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Redefined neutrosophic composite relation and its application in medical diagnosis

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Abstract

In this article, we redefine the single-valued neutrosophic composite relation and apply it to medical diagnosis. We also show that the redefined neutrosophic composite relation gives a better result.

Keywords: Single valued neutrosophic set, Single valued neutrosophic relation, Single valued neutrosophic composite relation, Neutrosophic medical diagnosis.
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1 Introduction

The notion of Fuzzy set was brought to light by Zadeh[35] in 1965 and Intuitionistic fuzzy set, a generalized version of fuzzy set, was introduced by Atanassov[6] in 1986. After a decade, a new branch of philosophy recognised as Neutrosophy was developed and studied by Florentin Smarandache [28, 29, 30]. Smarandache [30] proved that neutrosophic set was a generalization of intuitionistic fuzzy set. Like intuitionistic fuzzy set, an element in a neutrosophic set has the degree of membership and the degree of non-membership but it has another grade of membership known as the degree of indeterminacy and one very important point about neutrosophic set is that all the three neutrosophic components are independent of one another.

After Smarandache had brought the thought of neutrosophy, it was studied and taken ahead by many researchers [22, 23, 25, 24, 21, 31]. In the year 2010, Wang et.al.[31] developed the notion of single valued neutrosophic set. Salma et.al.[26, 24] added the thinking of neutrusophic relation and studied some of its properties. Yang et.al.[32] in 2016 introduced single valued neutrosophic relation and investigated some properties. Generalizing the concept in [32], Kim et.al.[15] introduced the notion of single valued neutrosophic relation from a set X to the set Y. The authors also introduced composition of two neutrosophic relations and studied various properties.

Neutrosophy, due to the fact of its of flexibility and effectiveness, is attracting the researchers throughout the world and is very useful not only in the developement of science and technology but also in various other fields. For instance, Abdel-Basset et.al. [1, 4, 2, 5] studied the applications of neutrosophic theory in a number of scientific fields. Pramanik and Roy [20] in 2014 studied on the conflict between India and Pakistan over Jammu-Kashmir through neutrosophic

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game theory. Works on medical diagnosis[27, 3, 12, 34], decision making problem[33, 8, 9], image processing[10, 13], social issues[16, 19], educational problems[17, 18] were also done under neutrosophic environment.

In the year 2001, De et.al.[11] developed the method of intuitionistic medical diagnosis using intuitionistic fuzzy relation developed by R.Biswas[7]. In this article, we redefine the composition of two neutrosophic relations on single valued neutrosophic sets and apply it to medical diagnosis. The article is organized by conferring some basic notions of single valued neutrosophic sets and single valued neutrosophic relations in section 2. In section 3, we present the definition of redefined neutrosophic composite relation with example. Section 4 throws light on the application of single valued neutrosophic relations in medical diagnosis using both max-min-max composite relation and redefined composite relation separately. In the last part of this section we compare the outcomes coming up through two different types of composite relations and show that the redefined composite relation provides a better result. In section 5, we confer a conclusion.

2 Preliminaries

Definition 2.1. [31] Let X be the universe of discourse. A single valued neutrosophic set A over X is defined as $A = \{\langle x, \mathcal{T}_A(x), \mathcal{I}_A(x), \mathcal{F}_A(x)\rangle : x \in X\}$, where $\mathcal{T}_A, \mathcal{I}_A, \mathcal{F}_A$ are functions from X to $[0,1]$ and $0 \leq \mathcal{T}_A(x)+\mathcal{I}_A(x)+\mathcal{F}_A(x) \leq 3$.

The functions $\mathcal{T}_A, \mathcal{I}_A, \mathcal{F}_A$ denote respectively the degrees of truth-membership, indeterminacy-membership, falsehood-membership of the element $x \in X$ in A .

The set of all single valued neutrosophic sets over X is denoted by $\mathcal{N}(X)$.

Throughout this article, a neutrosophic set(NS, for short) will mean a single valued neutrosophic set.

Example 2.2. Let $X = \{a, b\}$ be the universe of discourse and $A = \{\langle a, 0.5, 0.4, 0.3\rangle, \langle b, 0.4, 0.5, 0.6\rangle\}$. Then A is a NS over X with $\mathcal{T}_A(a) = 0.5, \mathcal{I}_A(a) = 0.4, \mathcal{F}_A(a) = 0.3$ and $\mathcal{T}_A(b) = 0.4, \mathcal{I}_A(b) = 0.5, \mathcal{F}_A(b) = 0.6$.

Definition 2.3. [14] Let $A, B \in \mathcal{N}(X)$. Then

(i) (Inclusion): If $\mathcal{T}_A(x) \leq \mathcal{T}_B(x), \mathcal{I}_A(x) \geq \mathcal{I}_B(x), \mathcal{F}_A(x) \geq \mathcal{F}_B(x)$ for all $x \in X$ then A is said to be a neutrosophic subset of B and which is denoted by $A \subseteq B$.
(ii) (Equality): If $A \subseteq B$ and $B \subseteq A$ then $A = B$.
(iii) (Intersection): The intersection of A and B, denoted by $A \cap B$, is defined as $A \cap B = \{\langle x, \mathcal{T}_A(x) \wedge \mathcal{T}_B(x), \mathcal{I}_A(x) \vee \mathcal{I}_B(x), \mathcal{F}_A(x) \vee \mathcal{F}_B(x)\rangle : x \in X\}$.
(iv) (Union): The union of A and B, denoted by $A \cup B$, is defined as $A \cup B = \{\langle x, \mathcal{T}_A(x) \vee \mathcal{T}_B(x), \mathcal{I}_A(x) \wedge \mathcal{I}_B(x), \mathcal{F}_A(x) \wedge \mathcal{F}_B(x)\rangle : x \in X\}$.
(v) (Complement): The complement of the neutrosophic set A, denoted by A^c, is defined as $A^c = \{\langle x, \mathcal{F}_A(x), 1 - \mathcal{I}_A(x), \mathcal{T}_A(x)\rangle : x \in X\}$
(vi) (Universal Set): If $\mathcal{T}_A(x) = 1, \mathcal{I}_A(x) = 0, \mathcal{F}_A(x) = 0$ for all $x \in X$ then A is said to be neutrosophic universal set and which is denoted by $\tilde{X}$.
(vii) (Empty Set): If $\mathcal{T}_A(x) = 0, \mathcal{I}_A(x) = 1, \mathcal{F}_A(x) = 1$ for all $x \in X$ then A is said to be neutrosophic empty set and which is denoted by $\tilde{\emptyset}$.

Definition 2.4. [23] Let $\{A_i : i \in \triangle\} \subseteq \mathcal{N}(X)$, where $\triangle$ is an index set. Then

(i) $\cup_{i\in\triangle} A_i = \{\langle x, \vee_{i\in\triangle}\mathcal{T}_{A_i}(x), \wedge_{i\in\triangle}\mathcal{I}_{A_i}(x), \wedge_{i\in\triangle}\mathcal{F}_{A_i}(x)\rangle : x \in X\}$.
(ii) $\cap_{i\in\triangle} A_i = \{\langle x, \wedge_{i\in\triangle}\mathcal{T}_{A_i}(x), \vee_{i\in\triangle}\mathcal{I}_{A_i}(x), \vee_{i\in\triangle}\mathcal{F}_{A_i}(x)\rangle : x \in X\}$.

Definition 2.5. [14] Let $A, B \in \mathcal{N}(X)$ and $\{A_i : i \in \triangle\} \subseteq \mathcal{N}(X)$, $\triangle$ is an index set. Then the following hold.

(i) $A \cup A = A$ and $A \cap A = A$
(ii) $A \cup B = B \cup A$ and $A \cap B = B \cap A$
(iii) $A \cup \tilde{\emptyset} = A$ and $A \cup \tilde{X} = \tilde{X}$
(iv) $A \cap \tilde{\emptyset} = \tilde{\emptyset}$ and $A \cap \tilde{X} = A$
(v) $A \cap (B \cap C) = (A \cap B) \cap C$ and $A \cup (B \cup C) = (A \cup B) \cup C$
(vi) $(A^c)^c = A$
(vii) $(A \cup B)^c = A^c \cap B^c$ and $(A \cap B)^c = A^c \cup B^c$

(viii) $(\cup_{i\in\Delta}A_i)^c = \cap_{i\in\Delta}A_i^c$ and $(\cap_{i\in\Delta}A_i)^c = \cup_{i\in\Delta}A_i^c$
(ix) $B\cup(\cap_{i\in\Delta}A_i) = \cap_{i\in\Delta}(B\cup A_i)$
(x) $B\cap(\cup_{i\in\Delta}A_i) = \cup_{i\in\Delta}(B\cap A_i)$

Definition 2.6. [15] Let X, Y, Z be three ordinary sets. Then R is called a single valued neutrosophic relation(SVNR, for short) from X to Y if it is a SVNS in $X\times Y$ having the form $R = \{\langle (x,y), \mathcal{T}_R(x,y), \mathcal{I}_R(x,y), \mathcal{F}_R(x,y)\rangle : (x,y)\in X\times Y\}$, where $\mathcal{T}_R : X\times Y\to[0,1], \mathcal{I}_R : X\times Y\to[0,1], \mathcal{F}_R : X\times Y\to[0,1]$ denote the truth-membership function, indeterminacy-membership function, falsity-membership function respectively.

In particular, a SVNR from from X to X is called a SVNR in X.

The empty SVNR and the whole SVNR in X, denoted by $\tilde{\emptyset}_N$ and $\tilde{X}_N$ respectively, are defined as $\tilde{\emptyset}_N = \{\langle (x,y),0,1,1\rangle : (x,y)\in X\times X\}$ and $\tilde{X}_N = \{\langle (x,y),1,0,0\rangle : (x,y)\in X\times X\}$.

The set of all SVNRs from X to Y is denoted by $SVNR(X\times Y)$ and the set of all SVNRs in X is denoted by $SVNR(X)$.

Definition 2.7. [15] Let $R\in SVNR(X\times Y)$. Then

(i) the inverse of R, denoted by R^{-1}, is a SVNR from Y to X defined as $R^{-1}(y,x) = R(x,y)$ for each $(y,x)\in Y\times X$.
(ii) the complement of R, denoted by R^c, is a SVNR from X to Y defined as $\mathcal{T}_R^c(x,y) = \mathcal{F}_R(x,y), \mathcal{I}_R^c(x,y) = 1-\mathcal{I}_R(x,y), \mathcal{F}_R^c(x,y) = \mathcal{T}_R(x,y)$ for each $(x,y)\in X\times Y$.

Example 2.8. Let $X = \{a,b\}$ and $Y = \{p,q,r\}$. Then a SVNR R from X to Y is given by the following table.

R	p	q	r
a	(0.6, 0.1, 0.3)	(0.7, 0.3, 0.2)	(0.7, 0.6, 0.3)
b	(0.5, 0.3, 0.2)	(0.5, 0.2, 0.3)	(0.5, 0.4, 0.1)

Here $\mathcal{T}_R(a,p) = 0.6, \mathcal{I}_R(a,p) = 0.1, \mathcal{F}_R(a,p) = 0.3$ etc.

The complement of R, i.e., R^c is

R^c	p	q	r
a	(0.3, 0.9, 0.6)	(0.2, 0.7, 0.7)	(0.3, 0.4, 0.7)
b	(0.2, 0.7, 0.5)	(0.3, 0.8, 0.5)	(0.1, 0.6, 0.5)

and the inverse of R, i.e., R^{-1} is

R^{-1}	a	b
p	(0.6, 0.1, 0.3)	(0.5, 0.3, 0.2)
q	(0.7, 0.3, 0.2)	(0.5, 0.2, 0.3)
r	(0.7, 0.6, 0.3)	(0.5, 0.4, 0.1)

Definition 2.9. [15] Let $R, S\in SVNR(X\times Y)$. Then

(i) R is said to be contained in S, denoted by $R\subseteq S$, if $\mathcal{T}_R(x,y)\leq\mathcal{T}_S(x,y), \mathcal{I}_R(x,y)\geq\mathcal{I}_S(x,y), \mathcal{F}_R(x,y)\geq\mathcal{I}_S(x,y)$ for each $(x,y)\in X\times Y$.
(ii) R is said to be equal to S, denoted by $R = S$, if $R\subseteq S$ and $S\subseteq R$.
(iii) The intersection of R and S, denoted by $R\cap S$, is defined as $R\cap S = \{\langle (x,y), \mathcal{T}_R(x,y)\wedge\mathcal{T}_S(x,y), \mathcal{I}_R(x,y)\vee\mathcal{I}_S(x,y), \mathcal{F}_R(x,y)\vee\mathcal{F}_S(x,y)\rangle : (x,y)\in X\times Y\}$.
(iv) The union of R and S, denoted by $R\cup S$, is defined as $R\cup S = \{\langle (x,y), \mathcal{T}_R(x,y)\vee\mathcal{T}_S(x,y), \mathcal{I}_R(x,y)\wedge\mathcal{I}_S(x,y), \mathcal{F}_R(x,y)\wedge\mathcal{F}_S(x,y)\rangle : (x,y)\in X\times Y\}$.

Definition 2.10. [15] Let X, Y, Z be three ordinary sets. Also let $R\in SVNR(X\times Y)$ and $S\in SVNR(Y\times Z)$. Then the composition(max-min-max composition) of R and S, denoted by $S\circ R$, is a SVNR from X to Z defined as $S\circ R = \{\langle (x,z), \mathcal{T}_{S\circ R}(x,z), \mathcal{I}_{S\circ R}(x,z), \mathcal{F}_{S\circ R}(x,z)\rangle : (x,z)\in X\times Z\}$, where

$$\mathcal{T}_{S\circ R}(x,z)=\vee_{y\in Y}(\mathcal{T}_R(x,y)\wedge\mathcal{T}_S(y,z)),$$
$$\mathcal{I}_{S\circ R}(x,z)=\wedge_{y\in Y}(\mathcal{I}_R(x,y)\vee\mathcal{I}_S(y,z)),$$
$$\mathcal{F}_{S\circ R}(x,z)=\wedge_{y\in Y}(\mathcal{F}_R(x,y)\vee\mathcal{F}_S(y,z)).$$

Example 2.11. Let $X=\{a,b\},Y=\{p,q\},Z=\{u,v\}$. Also let $R\in SVNR(X\times Y),S\in SVNR(Y\times Z)$ be given by the following tables.

R	p	q
a	(0.6, 0.1, 0.2)	(0.1, 0.2, 0.7)
b	(0.5, 0.6, 0.7)	(0.3, 0.2, 0.1)

S	u	v
p	(0.5, 0.3, 0.2)	(0.6, 0.4, 0.3)
q	(0.9, 0.1, 0.2)	(0.2, 0.5, 0.4)

Then by using the defintion 2.10, $S\circ R\in SVNR(X\times Z)$ is as follows :

$S\circ R$	u	v
a	(0.5, 0.2, 0.2)	(0.6, 0.4, 0.3)
b	(0.5, 0.2, 0.2)	(0.5, 0.5, 0.4)

Definition 2.12. [15]

(i) The single valued neutrosophic identity relation in X, denoted by I_X, is defined as : for each $(x,y)\in X\times X$, $\mathcal{T}_{I_X}(x,y)=1,\mathcal{I}_{I_X}(x,y)=0,\mathcal{F}_{I_X}(x,y)=0$ if $x=y$ and $\mathcal{T}_{I_X}(x,y)=0,\mathcal{I}_{I_X}(x,y)=1,\mathcal{F}_{I_X}(x,y)=1$ if $x\neq y$.

(ii) A SVNR R in X is said to be reflexive if for each $x\in X$, $\mathcal{T}_R(x,x)=1,\mathcal{I}_R(x,x)=0,\mathcal{F}_R(x,x)=0$.

(iii) A SVNR R in X is said to be anti-reflexive if for each $x\in X$, $\mathcal{T}_R(x,x)=0,\mathcal{I}_R(x,x)=1,\mathcal{F}_R(x,x)=1$.

(iv) A SVNR R in X is said to be symmetric if for each $(x,y)\in X\times X$, $\mathcal{T}_R(x,y)=\mathcal{T}_R(y,x),\mathcal{I}_R(x,y)=\mathcal{I}_R(y,x),\mathcal{F}_R(x,y)=\mathcal{F}_R(y,x)$.

(v) A SVNR R in X is said to be anti-symmetric if for each $(x,y)\in X\times X$, with $x\neq y$, $\mathcal{T}_R(x,y)\neq\mathcal{T}_R(y,x),\mathcal{I}_R(x,y)\neq\mathcal{I}_R(y,x),\mathcal{F}_R(x,y)\neq\mathcal{F}_R(y,x)$.

(vi) A SVNR R in X is said to be transitive if $R\circ R\subseteq R$, i.e., $R^2\subseteq R$.

We now move to the main part of this article.

3 Redefined neutrosophic composite relation :

Here we define the composition of two neutrosophic relations for single valued neutrosophic set with some change in the definition introduced in [15] and give an example.

Definition 3.1. Let X,Y,Z be three ordinary sets. Also let $R\in SVNR(X\times Y)$ and $S\in SVNR(Y\times Z)$. Then the redefined composite relation of R and S, denoted by $S\circ R$, is a SVNR from X to Z defined as

$S\circ R=\{\langle(x,z),\mathcal{T}_{S\circ R}(x,z),\mathcal{I}_{S\circ R}(x,z),\mathcal{F}_{S\circ R}(x,z)\rangle:(x,z)\in X\times Z\}$, where

$$\mathcal{T}_{S\circ R}(x,z)=\bigvee_{y\in Y}\frac{\mathcal{T}_R(x,y)+\mathcal{T}_S(y,z)}{2},$$
$$\mathcal{I}_{S\circ R}(x,z)=\bigwedge_{y\in Y}\frac{\mathcal{I}_R(x,y)+\mathcal{I}_S(y,z)}{2},$$
$$\mathcal{F}_{S\circ R}(x,z)=\bigwedge_{y\in Y}\frac{\mathcal{F}_R(x,y)+\mathcal{F}_S(y,z)}{2}.$$

Example 3.2. Let $X=\{a,b\},Y=\{p,q\},Z=\{u,v\}$. Also let $R\in SVNR(X\times Y),S\in SVNR(Y\times Z)$ be given by the following tables.

R	p	q
a	(0.6, 0.1, 0.2)	(0.1, 0.2, 0.7)
b	(0.5, 0.6, 0.7)	(0.3, 0.2, 0.1)

S	u	v
p	(0.5, 0.3, 0.2)	(0.6, 0.4, 0.3)
q	(0.9, 0.1, 0.2)	(0.2, 0.5, 0.4)

Then by using the defintion 3.1, we have :

$$\mathcal{T}_{S\circ R}(a,u) = \bigvee_{y\in Y} \frac{\mathcal{T}_R(a,y)+\mathcal{T}_S(y,u)}{2} = \bigvee\{\frac{0.6+0.5}{2}, \frac{0.1+0.9}{2}\} = 0.55.$$
$$\mathcal{I}_{S\circ R}(a,u) = \bigwedge_{y\in Y} \frac{\mathcal{I}_R(a,y)+\mathcal{I}_S(y,u)}{2} = \bigwedge\{\frac{0.1+0.3}{2}, \frac{0.2+0.1}{2}\} = 0.15.$$
$$\mathcal{F}_{S\circ R}(a,u) = \bigwedge_{y\in Y} \frac{\mathcal{F}_R(a,y)+\mathcal{F}_S(y,u)}{2} = \bigwedge\{\frac{0.2+0.2}{2}, \frac{0.7+0.2}{2}\} = 0.20.$$

Similarly proceeding for the pairs $(a,v),(b,u),(b,v)$, we get the redefined composite relation $S\circ R \in SVNR(X\times Z)$ as given in the following table.

$S\circ R$	u	v
a	(0.55, 0.15, 0.20)	(0.60, 0.25, 0.25)
b	(0.60, 0.15, 0.15)	(0.55, 0.35, 0.25)

4 Application of SVNR in Medical diagnosis :

In this segment, we bring to light an application of single valued neutrosophic relation in medical diagnosis using the redefined composite relation for single valued neutrosophic sets. In a given pathology, suppose P is a set of patients, S is a set of symptoms and D is a set of diseases. In a similar way to De et.al.'s [11] idea of Intuitionistic medical knowledge, we define "Neutrosophic medical knowledge" as a single valued neutrosophic relation from the set of symptoms to the set of diseases which discloses the degrees of association, indeterminacy and non-association between the symptoms and the diseases.

4.1 Methodology

(1) Determination of symptoms in terms of a single valued neutrosophic relation.
(2) Formulation of medical knowledge based on the single valued neutrosophic relation.
(3) Determination of diagnosis on the basis of redefined single valued neutrosophic composition of relations.

If the condition of a particular patient is narrated in terms of a SVNR Q(patient-symptom relation) then the patient is supposed to be assigned a diagnosis through a SVNR R(symptom-disease relation) of "Neutrosophic medical knowledge" which is assumed to be pointed out by a doctor who is able to translate his/her own observation of the vaugeness involved in degrees of association, indeterminacy and non-association respectively, between symptoms and diagnosis.

We explain the notion for a finite number of patients. Let there be n patients $p_i, i=1,2,\cdots,n$ in a given laboratory. Then $p_i \in P$(or simply $p\in P$). Let us suppose that R is a SVNR from S to D and construct a SVNR Q from the set of patients P to the set of symptoms S. Clearly the redefined composite relation $T = R\circ Q$(patient-disease relation) of the SVNRs Q and R determines the state of patient p in terms of the diagnosis as a SVNR from P to D given by the membership functions

$$\mathcal{T}_{R\circ Q}(p,d) = \bigvee_{s\in S} \frac{\mathcal{T}_Q(p,s)+\mathcal{T}_R(s,d)}{2},$$
$$\mathcal{I}_{R\circ Q}(p,d) = \bigwedge_{s\in S} \frac{\mathcal{I}_Q(p,s)+\mathcal{I}_R(s,d)}{2},$$
$$\mathcal{F}_{R\circ Q}(p,d) = \bigwedge_{s\in S} \frac{\mathcal{F}_Q(p,s)+\mathcal{F}_R(s,d)}{2}.$$

$\forall p \in P$ and $\forall d \in D$.

For a given R and Q, the relation $T = R \circ Q$ can be calculated. From the knowledge of $R \circ Q$, an improved version $I_{R \circ Q}$ of the SVNR $R \circ Q$ can be obtained by using the formula

$$I_{R \circ Q}(p,d) = \mathcal{T}_{R \circ Q}(p,d) - \mathcal{I}_{R \circ Q}(p,d)\mathcal{F}_{R \circ Q}(p,d)$$

.

From this improved version $I_{R \circ Q}$, we render the decision-making. Decisions will be made based on the greatest value of the relation between patients and diseases. If equal values in different diagnosis in $I_{R \circ Q}$ are found then we consider the case in $R \circ Q$ for which the degree of indeterminacy is least. In case the doctor is not satisfied then R is modified as R evidently plays a significant role in this process. From this "Neutrosophic medical knowledge", it will be easier for the doctor to make a proper decision about the disease of the patient.

4.2 Case study using redefined composite relation

Suppose that there are four patients Ram, Sita, Biltu, Kaberi and their symptoms are temperature, headache, stomach pain, cough and chest pain. Then $P = \{$Ram, Sita, Biltu, Kaberi$\}$ and $S = \{$Temperature, Headache, Stomach pain, Cough, The SVNR $Q(P \times S)$ is given hypothetically in table 1. Let the set of diseases the patients are suspected to be affected by be $D = \{$Viral fever, Malaria, Typhoid, Stomach problem, Chest problem$\}$. The SVNR $R(S \times D)$ is given hypothetically in table 2. Using the definition 3.1, the redefined composite relation $T = R \circ Q(P \times D)$ is given in table 3. In table 4, we calculate $I_{R \circ Q}$ from table 3.

Table 1: Patient-Symptom relation

$Q(P \times S)$	Temperature	Headache	Stomach pain	Cough	Chest pain
Ram	(0.8, 0.2, 0.1)	(0.6, 0.3, 0.2)	(0.3, 0.1, 0.7)	(0.5, 0.3, 0.2)	(0.2, 0.3, 0.7)
Sita	(0.0, 0.1, 0.8)	(0.4, 0.1, 0.5)	(0.6, 0.2, 0.1)	(0.1, 0.3, 0.7)	(0.1, 0.2, 0.8)
Biltu	(0.8, 0.1, 0.1)	(0.8, 0.2, 0.1)	(0.0, 0.4, 0.7)	(0.2, 0.3, 0.7)	(0.0, 0.4, 0.5)
Kaberi	(0.6, 0.3, 0.1)	(0.5, 0.1, 0.4)	(0.3, 0.3, 0.4)	(0.7, 0.2, 0.2)	(0.4, 0.3, 0.4)

Table 2: Symptom-Disease relation

$R(S \times D)$	Viral fever	Malaria	Typhoid	Stomach problem	Chest problem
Temperature	(0.4, 0.2, 0.1)	(0.7, 0.1, 0.0)	(0.3, 0.3, 0.4)	(0.1, 0.2, 0.7)	(0.1, 0.2, 0.8)
Headache	(0.4, 0.3, 0.6)	(0.3, 0.3, 0.7)	(0.7, 0.2, 0.1)	(0.3, 0.4, 0.5)	(0.0, 0.1, 0.8)
Stomach pain	(0.2, 0.2, 0.8)	(0.1, 0.2, 0.9)	(0.3, 0.2, 0.8)	(0.8, 0.3, 0.0)	(0.3, 0.1, 0.9)
Cough	(0.5, 0.2, 0.4)	(0.8, 0.3, 0.0)	(0.3, 0.2, 0.7)	(0.3, 0.1, 0.8)	(0.3, 0.2, 0.9)
Chest pain	(0.2, 0.2, 0.8)	(0.2, 0.2, 0.9)	(0.2, 0.1, 0.8)	(0.3, 0.2, 0.8)	(0.9, 0.1, 0.1)

Table 3: Patient-Disease relation

$T(P \times D)$	Viral fever	Malaria	Typhoid	Stomach problem	Chest problem
Ram	(0.60,0.15,0.10)	(0.75,0.15,0.05)	(0.65,0.15,0.15)	(0.55,0.20,0.35)	(0.55,0.10,0.4)
Sita	(0.40,0.15,0.45)	(0.45,0.10,0.35)	(0.55,0.15,0.30)	(0.70,0.15,0.05)	(0.50,0.10,0.45)
Biltu	(0.60,0.15,0.10)	(0.75,0.10,0.05)	(0.75,0.20,0.10)	(0.55,0.15,0.30)	(0.45,0.15,0.30)
Kaberi	(0.60,0.20,0.10)	(0.75,0.20,0.05)	(0.60,0.15,0.25)	(0.55,0.15,0.20)	(0.65,0.10,0.25)

From the table 4, we conclude that Ram, Biltu and Kaberi are suffering from malaria while Sita is suffering from stomach problem.

Table 4: (From Table 3)

$I_{R\circ Q}$	Viral fever	Malaria	Typhoid	Stomach problem	Chest problem
Ram	0.585	**0.7425**	0.6275	0.48	0.51
Sita	0.3325	0.415	0.505	**0.6925**	0.455
Biltu	0.585	**0.745**	0.73	0.505	0.405
Kaberi	0.58	**0.74**	0.5625	0.52	0.625

4.3 Comparison between Max-Min-Max and Redefined composite relations

In this section we take up the same case study as in 4.2 (i.e., Q and R as in 4.2) and find $R \circ Q$ and $I_{R\circ Q}$ using max-min-max composite relation. Then we compare the outcomes with the outcomes obtained in 4.2 using redefined composite relation. But before going to do that we shall first verify numerically to ascertain which one between max-min-max composite relation and redefined composite relation provides better result by comparing the relational values.

4.3.1 Numerical verification

Let $X = \{a, b\}, Y = \{p, q\}, Z = \{u, v\}$. Also let $R \in SVNR(X \times Y), S \in SVNR(Y \times Z)$ be given in table 5 and table 6 respectively.

Table 5:

R	p	q
a	(0.6, 0.1, 0.2)	(0.1, 0.2, 0.7)
b	(0.5, 0.6, 0.7)	(0.3, 0.2, 0.1)

Table 6:

S	u	v
p	(0.5, 0.3, 0.2)	(0.6, 0.4, 0.3)
q	(0.9, 0.1, 0.2)	(0.2, 0.5, 0.4)

Table 7: Max-Min-Max composite relation of R and S

$S \circ R$	u	v
a	(0.5, 0.2, 0.2)	(0.6, 0.4, 0.3)
b	(0.5, 0.2, 0.2)	(0.5, 0.5, 0.4)

Table 8: Redefined composite relation of R and S

$S \circ R$	u	v
a	(0.55, 0.15, 0.20)	(0.60, 0.25, 0.25)
b	(0.60, 0.15, 0.15)	(0.55, 0.35, 0.25)

We now find $I_{S\circ R}$ for the max-min-max composite relation $S \circ R$.

Table 9: (From table 7)

$I_{S\circ R}$	u	v
a	0.46	0.48
v	0.46	0.30

Next we find $I_{S\circ R}$ for the redefined composite relation $S \circ R$.

Table 10: (From table 8)

$I_{S\circ R}$	u	v
a	0.52	0.5375
v	0.5775	0.4625

From the tables 9 and 10, it is very clear that for each of the pairs $(a, u), (a, v), (b, u), (b, v)$ the value of $I_{S\circ R}$ calculated from redefined composite relation is greater than the value of $I_{S\circ R}$ calculated from max-min-max composite relation.

Hence we can conclude that the redefined composite relation provides higher relational values as compared to max-min-max composite relation.

4.3.2 Case study using Max-Min-Max composite relation

For the same relations Q and R in 4.2, we find $T = R \circ Q$ and $I_{R\circ Q}$ by using max-min-max composite relation.

Table 11: Using max-min-max composite relation

$T(P \times D)$	Viral fever	Malaria	Typhoid	Stomach problem	Chest problem
Ram	(0.5, 0.2, 0.1)	(0.7, 0.2, 0.1)	(0.6, 0.2, 0.2)	(0.3, 0.2, 0.5)	(0.3, 0.1, 0.7)
Sita	(0.4, 0.2, 0.6)	(0.3, 0.1, 0.7)	(0.4, 0.2, 0.5)	(0.6, 0.2, 0.1)	(0.3, 0.1, 0.8)
Biltu	(0.4, 0.2, 0.1)	(0.7, 0.1, 0.1)	(0.7, 0.2, 0.1)	(0.3, 0.2, 0.5)	(0.2, 0.2, 0.5)
Kaberi	(0.5, 0.2, 0.1)	(0.7, 0.3, 0.1)	(0.5, 0.2, 0.4)	(0.3, 0.2, 0.4)	(0.4, 0.1, 0.4)

Table 12: (From table 11)

$I_{R\circ Q}$	Viral fever	Malaria	Typhoid	Stomach problem	Chest problem
Ram	0.48	**0.68**	0.56	0.2	0.23
Sita	0.28	0.23	0.30	**0.58**	0.22
Biltu	0.38	**0.69**	0.68	0.20	0.10
Kaberi	0.48	**0.67**	0.42	0.22	0.36

In the table 12, we see that Ram, Biltu and Kaberi are suffering from malaria while Sita is suffering from stomach problem.

4.3.3 Decision on comparison study between usage of two composite relations

From the tables 4 and 12, we observe that the decisions using max-min-max composite relation as well as using redefined composite relation are exactly same but with a difference that the redefined composite relation for gives higher relational values. This shows that the redefined composite relation capitulates a better result when compared to max-min-max composite relation for neutrosophic sets.

5 Conclusion

Like fuzzy and intuitionistic fuzzy theories, neutrosophic theory also deals with vague situation and is a very ingenious mathematical tool with noteworthy potential to handle the indeterminacy adorned in decision-making problem. In this article we have redefined the neutrosophic composite relation on single valued neutrosophic set and then applied it to medical diagnosis following the approach of De et.al.'s "Intuitionistic medical knowledge". Lastly a comparison study between the outcomes coming up from using max-min-max composite relation and redefined composite relation has been done and it has been noticed that the redefined composite relation yields better result. In coming future we shall try to study some other applications of neutrosophic theory.

6 Conflict of interest

We certify that there is no actual or potential conflict of interest in relation to this article.

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