Applications of Neutrosophic Logic to Robotics
An Introduction

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Abstract— In this paper we present the N-norms/N-conorms in neutrosophic logic and set as extensions of T-norms/T-conorms in fuzzy logic and set. Then we show some applications of the neutrosophic logic to robotics.

Keywords: N-norm, N-conorm, N-pseudonorm, N-pseudoconorm, Neutrosophic set, Neutrosophic logic, Robotics

I. DEFINITION OF NEUTROSOPHIC SET
Let T, I, F be real standard or non-standard subsets of \([0, 1]\), with sup T = t_sup, inf T = t_inf, sup I = i_sup, inf I = i_inf, sup F = f_sup, inf F = f_inf, and n_sup = t_sup+i_sup+f_sup, n_inf = t_inf+i_inf+f_inf.
Let U be a universe of discourse, and M a set included in U. An element x from U is noted with respect to the set M as x(T, I, F) and belongs to M in the following way: it is t% true in the set, i% indeterminate (unknown if it is or not) in the set, and f% false, where t varies in T, i varies in I, f varies in F ([1], [3]).
Statically T, I, F are subsets, but dynamically T, I, F are functions/operators depending on many known or unknown parameters.

II. DEFINITION OF NEUTROSOPHIC LOGIC
In a similar way we define the Neutrosophic Logic: A logic in which each proposition x is T% true, I% indeterminate, and F% false, and we write it x(T,I,F), where T, I, F are defined above.

III. PARTIAL ORDER
We define a partial order relationship on the neutrosophic set/logic in the following way:
\[ x(T_1, I_1, F_1) \leq y(T_2, I_2, F_2) \text{ iff (if and only if)} \]
\[ T_1 \leq T_2, I_1 \geq I_2, F_1 \geq F_2 \]
for crisp components.
And, in general, for subunitary set components:
\[ x(T_1, I_1, F_1) \leq y(T_2, I_2, F_2) \text{ iff} \]
\[ \inf T_1 \leq \inf T_2, \sup T_1 \leq \sup T_2, \]
\[ \inf I_1 \geq \inf I_2, \sup I_1 \geq \sup I_2, \]
\[ \inf F_1 \geq \inf F_2, \sup F_1 \geq \sup F_2, \]
for subunitary sets.

IV. N-NORM AND N-CONORM
As a generalization of T-norm and T-conorm from the Fuzzy Logic and Set, we now introduce the N-norms and N-conorms for the Neutrosophic Logic and Set.
A. N-norm
\[ N_n(\{0,1\} \times \{0,1\} \times \{0,1\}) \rightarrow \{0,1\} \times \{0,1\} \times \{0,1\} \]
\[ N_n(x(T_1, I_1, F_1), y(T_2, I_2, F_2)) = (N_nT(x,y), N_nI(x,y), N_nF(x,y)), \]
where \( N_nT(.,.), N_nI(.,.), N_nF(.,.) \) are the truth/membership, indeterminacy, and respectively falsehood/nonmembership components.

If we have mixed - crisp and subunitary - components, or only crisp components, we can transform any crisp component, say “a” with a \( A \) \([0,1]\) or a \( A \) \([-0,1]\), into a subunitary set \([a, a] \). So, the definitions for subunitary set components should work in any case.

N_n have to satisfy, for any x, y, z in the neutrosophic logic/set M of the universe of discourse U, the following axioms:
a) Boundary Conditions: \( N_n(x, 0) = 0, N_n(x, 1) = x \).
b) Commutativity: \( N_n(x, y) = N_n(y, x) \).
c) Monotonicity: If \( x \leq y \), then \( N_n(x, z) \leq N_n(y, z) \).
d) Associativity: \( N_n(N_n(x, y, z) = N_n(x, N_n(y, z)) \).

There are cases when not all these axioms are satisfied, for example the associativity when dealing with the neutrosophic normalization after each neutrosophic operation. But, since we work with approximations, we can call these N-pseudo-norms, which still give good results in practice.

N_n represent the and operator in neutrosophic logic, and respectively the intersection operator in neutrosophic set theory.

Let J \( \in \{T, I, F\} \) be a component.
Most known N-norms, as in fuzzy logic and set the T-norms, are:
- The Algebraic Product N-norm: \( N_{n-algebraic}(x, y) = x \cdot y \)
- The Bounded N-Norm: \( N_{n-bounded}(x, y) = \max\{0, x + y - 1\} \)
- The Default (min) N-norm: \( N_{n-min}(x, y) = \min\{x, y\} \).
A general example of N-norm would be this. Let \( x(T_1, I_1, F_1) \) and \( y(T_2, I_2, F_2) \) be in the neutrosophic set/logic \( M \). Then:
\[
N_n(x, y) = (T_1 \land T_2, I_1 \lor I_2, F_1 \lor F_2)
\]
where the "\( \land \)" operator, acting on two (standard or non-standard) subunitary sets, is a N-norm (verifying the above N-norms axioms); while the "\( \lor \)" operator, also acting on two (standard or non-standard) subunitary sets, is a N-conorm (verifying the above N-conorms axioms).

For example, \( \land \) can be the Algebraic Product T-norm/N-norm, so \( T_1 \land T_2 = T_1 \cdot T_2 \) (herein we have a product of two subunitary sets – using simplified notation); and \( \lor \) can be the Algebraic Product T-conorm/N-conorm, so \( T_1 \lor T_2 = T_1 + T_2 - T_1 \cdot T_2 \) (herein we have a sum, then a product, and afterwards a subtraction of two subunitary sets).

Or \( \land \) can be any T-norm/N-norm, and \( \lor \) any T-conorm/N-conorm from the above; for example the easiest way would be to consider the \( \min \) for crisp components (or \( \inf \) for subset components) and respectively \( \max \) for crisp components (or \( \sup \) for subset components).

If we have crisp numbers, we can at the end neutrosophically normalize.

### B. N-conorm
\[
N_c: ([0,1], \times, [0,1], \times) \rightarrow ([0,1], \times, [0,1], \times)
\]

\( N_c(x(T_1, I_1, F_1), y(T_2, I_2, F_2)) = (N_cT(x,y), N_cI(x,y), N_cF(x,y)) \), where \( N_cT(\ldots), N_cI(\ldots), N_cF(\ldots) \) are the truth/membership, indeterminacy, and respectively falsehood/nonmembership components.

\( N_c \) have to satisfy, for any \( x, y, z \) in the neutrosophic logic/set \( M \) of universe of discourse \( U \), the following axioms:

- **Boundary Conditions:** \( N_c(x, 1) = 1, N_c(x, 0) = x \).
- **Commutativity:** \( N_c(x, y) = N_c(y, x) \).
- **Monotonicity:** if \( x \leq y \), then \( N_c(x, z) \leq N_c(y, z) \).
- **Associativity:** \( N_c(N_c(x, y), z) = N_c(x, N_c(y, z)) \).

There are cases when not all these axioms are satisfied, for example the associativity when dealing with the neutrosophic normalization after each neutrosophic operation. But, since we work with approximations, we can call these **N-pseudo-conorms**, which still give good results in practice.

\( N_c \) represent the or operator in neutrosophic logic, and respectively the union operator in neutrosophic set theory.

Let \( J \in \{T, I, F\} \) be a component.

Most known N-conorms, as in fuzzy logic and set the T-conorms, are:

- **The Algebraic Product N-conorm:** \( N_{c-algebraic}(x, y) = x + y - x \cdot y \)
- **The Bounded N-conorm:** \( N_{c-bounded}(x, y) = \min\{1, x + y\} \)
- **The Default (max) N-conorm:** \( N_{c-max}(x, y) = \max\{x, y\} \).

Since the \( \min/\max \) (or \( \inf/\sup \)) operators work the best for subunitary set components, let’s present their definitions below. They are extensions from subunitary intervals \( \{\text{defined in [3]}\} \) to any subunitary sets. Analogously we can do for all neutrosophic operators defined in [3].

Let \( x(T_1, I_1, F_1) \) and \( y(T_2, I_2, F_2) \) be in the neutrosophic set/logic \( M \).

### C. More Neutrosophic Operators

**Neutrosophic Conjunction/Intersection:**
\[
x \land y = (T_1 \land T_2, I_1 \lor I_2, F_1 \lor F_2)
\]
where \( \inf T_1 = \min\{\inf T_1, \inf T_2\} \)
\[
sup T_1 = \min\{\sup T_1, \sup T_2\}
\]
\[
\inf I_1 = \max\{\inf I_1, \inf I_2\}
\]
\[
sup I_1 = \max\{\sup I_1, \sup I_2\}
\]
\[
\inf F_1 = \max\{\inf F_1, \inf F_2\}
\]
\[
sup F_1 = \max\{\sup F_1, \sup F_2\}
\]

**Neutrosophic Disjunction/Union:**
\[
x \lor y = (T_1 \lor T_2, I_1 \land I_2, F_1 \land F_2)
\]
where \( \inf T_1 = \max\{\inf T_1, \inf T_2\} \)
\[
sup T_1 = \max\{\sup T_1, \sup T_2\}
\]
\[
\inf I_1 = \min\{\inf I_1, \inf I_2\}
\]
\[
sup I_1 = \min\{\sup I_1, \sup I_2\}
\]
\[
\inf F_1 = \min\{\inf F_1, \inf F_2\}
\]
\[
sup F_1 = \min\{\sup F_1, \sup F_2\}
\]

**Neutrosophic Negation/Complement:**
\[
C(x) = (T_c, I_c, F_c)
\]
where \( T_c = F_1 \)
\[
\inf I_c = 1 - \sup I_1
\]
sup I_C = 1 - inf I_I
F_C = T_I

Upon the above Neutrosophic Conjunction/Intersection, we can define the

**Neutrosophic Containment:**

We say that the neutrosophic set A is included in the neutrosophic set B of the universe of discourse U, iff for any x(T_A, I_A, F_A) I A with x(T_B, I_B, F_B) I B we have:
inf T_A ≤ inf T_B; sup T_A ≤ sup T_B;
inf I_A ≥ inf I_B; sup I_A ≥ sup I_B;
inf F_A ≥ inf F_B; sup F_A ≥ sup F_B.

**D. Remarks**

a) The non-standard unit interval \( ]0, 1[ \) is merely used for philosophical applications, especially when we want to make a distinction between relative truth (truth in at least one world) and absolute truth (truth in all possible worlds), and similarly for distinction between relative or absolute falsehood, and between relative or absolute indeterminacy.

But, for technical applications of neutrosophic logic and set, the domain of definition and range of the N-norm and N-conorm can be restrained to the normal standard real unit interval \([0, 1]\), which is easier to use, therefore:

\[
N_o: ( [0,1] \times [0,1] \times [0,1] )^2 \rightarrow [0,1] \times [0,1] \times [0,1]
\]

and

\[
N_c: ( [0,1] \times [0,1] \times [0,1] )^2 \rightarrow [0,1] \times [0,1] \times [0,1].
\]

b) Since in NL and NS the sum of the components (in the case when T, I, F are crisp numbers, not sets) is not necessary equal to 1 (so the normalization is not required), we can keep the final result un-normalized.

But, if the normalization is needed for special applications, we can normalize at the end by dividing each component by the sum all components.

If we work with intutionistic logic/set (when the information is incomplete, i.e. the sum of the crisp components is less than 1, i.e. sub-normalized), or with paraconsistent logic/set (when the information overlaps and it is contradictory, i.e. the sum of crisp components is greater than 1, i.e. over-normalized), we need to define the neutrosophic measure of a proposition/set.

If \( x(T,I,F) \) is a NL/NS, and T,I,F are crisp numbers in \([0,1]\), then the **neutrosophic vector norm** of variable/set x is the sum of its components:

\[
N_{\text{vector-norm}}(x) = T + I + F.
\]

Now, if we apply the \( N_o \) and \( N_c \) to two propositions/sets which maybe intuitionistic or paraconsistent or normalized (i.e. the sum of components less than 1, bigger than 1, or equal to 1), x and y, what should be the neutrosophic measure of the results \( N_o(x,y) \) and \( N_c(x,y) \)?

Herein again we have more possibilities:

- either the product of neutrosophic measures of x and y:
  \[
  N_{\text{vector-norm}}(N_o(x,y)) = N_{\text{vector-norm}}(x) \cdot N_{\text{vector-norm}}(y),
  \]
- or their average:
  \[
  N_{\text{vector-norm}}(N_c(x,y)) = \frac{(N_{\text{vector-norm}}(x) + N_{\text{vector-norm}}(y))}{2},
  \]
- or other function of the initial neutrosophic measures:
  \[
  N_{\text{vector-norm}}(N_o(x,y)) = f(N_{\text{vector-norm}}(x), N_{\text{vector-norm}}(y)), \text{ where } f(.,.) \text{ is a function to be determined according to each application.}
  \]

Similarly for \( N_{\text{vector-norm}}(N_c(x,y)) \).

Depending on the adopted neutrosophic vector norm, after applying each neutrosophic operator the result is neutrosophically normalized. We’d like to mention that “**neutrosophically normalizing**” doesn’t mean that the sum of the resulting crisp components should be 1 as in fuzzy logic/set or intuitionistic fuzzy logic/set, but the sum of the components should be as above: either equal to the product of neutrosophic vector norms of the initial propositions/sets, or equal to the neutrosophic average of the initial propositions/sets vector norms, etc.

In conclusion, we neutrosophically normalize the resulting crisp components \( T',I',F' \) by multiplying each neutrosophic component \( T',I',F' \) with \( S/(T'+I'+F') \), where

\[
S= N_{\text{vector-norm}}(N_o(x,y)) \text{ for a N-norm or } S= N_{\text{vector-norm}}(N_c(x,y)) \text{ for a N-conorm - as defined above.}
\]

c) If T, I, F are subsets of \([0, 1]\) the problem of neutrosophic normalization is more difficult.

i) If \( \text{sup}(T)+\text{sup}(I)+\text{sup}(F) < 1 \), we have an **intuitionistic proposition/set**.

ii) If \( \text{inf}(T)+\text{inf}(I)+\text{inf}(F) > 1 \), we have a **paraconsistent proposition/set**.

iii) If there exist the crisp numbers \( t \in T, i \in I, \) and \( f \in F \) such that \( t+i+f =1 \), then we can say that we have a **plausible normalized proposition/set**.

But in many such cases, besides the normalized particular case showed herein, we also have crisp numbers, say \( t_j \in T, i_j \in I, \) and \( f_j \in F \) such that \( t_i+i_j+f_j < 1 \) (incomplete
information) and \( t_2 \in T, i_2 \in I, \) and \( f_2 \in F \) such that \( t_2 + i_2 + f_2 > 1 \) (paraconsistent information).

E. Examples of Neutrosophic Operators which are \( N \)-norms or \( N \)-pseudonorms or, respectively \( N \)-conorms or \( N \)-pseudoconorms

We define a binary neutrosophic conjunction (intersection) operator, which is a particular case of a \( N \)-norm (neutrosophic norm, a generalization of the fuzzy \( T \)-norm):

\[
\mathcal{N}_T : ([0.1] \times [0.1] \times [0.1])^2 \rightarrow [0.1] \times [0.1] \times [0.1]
\]

\[
\mathcal{N}_T (x, y) = (T_1 T_2, I_1 I_2, F_1 F_2)
\]

The neutrosophic conjunction (intersection) operator \( x \wedge_N y \) component truth, indeterminacy, and falsehood values result from the multiplication

\[
(T_1 + I_1 + F_1) \cdot (T_2 + I_2 + F_2)
\]

since we consider in a prudent way \( T \ p I \ p F \), where “\( p \)” is a neutrosophic relationship and means “weaker”, i.e. the products \( T_i I_j \) will go to \( I \), \( T_i F_j \) will go to \( F \), and \( I_i F_j \) will go to \( F \) for all \( i, j \in \{1, 2\}, i \neq j \), while of course the product \( T_1 T_2 \) will go to \( T \), \( I_1 I_2 \) will go to \( I \), and \( F_1 F_2 \) will go to \( F \) (or reciprocally we can say that \( F \) prevails in front of \( I \) which prevails in front of \( T \), and this neutrosophic relationship is transitive):

\[
\begin{align*}
&T_1 I_1 F_1, & (T_1, I_1, F_1) \\
&T_2 I_2 F_2, & (T_2, I_2, F_2) \\
&T_1 I_2 F_1, & (T_1, I_2, F_1) \\
&T_2 I_1 F_2, & (T_2, I_1, F_2)
\end{align*}
\]

So, the truth value is \( T_1 T_2 \), the indeterminacy value is \( I_1 I_2 + I_1 T_2 + T_1 I_2 \) and the false value is \( F_1 F_2 + F_1 I_2 + F_1 T_2 + F_2 T_1 + F_1 I_1 \). The norm of \( x \wedge_N y \) is \( (T_1 + I_1 + F_1)(T_2 + I_2 + F_2) \). Thus, if \( x \) and \( y \) are normalized, then \( x \wedge_N y \) is also normalized. Of course, the reader can redefine the neutrosophic conjunction operator, depending on application, in a more optimistic way, i.e. \( I \ p T \ p F \) or \( T \) prevails with respect to \( I \), then we get:

\[
\mathcal{NF}_N (x, y) = (T_1 T_2, T_1 I_2, T_1 F_2, F_1 I_2, F_1 F_2, F_1 T_2, F_1 T_1, F_1 I_1)
\]

Or, the reader can consider the order \( T \ p F \ p I \), etc.

V. ROBOT POSITION CONTROL BASED ON KINEMATICS EQUATIONS

A robot can be considered as a mathematical relation of actuated joints which ensures coordinate transformation from one axis to the other connected as a serial link manipulator where the links sequence exists. Considering the case of revolute-geometry robot all joints are rotational around the freedom axis \([4,5]\). In general having a six degrees of freedom the manipulator mathematical analysis becomes very complicated. There are two dominant coordinate systems: Cartesian coordinates and joints coordinates. Joint coordinates represent angles between links and link extensions. They form the coordinates where the robot links are moving with direct control by the actuators.

So, the truth value is \( T_1 T_2 \), the indeterminacy value is \( I_1 I_2 + I_1 T_2 + T_1 I_2 \) and the false value is \( F_1 F_2 + F_1 I_2 + F_1 T_2 + F_2 T_1 + F_1 I_1 \). The norm of \( x \wedge_N y \) is \( (T_1 + I_1 + F_1)(T_2 + I_2 + F_2) \). Thus, if \( x \) and \( y \) are normalized, then \( x \wedge_N y \) is also normalized. Of course, the reader can redefine the neutrosophic conjunction operator, depending on application, in a more optimistic way, i.e. \( I \ p T \ p F \) or \( T \) prevails with respect to \( I \), then we get:

\[
\mathcal{NF}_N (x, y) = (T_1 T_2, T_1 I_2, T_1 F_2, F_1 I_2, F_1 F_2, F_1 T_2, F_1 T_1, F_1 I_1)
\]

Or, the reader can consider the order \( T \ p F \ p I \), etc.

The position and orientation of each segment of the linkage structure can be described using Denavit-Hartenberg (DH) transformation [6]. To determine the D-H transformation matrix (Fig. 1) it is assumed that the \( Z \)-axis (which is the system’s axis in relation to the motion surface) is the axis of rotation in each frame, with the following notations: \( \theta_j \) - joint angled is the joint angle positive in the right hand sense about \( jZ \); \( a_j \) - link length is the length of the common normal, positive in the direction of \((j+1)X\); \( \alpha_j \) - twist angled is the angle between \( jZ \) and \((j+1)Z\), positive in the right hand sense about the common normal; \( d_j \) - offset distance is the value of \( jZ \) at which the common normal intersects \( jZ \); as well if \( jX \) and \((j+1)X\) are parallel and in the
same direction, then \( \theta_i = 0 ; (j+1)_i \) is chosen to be collinear with the common normal between \( j_z \) and \((j+1)_z \) [7, 8]. Figure 1 illustrates a robot position control based on the Denavit-Hartenberg transformation. The robot joint angles, \( \theta_i \), are transformed in \( X_i \) - Cartesian coordinates with D-H transformation. Considering that a point in \( j \), respectively \( j+1 \) is given by:

\[
\begin{bmatrix}
X \\
Y \\
Z \\
1
\end{bmatrix}_j = \begin{bmatrix}
\cos \theta_j - \sin \theta_j \cos \alpha_j + \sin \alpha_j \sin \gamma_j \\
\sin \theta_j - \cos \theta_j \cos \alpha_j - \cos \gamma_j \sin \alpha_j \\
0 & \sin \theta_j & \cos \theta_j & d_j \\
0 & 0 & 0 & 1
\end{bmatrix} \begin{bmatrix}
X \\
Y \\
Z \\
1
\end{bmatrix}_{j+1}
\]

then \( jP \) can be determined in relation to \( j+1P \) through the equation:

\[
\begin{bmatrix}
X \\
Y \\
Z \\
1
\end{bmatrix}_j \cdot \begin{bmatrix}
X \\
Y \\
Z \\
1
\end{bmatrix}_{j+1} = \begin{bmatrix}
X \\
Y \\
Z \\
1
\end{bmatrix}_{j+1} P
\]

(1)

where the transformation matrix \( jA_{j+1} \) is:

\[
\begin{bmatrix}
\cos \theta_j - \sin \theta_j \cos \alpha_j + \sin \alpha_j \sin \gamma_j \\
\sin \theta_j - \cos \theta_j \cos \alpha_j - \cos \gamma_j \sin \alpha_j \\
0 & \sin \theta_j & \cos \theta_j & d_j \\
0 & 0 & 0 & 1
\end{bmatrix}
\]

Control through forward kinematics consists of transforming the robot coordinates at any given moment, resulting directly from the measurement transducers of each axis, to Cartesian coordinates and comparing them with the desired coordinates with D-H transformation, where a matrix based on the Denavit-Hartenberg transformation. The robot joint angles, \( \theta_i \), are transformed in \( X_i \) - Cartesian coordinates with D-H transformation, where a matrix results from (1) and (2) with \( \theta_i \) - joint angle, \( d_j \) - offset distance, \( a_{ij} \) - link length, \( \alpha_i \) - twist.

Position and orientation of the end effector with respect to the base coordinate frame is given by \( X_C \):

\[
X_C = A_1 \cdot A_2 \cdot A_3 \cdot \ldots \ldots \cdot A_6 \quad (3)
\]

Position error \( \Delta X \) is obtained as a difference between desired and current position. There is difficulty in controlling robot trajectory, if the desired conditions are specified using position difference \( \Delta X \) with continuously measurement of current position \( \theta_{1,2,\ldots,6} \).

\[
X_C = A_1 \cdot A_2 \cdot \ldots \cdot A_6
\]

(4)

where \( \theta \) is vector representing the degrees of freedom of robot. By differentiating we will have: \( \delta X_6 = J(\theta) \cdot \delta \theta_{1,2,\ldots,6} \), where \( \delta X_6 \) represents differential linear and angular changes in the end effector at the currently values of \( X_6 \), and \( \delta \theta_{1,2,\ldots,6} \) represents the differential change of the set of joint angles. \( J(\theta) \) is the Jacobean matrix in which the elements \( a_{ij} \) satisfy the relation: \( a_{ij} = \delta f_{i,j} / \delta \theta_{j,1} \), (x.6) where \( i,j \) are corresponding to the dimensions of \( x \) respectively \( \theta \). The inverse Jacobean transforms the Cartesian position \( \delta X_6 \) respectively \( \delta \theta_{1,2,\ldots,6} \) in joint angle error (\( \Delta \theta \)): \( \delta \theta_{1,2,\ldots,6} = J^{-1}(\theta) \cdot \delta X_6 \).

VI. HYBRID POSITION AND FORCE CONTROL OF ROBOTS

Hybrid position and force control of industrial robots equipped with compliant joints must take into consideration the passive compliance of the system. The generalized area where a robot works can be defined in a constraint space with six degrees of freedom (DOF), with position constrains along the normal force of this area and force constrains along the tangents. On the basis of these two constrains there is described the general scheme of hybrid position and force control in figure 3. Variables \( X_C \) and \( F_C \) represent the Cartesian position and the Cartesian force exerted onto the environment. Considering \( X_C \) and \( F_C \) expressed in specific frame of coordinates, its can be determinate selection matrices \( S_x \) and \( S_f \), which are diagonal matrices with 0 and 1.
diagonal elements, and which satisfy relation: \( S_x + S_f = I_6 \), where \( S_x \) and \( S_f \) are methodically deduced from kinematics constrains imposed by the working environment [9, 10].

For the fusion of information received from various sensors, information that can be conflicting in a certain degree, the robot uses the fuzzy and neutrosophic logic or set [3]. In a real time it is used a neutrosophic dynamic fusion, so an autonomous robot can take a decision at any moment.

CONCLUSION

In this paper we have provided in the first part an introduction to the neutrosophic logic and set operators and in the second part a short description of mathematical dynamics of a robot and then a way of applying neutrosophic science to robotics. Further study would be done in this direction in order to develop a robot neutrosophic control.

REFERENCES