a single choice; cause it is natural that the behaviour is dependent on several external and internal factors, varying from the person's mood to surrounding. So a person might not always react in a particular way, in a particular scenario. There is always a degree to which the person will strongly agree to the statement (say 0.7), will just agree (0.1), neither agree or disagree (0.05), will agree (0.1) and will strongly disagree(0.05). When a person is taking a personality test he/she is forced to opt for a single choice, thereby the degrees of membership of others are completely lost. Whereas using TRINS this statement is represented as $\langle 07, 0.1, 0.05, 0.1, 0.05\rangle$, it can be evaluated accurately; thereby giving very useful necessary precision to the result. All the various choices are captures thereby avoiding the preferential choice that is executed in the classical method.

Section one is introductory in nature. Section two recalls some basic concepts about neutrosophy and The Open Extended Jungian Type Scales (OEJTS) personality test. Section three introduces TRINS and related set theoretic concepts. Section four defines the distance measure over TRINS. The indeterminacy based OEJTS is introduced in section five. Section six provides the comparison of existing personality test and the indeterminacy based OEJTS test. The conclusions and future research on this topic is provided in the final section.

II. Basic Concepts

A. Personality test

Of all the categories of personality tests, the usual type is the objective personality tests.

It comprises of several questions/statements given to people who answer by rating the degree to which each item reveals their nature and which can be evaluated objectively. These statements on questionnaires allow people to specify the degree of acceptance.

Frequently taken personality test is the Myers-Briggs Type Indicator test. Many personality tests available on the internet provide meagre information about their formulation or evaluation.

A comparative study of different tests has not been carried out. There are currently no criteria for what makes a good Myers-Briggs/Jungian type. Of course, it could just be accepted that the Myers-Briggs Type Indicator (MBTI) defines Myers-Briggs/Jungian types and so that means that the measure of a test is just how similar it is to the MBTI.

The Open Extended Jungian Type Scales test [20] is an open source alternative to the Myers Briggs type indicator test. A comparative validity study of the Open Extended Jungian Type Scales was done using three other on-line tests. The OEJTS test has the capacity to distinguish personalities considerably better than other tests. It indicates OEJTS test is best precise on-line Myers-Briggs/Jungian type test. Of the numerous on-line Myers-Briggs tests, only three were selected on the basis of their acceptance within Myers-Briggs supporters. The Human Metrics Jung Typology Test, Similar Minds Jung Personality Test and 16-Personalities personality test were the selected ones.

The OEJTS test alone is taken for future discussion in this paper.

B. The Open Extended Jungian Type Scales (OEJTS)

An extension of the Jung's Theory of psychological type casting is the Myers-Briggs Type Indicator (MBTI). It has four personality dichotomies that are combined to yield 16 personality types. The dichotomies given in [20] are

1) Introversion (I) vs. Extroversion (E); sometimes is described as a persons orientation, they either orient within themselves or to the outside world. Other times the focus is put more openly on social communication and interactions, with some stating that social activities and interactions tires introverts whereas it increases the energy level of extroverts.
2) Sensing (S) vs. Intuition (N); how a person takes in information. Sensors generally focus on the five senses while intuitives focus on possibilities.
3) Feeling (F) vs. Thinking (T); is based on what a person uses to take their decisions: whether it is interpersonal considerations or through dispassionate logic.
4) Judging (J) vs. Perceiving (P); was a dichotomy added by Myers and Briggs to choose between the 2nd and 3rd pair of functions. Individuals who desire a organized lifestyle are supposed to use their judging functions (thinking and feeling) while individuals who prefer a flexible lifestyle use their sensing functions (intuition and sensing).

The Open Extended Jungian Type Scales (OEJTS) evaluates four scales, each planned to produce a huge score differential along one dichotomy.

TABLE I
QUESTIONNAIRE

Q		Scale	
Q_1	makes lists	1 2 3 4 5	relies on memory
Q_2	sceptical	1 2 3 4 5	wants to believe
Q_3	bored by time alone	1 2 3 4 5	needs time alone
Q_7	energetic	1 2 3 4 5	mellow
Q_{11}	works best in groups	1 2 3 4 5	works best alone
Q_{15}	worn out by parties	1 2 3 4 5	gets fired up by parties
Q_{19}	talks more	1 2 3 4 5	listens more
Q_{23}	stays at home	1 2 3 4 5	goes out on the town
Q_{27}	finds it difficult to yell very loudly	1 2 3 4 5	yelling to others when they are far away comes naturally
Q_{31}	perform in public	1 2 3 4 5	avoids public speaking

The format for the OEJTS has been preferred to be two statements that form a bipolar scale (e.g. humble to arrogant), operationalized on a five point scale. A sample questionnaire is shown in Table I.

C. Working of the Open Extended Jungian Type Scales

The OEJTS personality test provides a result equivalent to the Myers-Briggs Type Indicator, even though it is not the MBTI and has no association with it. In this test 32 pairs of personality descriptions are connected by a five point scale. For each pair, marking on the scale is a choice based on what you think you are. For example, if the personality description is angry versus calm, you should circle 1 if you think you are mostly angry and never calm; 3 if you are sometimes angry and sometimes calm, and so on. Sample questions are as shown in Table I. Questions 3, 7, 11, 15, 19, 23, 17 and 31 are related to Extrovert Introvert.

The scoring instructions from [20] are as follows:

$$IE = 30 - Q_3 - Q_7 - Q_{11} + Q_{15} - Q_{19} + Q_{23} + Q_{27} - Q_{31}$$

$$SN = 12 + Q_4 + Q_8 + Q_{12} + Q_{16} + Q_{20} - Q_{24} - Q_{28} + Q_{32}$$

$$FT = 30 - Q_2 + Q_6 + Q_{10} - Q_{14} - Q_{18} + Q_{22} - Q_{26} - Q_{30}$$

$$JP = 18 + Q_1 + Q_5 - Q_9 + Q_{13} - Q_{17} + Q_{21} - Q_{25} + Q_{29}$$

If IE score is more than 24, you are extrovert (E), otherwise you are introvert (I). If SN score is greater than 24, you are intuitive (N), otherwise you are sensing (S). If FT score is more than 24, you are thinking (T), otherwise you are feeling (F). If JP score is higher than 24, you are perceiving (P), otherwise you are judging (J). The four letters are combined together to obtain the personality type (e.g. I, S, F, P = ISFP).

D. Neutrosophy and Single Valued Neutrosophic Set (SVNS)

Neutrosophy is a section of philosophy, familiarized by Smarandache [6], that analyses the beginning, property, and scope of neutralities, as well as their connections with various concepts. It studies a concept, event, theory, proposition, or entity, "A" in relation to its contrary, "Anti-A" and that which is not A, "Non-A", and that which is neither "A" nor "Anti-A", denoted by "Neut-A". Neutrosophy is the foundation of neutrosophic set, neutrosophic probability, neutrosophic statistics and neutrosophic logic.

The notion of a neutrosophic set from philosophical angle, founded by Smarandache [6], is as follows.

Definition 1. *[6] Let X be a space of points (objects), with a generic element in X denoted by x. A neutrosophic set A in X is described by a truth membership function $T_A(x)$, an indeterminacy membership function $I_A(x)$, and a falsity membership function $F_A(x)$. The functions $T_A(x)$, $I_A(x)$, and $F_A(x)$ are nonstandard or real standard subsets of $]^-0, 1^+[$, that is, $T_A(x) : X \to]^-0, 1^+[, I_A(x) : X \to]^-0, 1^+[$, and $F_A(x) : X \to]^-0, 1^+[$, under the rule $^-0 \leq supT_A(x) + supI_A(x) + supF_A(x) \leq 3^+$.*

This concept of neutrosophic set is not easy to use in real world application of scientific and engineering fields. Therefore, the concept of Single Valued Neutrosophic Set (SVNS), which is an instance of a neutrosophic set was introduced by Wang et al. [7].

Definition 2. *[7] Let X be a space of points (objects) with generic elements in X denoted by x. An Single Valued Neutrosophic Set (SVNS) A in X is characterized by truth membership function $T_A(x)$, indeterminacy membership function $I_A(x)$, and falsity membership function $F_A(x)$. For each point x in X, there are $T_A(x), I_A(x), F_A(x) \in [0, 1]$, and $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$. Therefore, an SVNS A can be represented by $A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle \mid x \in X\}$. The following expressions are defined in [7] for SVNSs A, B:*

- $A \in B \iff T_A(x) \leq T_B(x), I_A(x) \geq I_B(x), F_A(x) \geq F_B(x)$ *for any x in X.*
- $A = B \iff A \subseteq B$ *and* $B \subseteq A$.
- $A^c = \{\langle x, F_A(x), 1 - I_A(x), T_A(x)\rangle | x \in X\}$.

The refined neutrosophic logic defined by [21] is as follows:

Definition 3. *T can be split into many types of truths: $T_1, T_2, \ldots, T_p$, and I into many types of indeterminacies: I_1, $I_2, \ldots, I_r$, and F into many types of falsities: $F_1, F_2, \ldots, F_s$, where all $p, r, s \geq 1$ are integers, and $p + r + s = n$. In the same way, but all subcomponents T_j, I_k, F_l are not symbols, but subsets of [0, 1], for all $j \in \{1, 2, \ldots, p\}$ all $k \in \{1, 2, \ldots, r\}$ and all $l \in \{1, 2, \ldots, s\}$. If all sources of information that separately provide neutrosophic values for a specific subcomponent are independent sources, then in the general case we consider that each of the subcomponents T_j, I_k, F_l is independent with respect to the others and it is in the non-standard set $]^-0, 1^+[$.*

III. TRIPLE REFINED INDETERMINACY NEUTROSOPHIC SET (TRINS)

Here the indeterminacy concept is divided into three, as indeterminacy leaning towards truth membership, indeterminacy membership and indeterminacy leaning towards false membership. This division aids in increasing the accuracy and precision of the indeterminacy and to fit in the Likert's scale which is usually used in personality test. This refined neutrosophic set is defined as the Triple Refined Indeterminate Neutrosophic Sets (TRINS).

Definition 4. *Consider X to be a set of points (objects) with generic entities in X denoted by x. A Triple Refined Indeterminate Neutrosophic Set (TRINS) A in X is considered as truth membership function $T_A(x)$, indeterminacy leaning towards truth membership function $I_{TA}(x)$, indeterminacy membership function $I_A(x)$, indeterminacy leaning towards falsity membership function $I_{FA}(x)$, and falsity membership function $F_A(x)$. Each membership function has a weight $w_m \in [0,5]$ associated with it. For each generic element $x \in X$, there are*

$$T_A(x),\ I_{TA}(x),\ I_A(x),\ I_{FA}(x),\ F_A(x) \in [0,1],$$
$$w_T(T_A(x)),\ w_{I_T}(I_{TA}(x)),\ w_I(I_A(x)),\ w_{I_F}(I_{FA}(x)),$$
$$w_F(F_A(x)) \in [0,5],$$

and

$$0 \leq T_A(x) + I_{TA}(x) + I_A(x) + I_{FA}(x) + F_A(x) \leq 5.$$

Therefore, a TRINS A can be represented by

$$A = \{\langle x, T_A(x), I_{TA}(x), I_A(x), I_{FA}(x), F_A(x)\rangle \mid x \in X\}.$$

A TRINS A is represented as

$$A = \int_X \{\langle T(x), I_T(x), I(x), I_F(x), F(x)\rangle / dx, x \in X\} \quad (1)$$

when X is continuous. It is represented as

$$A = \sum_{i=1}^{n} \{\langle T(x_i), I_T(x_i), I(x_i), I_F(x_i), F(x_i)\rangle \mid x_i, x_i \in X\} \quad (2)$$

when X is discrete.

Example 1. *Let $X = [x_1, x_2]$ where x_1 is question 1 and x_2 is question 2 from Table II. Let x_1, $x_2 \in [0,1]$ and when the membership weight is applied the values of $w_m(x_1)$ and $w_m(x_2)$ are in $[1,5]$. This is obtained from the questionnaire of the user.*

Consider question 1, instead of a forced single choice; their option for question 1 would be a degree of "make list", a degree of indeterminacy choice towards "make list" , a degree of uncertain and indeterminate combination of making list and depending on memory, an degree of indeterminate choice more of replying on memory, and a degree of "relying on memory".

A is a TRINS of X defined by

$$A = \langle 0.0, 0.4, 0.1, 0.0, 0.5\rangle / x_1 + \langle 0.5, 0.1, 0.1, 0.1, 0.2\rangle / x_2.$$

The associated membership weights are w_T = 1, w_{I_T} = 2, w_I = 3, w_{I_F} = 4, w_F = 5. Then the weighted TRINS $w_T(T_A(x))$, $w_{I_T}(I_{TA}(x))$, $w_I(I_A(x))$, $w_{I_F}(I_{FA}(x))$, $w_F(F_A(x)) \in [0,5]$, will be

$$A = \langle 0.0, 0.8, 0.3, 0.0, 1.5\rangle / x_1 + \langle 0.5, 0.2, 0.3, 0.4, 1.0\rangle / x_2.$$

Definition 5. *Consider TRINS A, its complement is denoted by $c(A)$ and is defined as*

1) $T_{c(A)}(x) = F_A(x)$
2) $I_{Tc(A)}(x) = 1 - I_{TA}(x)$
3) $I_{c(A)}(x) = 1 - I_A(x)$
4) $I_{Fc(A)}(x) = 1 - I_{FA}(x)$
5) $F_{c(A)}(x) = T_A(x)$

for all x in X.

Definition 6. *A TRINS A is contained in the other TRINS B, $A \subseteq B$, if and only if*

1) $T_A(x) \leq T_B(x)$
2) $I_{TA}(x) \leq I_{TB}(x)$
3) $I_A(x) \leq I_B(x)$
4) $I_{FA}(x) \leq I_{FB}(x)$
5) $F_A(x) \geq F_B(x)$

for all x in X.

X is a partially ordered set and not a totally ordered set, by the containment relation definition.

For example, let A and B be the TRINSs as defined in Example 1, then $A \nsubseteq B$ and $B \nsubseteq A$.

Definition 7. *Two TRINSs A and B are equal, denoted as $A = B \iff A \subseteq B$ and $B \subseteq A$.*

Theorem 1. $A \subseteq B \iff c(B) \subseteq c(A)$.

Definition 8. *The union of two TRINSs A and B is a TRINS C, denoted as $C = A \cup B$, whose truth membership, indeterminacy leaning towards truth membership, indeterminacy membership, indeterminacy leaning towards falsity membership and falsity membership functions are associated to A and B by the following*

1) $T_C(x) = max(T_A(x), T_B(x))$
2) $I_{TC}(x) = max(I_{TA}(x), I_{TB}(x))$
3) $I_C(x) = max(I_A(x), I_B(x))$
4) $I_{FC}(x) = max(I_{FA}(x), I_{FB}(x))$
5) $F_C(x) = min(F_A(x), F_B(x))$

$\forall x$ in X.

Theorem 2. *$A \cup B$ is the smallest TRINS containing both A and B.*

Proof. It is direct from definition of union operator. □

Definition 9. *The intersection of two TRINSs A and B is a TRINS C, denoted as $C = A \cap B$, whose truth, indeterminacy leaning towards truth, indeterminacy, indeterminacy leaning towards falsity, and falsity memberships functions are associated to A and B by the following*

1) $T_C(x) = min(T_A(x), T_B(x))$
2) $I_{TC}(x) = min(I_{TA}(x), I_{TB}(x))$
3) $I_C(x) = min(I_A(x), I_B(x))$
4) $I_{FC}(x) = min(I_{FA}(x), I_{FB}(x))$
5) $F_C(x) = max(F_A(x), F_B(x))$

for all $x \in X$.

Theorem 3. *The largest TRINS contained in both A and B is $A \cap B$.*

Proof. From the intersection operator definition, it is direct. □

Definition 10. *The difference of two TRINSs D, written as $D = A \setminus B$, whose truth membership, indeterminacy leaning towards truth membership, indeterminacy membership, indeterminacy leaning towards falsity membership and falsity membership functions are related to those of A and B by*

1) $T_D(x) = min(T_A(x), F_B(x))$
2) $I_{TD}(x) = min(I_{TA}(x), 1 - I_{TB}(x))$
3) $I_D(x) = min(I_A(x), 1 - I_B(x))$
4) $I_{FD}(x) = min(I_{FA}(x), 1 - I_{FB}(x))$
5) $F_D(x) = min(F_A(x), T_B(x))$

for all x in X.

Three operators truth favourite ($\triangle$), falsity favourite ($\bigtriangledown$) and indeterminacy neutral (∇) are defined over TRINSs. Two operators truth favourite ($\triangle$) and falsity favourite ($\bigtriangledown$) are defined to alter the indeterminacy in the TRINSs and convert it into intuitionistic fuzzy sets or paraconsistent sets. Similarly the TRINS is transformed into a SVNS by operator indeterminacy neutral (∇) by combining the indeterminacy values of the TRINS. These three operators are unique on TRINS.

Definition 11. *The truth favourite of a TRINS A is a TRINS B, written as $B = \triangle A$, whose truth membership and falsity membership functions are related to those of A by*

1) $T_B(x) = min(T_A(x) + I_{TA}(x), 1)$
2) $I_{TB}(x) = 0$
3) $I_B(x) = 0$
4) $I_{FB}(x) = 0$
5) $F_B(x) = F_A(x)$

for all x in X.

Definition 12. *The falsity favourite of a TRINS A, written as $B = \bigtriangledown A$, whose truth membership and falsity membership functions are related to those of A by*

1) $T_B(x) = T_A(x)$
2) $I_{TB}(x) = 0$
3) $I_B(x) = 0$
4) $I_{FB}(x) = 0$
5) $F_B(x) = min(F_A(x) + I_{FA}(x), 1)$

for all x in X.

Definition 13. *The indeterminacy neutral of a TRINS A is a TRINS B, written as $B = \nabla A$, whose truth membership, indeterminate membership and falsity membership functions are related to those of A by*

1) $T_B(x) = T_A(x)$
2) $I_{TB}(x) = min(I_{TA}(x) + I_B(x) + I_{FB}(x), 1)$
3) $I_B(x) = 0$
4) $I_{FB}(x) = 0$
5) $F_B(x) = F_A(x)$

for all x in X.

Proposition 1. *The following set theoretic operators are defined over TRINS X, Y and Z.*

1) *(Property 1) (Commutativity):*
$$X \cup Y = Y \cup X,$$
$$X \cap Y = Y \cap X,$$
$$X \times Y = Y \times X.$$
2) *(Property 2) (Associativity):*
$$X \cup (Y \cup Z) = (X \cup Y) \cup Z,$$
$$X \cap (Y \cap Z) = (X \cap Y) \cup Z,$$
$$X \times (Y \times Z) = (X \times Y) \times Z.$$
3) *(Property 3) (Distributivity):*
$$X \cup (Y \cap Z) = (X \cup Y) \cap (X \cup Z),$$
$$X \cap (Y \cup Z) = (X \cap Y) \cup (X \cap Z).$$
4) *(Property 4) (Idempotency):*
$$X \cup X = X,\ X \cap X = X,$$
$$\triangle \triangle X = \triangle X,\ \bigtriangledown \bigtriangledown X = \bigtriangledown X.$$
5) *(Property 5)*
$$X \cap \phi = \phi,\ X \cap X = X,$$
where $T\phi = I\phi = 0, F\phi = 1$ *and* $T_X = I_{TX} = I_{FX} = 1, F_X = 0$.
6) *(Property 6)*
$$X \cup \phi = X,\ X \cap X = X,$$
where $T\phi = I_I\phi = I_F\phi = 0, F\phi = 1$ *and* $T_X = I_X = 1, F_X = 0$.
7) *(Property 7) (Absorption):*
$$X \cup (X \cap Y) = X,\ X \cap (X \cup Y) = X.$$
8) *(Property 8) (De Morgan's Laws):*
$$c(X \cup Y) = c(X) \cap c(Y),\ c(X \cap Y) = c(X) \cup c(Y).$$
9) *(Property 9) (Involution):* $c(c(X)) = X$.

Almost all properties of classical set, fuzzy set, intuitionistic fuzzy set and SNVS are satisfied by TRINS. The principle of middle exclude is not satisfied by these sets.

IV. Distance Measures of TRINS

The weight measures over TRINS is defined in the following:

Consider TRINS A in a universe of discourse, $X = \{x_l, x_2, \ldots, x_n\}$, which are denoted by $A = \{\langle x_i,\ T_A(x_i), I_{TA}(x_i),\ I_A(x_i), I_{FA}(x_i), F_A(x_i)\rangle \mid x_i \in X\}$, where $T_A(x_i),\ I_{TA}(x_i),\ I_A(x_i), I_{FA}(x_i), F_A(x_i), \in [0, 1]$ for every $x_i \in X$. Let w_m be the weight of each membership, then $w_T(T_A(x)),\ w_{I_T}(I_{TA}(x)),\ w_I(I_A(x)),\ w_{I_F}(I_{FA}(x)), w_F(F_A(x)) \in [0, 5]$. Hereafter by the membership $T_A(x_i)$, $I_{TA}(x_i)$, $I_A(x_i)$, $I_{FA}(x_i)$, $F_A(x_i)$, we mean the weight membership $w_T(T_A(x))$, $w_{I_T}(I_{TA}(x))$, $w_I(I_A(x))$, $w_{I_F}(I_{FA}(x))$, $w_F(F_A(x))$.

Then, the generalized Triple Refined Indeterminate Neutrosophic weight is defined as follows:

$$w(A) = \{\sum_{i=1}^{n}\{w_T(T_A(x_i)) + w_{I_T}(I_{TA}(x_i)) + w_I(I_A(x_i)) + w_{I_F}(I_{FA}(x_i)) + w_F(F_A(x_i))\} \quad (3)$$

The distance measures over TRINSs is defined in the following and the related algorithm for determining the distance is given:

Consider two TRINSs A and B in a universe of discourse, $X = x_l, x_2, \ldots, x_n$, which are denoted by

$A = \{\langle x_i, T_A(x_i), I_{TA}(x_i), I_A(x_i), I_{FA}(x_i), F_A(x_i)\rangle \mid x_i \in X\}$, and $B = \{\langle x_i, T_B(x_i), I_{TB}(x_i), I_B(x_i), I_{FB}(x_i), F_A(x_i)\rangle \mid x_i \in X\}$,

where $T_A(x_i), I_{TA}(x_i), I_A(x_i), I_{FA}(x_i), F_A(x_i), T_B(x_i), I_{TB}(x_i), I_B(x_i), I_{FB}(x_i), F_B(x_i) \in [0,5]$ for every $x_i \in X$. Let $w_i(i = 1,2,\ldots,n)$ be the weight of an element $x_i(i = 1,2,\ldots,n)$, with $w_i \geq 0(i = 1,2,\ldots,n)$ and $\sum_{i=1}^{n} w_i = 1$.

Then, the generalized Triple Refined Indeterminate Neutrosophic weighted distance is defined as follows:

$$d_\lambda(A,B) = \{\frac{1}{5}\sum_{i=1}^{n} w_i[\mid T_A(x_i) - T_B(x_i)\mid^\lambda + \mid I_{TA}(x_i) - I_{TB}(x_i)\mid^\lambda + \mid I_A(x_i) - I_B(x_i)\mid^\lambda + \mid I_{FA}(x_i) - I_{FB}(x_i)\mid^\lambda + \mid F_A(x_i) - F_B(x_i)\mid^\lambda]\}^{1/\lambda} \tag{4}$$

where $\lambda > 0$.

Equation 4 reduces to the Triple Refined Indeterminate Neutrosophic weighted Hamming distance and the Triple Refined Indeterminate Neutrosophic weighted Euclidean distance, when $\lambda = 1, 2$, respectively. The Triple Refined Indeterminate Neutrosophic weighted Hamming distance is given as

$$d_\lambda(A,B) = \frac{1}{5}\sum_{i=1}^{n} w_i[\mid T_A(x_i) - T_B(x_i)\mid + \mid I_{TA}(x_i) - I_{TB}(x_i)\mid + \mid I_A(x_i) - I_T(x_i)\mid + \mid I_{FA}(x_i) - I_{FB}(x_i)\mid + \mid F_A(x_i) - F_B(x_i)\mid] \tag{5}$$

where λ = 1 in Equation 4.

The Triple Refined Indeterminate Neutrosophic weighted Euclidean distance is given as

$$d_\lambda(A,B) = \{\frac{1}{5}\sum_{i=1}^{n} w_i[\mid T_A(x_i) - T_B(x_i)\mid^2 + \mid I_{TA}(x_i) - I_{TB}(x_i)\mid^2 + \mid I_A(x_i) - I_B(x_i)\mid^2 \mid I_{FA}(x_i) - I_{FB}(x_i)\mid^2 + \mid F_A(x_i) - F_B(x_i)\mid^2]\}^{1/2} \tag{6}$$

where λ = 2 in Equation 4.

The algorithm to obtain the generalized Triple Refined Indeterminate Neutrosophic weighted distance $d_\lambda(A,B)$ is given in Algorithm 1.

The following proposition is given for the distance measure.

Proposition 2. *The generalized Triple Refined Indeterminate Neutrosophic weighted distance $d_\lambda(A,B)$ for $\lambda > 0$ satisfies the following properties:*

1) *(Property 1)* $d_\lambda(A,B) \geq 0$;
2) *(Property 2)* $d_\lambda(A,B) = 0$ *if and only if* $A = B$;
3) *(Property 3)* $d_\lambda(A,B) = d_\lambda(B,A)$;
4) *(Property 4) If* $A \subseteq B \subseteq C, C$ *is an TRINS in* X*, then* $d_\lambda(A,C) \geq d_\lambda(A,B)$ *and* $d_\lambda(A,C) \geq d_\lambda(B,C)$.

It can be easily seen that $d_\lambda(A,B)$ satisfies the properties (Property 1) to (Property 4).

The Triple Refined Indeterminate Neutrosophic distance matrix D is defined in the following.

Algorithm 1: Generalized Triple Refined Indeterminate Neutrosophic weighted distance $d_\lambda(A,B)$

Input: $X = x_l, x_2, \ldots, x_n$, TRINS A, B where $A = \{\langle x_i, T_A(x_i), I_{TA}(x_i), I_A(x_i), I_{FA}(x_i), F_A(x_i)\rangle \mid x_i \in X\}$, $B = \{\langle x_i, T_B(x_i), I_{TB}(x_i), I_B(x_i), I_{FB}(x_i), F_A(x_i)\rangle \mid x_i \in X\}$, $w_i(i = 1,2,\ldots,n)$

Output: $d_\lambda(A,B)$

```
begin
    d_λ ← 0
    for i = 1 to n do
        d_λ ← d_λ + w_i[| T_A(x_i) − T_B(x_i) |^λ +
        | I_TA(x_i) − I_TB(x_i) |^λ + | I_A(x_i) − I_B(x_i) |^λ +
        | I_FA(x_i) − I_FB(x_i) |^λ + | F_A(x_i) − F_B(x_i) |^λ]
    end
    d_λ ← d_λ /5
    d_λ ← d_λ^{1/λ}
end
```

Definition 14. *Let $A_j(j = 1,2,\ldots,m)$ be a collection of m TRINs, then $D = (d_{ij})_{m\times m}$ is called a Triple valued neutrosophic distance matrix, where $d_{ij} = d_\lambda(A_i, A_j)$ is the generalized Triple distance valued neutrosophic between A_i and A_j, and its properties are as follows:*

1) $0 \leq d_{ij} \leq 5$ *for all* $i, j = 1,2,\ldots,m$;
2) $d_{ij} = 0$ *if and only if* $A_i = A_j$;
3) $d_{ij} = d_{ji}$ *for all* $i, j = 1,2,\ldots,m$.

The algorithm to calculate the Triple Refined Indeterminate Neutrosophic weighted distance matrix D is given in Algorithm 2.

Algorithm 2: Triple Refined Indeterminate Neutrosophic weighted distance matrix D

Input: TRINS $A_1, \ldots, A_m$,

Output: Distance matrix D with elements d_{ij}

```
begin
    for i = 1 to m do
        for j = 1 to m do
            if i = j then
                d_ij ← 0
            else
                d_ij ← {d_λ (A_i, A_j)}
            end
        end
    end
end
```

V. The Indeterminacy Based Open Extended Jungian type Scales Using TRINS

A. Sample Questionnaire

A sample questionnaire of the indeterminacy based Open Extended Jungian Type Scales personality test using TRINS

TABLE II
SAMPLE QUESTIONNAIRE OF THE INDETERMINACY BASED OEJTS

Q		Scale weight 1 2 3 4 5	
Q_1	makes lists	□ □ □ □ □	relies on memory
Q_2	sceptical	□ □ □ □ □	wants to believe
Q_3	bored by time alone	□ □ □ □ □	needs time alone
Q_7	energetic	□ □ □ □ □	mellow
Q_{11}	works best in groups	□ □ □ □ □	works best alone
Q_{15}	worn out by parties	□ □ □ □ □	gets fired up by parties
Q_{19}	talks more	□ □ □ □ □	listens more
Q_{23}	stays at home	□ □ □ □ □	goes out on the town
Q_{27}	finds it difficult to yell very loudly	□ □ □ □ □	yelling to others ... comes naturally
Q_{31}	perform in public	□ □ □ □ □	avoids public speaking

will be as given in table II.

The user is expected to fill the degree accordingly.

Example 2. *Consider question 1, the different options would be*

1) *a degree of "make list",*
2) *a degree of indeterminacy choice towards "make list" ,*
3) *a degree of uncertain and indeterminate combination of making list and depending on memory,*
4) *a degree of indeterminate choice more of relying on memory, and*
5) *a degree of "relying on memory".*

Suppose the user thinks and marks a degree of "make list" is 0.0, a degree of indeterminate choice towards "make list" is 0.4 , a degree of uncertain and indeterminate combination of making list and depending on memory is 0.1, an degree of indeterminate choice more of relying on memory 0.3, and a degree of "relying on memory" is 0.2.

A is a TRINS of $Q = \{q_1\}$ defined by

$$A = \langle 0.0, 0.4, 0.1, 0.3, 0.2\rangle / q_1.$$

When the weight of each membership is applied, the TRINS A becomes

$$A = \langle 0.0, 0.8, 0.3, 1.2, 1.0\rangle / q_1$$
$$w(A) = 3.3.$$

In the general test, a whole number value from 1 to 5 will be obtained, whereas in the indeterminacy based OEJTS an accurate value is obtained. Thus the accuracy of the test is evident.

B. Calculating Results

Depending on the questionnaire the following grouping was carried out

TRINS E is defined in the discourse $Q_E = \{Q_{15}, Q_{23}, Q_{27}\}$ deals with the extrovert aspect and the introvert aspect is defined by TRINS I which is defined in the discourse $Q_I = \{Q_3, Q_7, Q_{11}, Q_{19}, Q_{31}\}$. The Sensing versus Intuition dichotomy is given by TRINSs S and N; S is defined in the discourse $Q_S = \{Q_{24}, Q_{28}\}$ and N is defined in the discourse $Q_N = \{Q_4, Q_8, Q_{12}, Q_{16}, Q_{20}, Q_{32}\}$. Similarly Feeling versus Thinking dichotomy is given by TRINSs F and T; F is defined in the discourse $Q_F = \{Q_2, Q_{14}, Q_{18}, Q_{26}, Q_{30}\}$ and T is defined the discourse $Q_T = \{Q_6, Q_{10}, Q_{22}\}$. TRINSs J and P are used to represent the judging versus perceiving dichotomy; J is defined in the discourse $Q_J = \{Q_{17}, Q_{25}\}$ and P is defined in the discourse $Q_P = \{Q_1, Q_5, Q_{13}, Q_{21}, Q_{29}\}$.

The weight of a TRINS E is given in Equations 3.

The calculation for scoring is as follows:

$$IE = 30 - w(I) + w(E)$$
$$SN = 12 - w(S) + w(N)$$
$$FT = 30 - w(F) + w(T)$$
$$JP = 18 - w(J) + w(P).$$

The score results are based on the following rules:

1) If IE is greater than 24, you are extrovert (E), otherwise you are introvert (I).
2) If SN is greater than 24, you are intuitive (N), otherwise you are sensing (S).
3) If FT is higher than 24, you are thinking (T), otherwise you are feeling (F).
4) If JP is higher than 24, you are perceiving (P), otherwise you are judging (J).

C. Comparing results of two people

Consider this personality test is taken by a group of people. Using the distance measure given in Algorithm 1 is defined over TRINS the difference and similarity in two or more person's personality can be analysed along a particular dichotomy. They can be analysed along extroversion (E), introversion (I), Intuitive (N), Sensing (S), Thinking (T), Feeling (F), Perceiving (P) or judging (J) or any combination of the eight. Clustering of the results using the distance matrix given in Algorithm 2 can also be carried out, it cluster and find similar personality people. This topic is left for future research.

VI. COMPARISON

The existing classical personality test force the test taker to select only one option and it is mostly what the user thinks he/she does often. The other options are lost to the test taker. It fails to capture the complete picture realistically. The dominant choice is selected, the selection might have very small margin. In such cases the accuracy of the test fails. Whereas when the indeterminacy based OEJTS Test is considered, it provides five different options to the test taker using TRINS for representing the choice.

It is important to understand why TRINS makes the candidate for this kind of personality test. The reason can be obtained by the following comparative analysis of the methods and their capacity to deal indeterminate, inconsistent and incomplete information.

TRINS is an instance of a neutrosophic set, which approaches the problem more logically with accuracy and precision to represent the existing uncertainty, imprecise, incomplete, and inconsistent information. It has the additional feature of being able to describe with more sensitivity the indeterminate and inconsistent information. TRINS alone can give scope for a person to express accurately the exact realistic choices instead of opting for a dominant choice. While, the SVNS can handle indeterminate information and inconsistent information, it is cannot describe with accuracy about the existing indeterminacy. It is known that the connector in fuzzy set is defined with respect to T (membership only) so the information of indeterminacy and non membership is lost. The connectors in intuitionistic fuzzy set are defined with respect to truth membership and false membership only; here the indeterminacy is taken as what is left after the truth and false membership. Hence a personality test based on TRINS gives the most accurate and realistic result, because it captures the complete scenario realistically.

VII. Conclusions

In objective type personality test like the MBTI or the OEJTS, the user is forced to select an option, and mostly lands up selecting the most dominant choice. The rest of the options are lost. A person may not be in general capable to judge his/her behaviour very precisely and categorize it into a particular choice. Since it is the person doing self rating there is a lot of uncertain, inexpressible and indeterminate feelings involved. The results of the test depend on a number of internal and external factors. To provide a more accurate and realistic result, a personality test needs to provide more choices and a degree of acceptance with that particular choice. To represent the Likert scale using neutrosophy, the concept of Triple Refined Indeterminate Neutrosophic Set (TRINS) was introduced. More precision is provided in handling indeterminacy; by classifying indeterminacy (I) into three, based on membership; as indeterminacy leaning towards truth membership (I_T), indeterminacy membership (I) and indeterminacy leaning towards false membership (I_F). TRINS can be used in any place where the Likert scale is used like personality test. In this paper a indeterminacy based personality test based on the OEJTS and TRINS was proposed. The calculation of results and personality types was discussed. This personality test is capable of accurately describing the perception of the test taker and their decision making tendencies. The personality of two people can be compared in detail using the distance measures defined over TRINS, however this is left for future study.

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