



On Overview of Neutrosophic and Plithogenic Theories and Applications

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Abstract

We present this research to all researchers and scholars who have realized the existence of indeterminacy in all data, through the results they obtain and the values that are not accurate enough and that may cause loss to the systems and facilities under study, and we will present through it the emergence, foundations and development of Neutrosophic theories and their applications for more than two decades (1995- 2023) since it was defined and studied, along with its applications, in order to be able to present new studies and research that keep pace with the great scientific development that our contemporary world is witnessing, through the use of research that has been published by the professionals and found on the attached open links.

Keywords: Neutrosophic; origin of the word Neutrosophic; stages of development of neutrosophic science; applications of neutrosophic science; research in neutrosophic science; neutrosophic journals

1. Introduction

The beginning of the great revolution in all fields of science was in the year 1995 when the American scientist Florentin Smarandache introduced the degree of indeterminacy/neutrality (I) as independent component in 1995 (published in 1998) and he defined the neutrosophic set on three components: $(T, I, F) = (\text{Truth, Indeterminacy, Falsehood})$, where in general T, I, F are subsets of the interval $[0, 1]$; in particular T, I, F may be intervals, hesitant sets, single-values, etc. Indeterminacy (or Neutrality), as independent component from the truth and from the falsehood, is the main distinction between Neutrosophic Theories and other classical and fuzzy theory or fuzzy extension theories [1]

Neutrosophic Set is a Generalization of Intuitionist Fuzzy Set, Inconsistent Intuitionist Fuzzy Set (Picture Fuzzy Set, Ternary Fuzzy Set), Pythagorean Fuzzy Set (Atanassov's Intuitionist Fuzzy Set of second type), q-Rung Orthopair Fuzzy Set, Spherical Fuzzy Set, and n-HyperSpherical Fuzzy Set, while Neutrosophication is a Generalization of Regret Theory, Grey System Theory, and Three-Ways Decision.[2,3]

Zadeh introduced the degree of membership/truth (T) in 1965 and defined the fuzzy set. **Atanassov** introduced the degree of nonmembership/falsehood (F) in 1986 and defined the intuitionistic fuzzy set. **Smarandache** introduced the degree of indeterminacy/neutrality (I) as independent component in 1995 (published in 1998) and he defined the neutrosophic set on three components: $(T, I, F) = (\text{Truth, Indeterminacy, Falsehood})$, where in general T, I, F are subsets of the interval $[0, 1]$; in particular T, I, F may be intervals, hesitant sets, single-values, etc. See F. Smarandache, Neutrosophy / Neutrosophic probability, set, and logic", Proquest, Michigan, USA, 1998,[4,5] reviewed in Zentralblatt für Mathematik (Berlin, Germany)[6], and cited by Denis Howe in The Free Online Dictionary of Computing, England, 1999. Neutrosophic Set and Logic are generalizations of classical, fuzzy, and intuitionist fuzzy set and logic[7,8]

2. Etymology

a. “Neutrosophy” and “Neutrosophic:

The words “neutrosophy” and “neutrosophic” were coined/invented by F. Smarandache in his 1998 book. Neutrosophy: A branch of philosophy, introduced by F. Smarandache in 1980, which studies the origin, nature, and scope of neutralities, as well as their interactions with different ideational spectra. Neutrosophy considers a proposition, theory, event, concept, or entity $\langle A \rangle$ in relation to its opposite $\langle \text{anti}A \rangle$, and with their neutral $\langle \text{neut}A \rangle$.

Neutrosophy (as dynamic of opposites and their neutrals) is an extension of the Dialectics and Yin Yang (which are the dynamic of opposites only).

Neutrosophy is the basis of neutrosophic set, neutrosophic logic, neutrosophic measure, neutrosophic probability, neutrosophic statistics[9]

b. Neutrosophic Logic:

Neutrosophic Logic is a general framework for unification of many existing logics, such as fuzzy logic (especially intuitionistic fuzzy logic), paraconsistent logic, intuitionist logic, etc. The main idea of NL is to characterize each logical statement in a 3D-Neutrosophic Space, where each dimension of the space represents respectively the truth (T), the falsehood (F), and the indeterminacy (I) of the statement under consideration, where T, I, F are standard or non-standard real subsets of $]0, 1+[$ with not necessarily any connection between them.

For software engineering proposals the classical unit interval $[0, 1]$ may be used.

While Neutrosophic Probability and Statistics are generalizations of classical and imprecise probability and classical statistics respectively.

c. The Most Important Books and Papers on the Advancement of Neutrosophics:

1980s - Foundation of Paradoxism that is an international movement in science and culture **based on excessive use of contradictions, antitheses, oxymoron, and paradoxes** [Smarandache]. During three decades (1980-2020) hundreds of authors from tens of countries around the globe contributed papers to 15 international paradoxist anthologies [10]

1995-1998: Smarandache extended the paradoxism (based on opposites) to a new branch of philosophy called Neutrosophy (based on opposites and their neutral), that gave birth to many scientific branches, such as: neutrosophic logic, neutrosophic set, neutrosophic probability and statistics, neutrosophic algebraic structures, and so on with multiple applications in all fields. Neutrosophy is also an extension of the Dialectics (which is a particular case of Yin-Yang ancient Chinese philosophy),[11]

introduced the neutrosophic set/logic/probability/statistics;

introduces the single-valued neutrosophic set (pp. 7-8) [12,13]

1998-2001: Introduction of Nonstandard Neutrosophic Logic, Set, Probability,

<https://arxiv.org/ftp/arxiv/papers/1903/1903.04558.pdf>

2002: Introduction of corner cases of sets / probabilities / statistics / logics, such as:- Neutrosophic intuitionistic set (different from intuitionist fuzzy set), neutrosophic paraconsistent set, neutrosophic fallibilists set, neutrosophic paradoxist set, neutrosophic pseudo-paradoxist set, neutrosophic tautological set, neutrosophic nihilist set, neutrosophic dialetheist set, neutrosophic trivialist set;

- Neutrosophic intuitionistic probability and statistics, neutrosophic paraconsistent probability and statistics, neutrosophic fallibilists probability and statistics, neutrosophic paradoxist probability and statistics, neutrosophic pseudo-paradoxist probability and statistics, neutrosophic tautological probability and statistics, neutrosophic nihilist probability and statistics, neutrosophic dialetheist probability and statistics, neutrosophic trivialist probability and statistics;

- Neutrosophic paradoxist logic (or paradoxism), neutrosophic pseudo-paradoxist logic (or neutrosophic pseudo-paradoxism), neutrosophic tautological logic (or neutrosophic tautologism)

<https://arxiv.org/ftp/math/papers/0301/0301340.pdf>

<http://fs.unm.edu/DefinitionsDerivedFromNeutrosophics.pdf>

2003 – Introduction by Kandasamy and Smarandache of Neutrosophic Numbers ($a+bI$), where I = literal indeterminacy, $I^2 = I$, which is different from the numerical indeterminacy that is a real set), I-Neutrosophic Algebraic Structures and Neutrosophic Cognitive Maps

2005 - Introduction of Interval Neutrosophic Set/Logic , <https://arxiv.org/pdf/cs/0505014.pdf>

<http://fs.unm.edu/INSL.pdf>

2006 – Introduction of Degree of Dependence and Degree of Independence between the Neutrosophic Components T, I, F. for single valued neutrosophic logic, the sum of the components is:

$0 \leq t+i+f \leq 3$ when all three components are independent;

$0 \leq t+i+f \leq 2$ when two components are dependent, while the third one is independent from them;

$0 \leq t+i+f \leq 1$ when all three components are dependent.

When three or two of the components T, I, F are independent, one leaves room for incomplete information (sum < 1), paraconsistent and contradictory information (sum > 1), or complete information (sum = 1).

If all three components T, I, F are dependent, then similarly one leaves room for incomplete information (sum < 1), or complete information (sum = 1).

In general, the sum of two components x and y that vary in the unitary interval [0, 1] is:

$0 \leq x + y \leq 2 - d^\circ(x, y)$, where $d^\circ(x, y)$ is the degree of dependence between x and y, while

$d^\circ(x, y)$ is the degree of independence between x and y.

Degrees of Dependence and Independence between Neutrosophic Components T, I, F are independent components, leaving room for incomplete information (when their superior sum < 1), paraconsistent and contradictory information (when the superior sum > 1), or complete information (sum of components = 1).

For software engineering proposals the classical unit interval [0, 1] is used ,

<https://doi.org/10.5281/zenodo.571359>

<http://fs.unm.edu/eBook-Neutrosophics6.pdf> (p. 92)

<http://fs.unm.edu/NSS/DegreeOfDependenceAndIndependence.pdf>

2007:

1- The neutrosophic set was extended [Smarandache, 2007] to neutrosophic overset (when some neutrosophic component is > 1), since he observed that, for example, an employee working overtime deserves a degree of membership > 1 , with respect to an employee that only works regular full-time and whose degree of membership = 1;

and to neutrosophic underset (when some neutrosophic component is < 0), since, for example, an employee making more damage than benefit to his company deserves a degree of membership < 0 , with respect to an employee that produces benefit to the company and has the degree of membership > 0 ;

and to and to neutrosophic offset (when some neutrosophic components are off the interval [0, 1], i.e. some neutrosophic component > 1 and some neutrosophic component < 0). then, similarly, the neutrosophic logic/measure/probability/statistics etc. were extended to respectively neutrosophic over-/under-/off- logic / measure / probability / statistics etc, <https://arxiv.org/ftp/arxiv/papers/1607/1607.00234.pdf>

<http://fs.unm.edu/NeutrosophicOversetUndersetOffset.pdf>

<http://fs.unm.edu/SVNeutrosophicOverset-JMI.pdf>

<http://fs.unm.edu/IV-Neutrosophic-Overset-Underset-Offset.pdf>

<http://fs.unm.edu/NSS/DegreesOf-Over-Under-Off-Membership.pdf>

2- Smarandache introduced the neutrosophic tripolar set and neutrosophic multipolar set and consequently the Neutrosophic Tripolar Graph and Neutrosophic Multipolar Graph , <http://fs.unm.edu/eBook-Neutrosophics6.pdf> (p. 93)

<http://fs.unm.edu/IFS-generalized.pdf>

2009 – Introduction of N-norm and N-conorm <https://arxiv.org/ftp/arxiv/papers/0901/0901.1289.pdf>

<http://fs.unm.edu/N-normN-conorm.pdf>

2013:

1- Development of neutrosophic measure and neutrosophic probability

(chance that an event occurs, indeterminate chance of occurrence, chance that the event does not occur)

<https://arxiv.org/ftp/arxiv/papers/0901/0901.1289.pdf>

<http://fs.unm.edu/N-normN-conorm.pdf>

2- Smarandache refined / split the neutrosophic components (t, i, f) into neutrosophic subcomponents (T1, T2, ...; I1, I2, ...; F1, F2, ...) <https://arxiv.org/ftp/arxiv/papers/1407/1407.1041.pdf>

<http://fs.unm.edu/n-ValuedNeutrosophicLogic-PiP.pdf>

2014:

1- Introduction of the Law of Included Multiple-Middle (as extension of the Law of Included Middle)(<A>, <neutA1>, <neutA2>, ...; <antiA>) <http://fs.unm.edu/LawIncludedMultiple-Middle.pdf>

2- Development of neutrosophic statistics (indeterminacy is introduced into classical statistics with respect to any data regarding the sample / population, probability distributions / laws / graphs / charts etc., with respect to the individuals that only partially belong to a sample / population, and so on),

<https://arxiv.org/ftp/arxiv/papers/1406/1406.2000.pdf>

<http://fs.unm.edu/NeutrosophicStatistics.pdf>

2015:

- 1- Introduction of Neutrosophic Precalculus and Neutrosophic Calculus ,
<https://arxiv.org/ftp/arxiv/papers/1509/1509.07723.pdf>
<http://fs.unm.edu/NeutrosophicPrecalculusCalculus.pdf>
 - 2- Refined Neutrosophic Numbers $(a + b_1I_1 + b_2I_2 + \dots + b_nI_n)$, where $I_1, I_2, \dots, I_n$ are SubIndeterminacies of Indeterminacy I,
 - 3- (t, i, f) -neutrosophic graphs
 - 4- Thesis-Antithesis-Neutrothesis, and Neutrosynthesis, Neutrosophic Axiomatic System, neutrosophic dynamic systems, symbolic neutrosophic logic, (t, i, f) -Neutrosophic Structures, I-Neutrosophic Structures, Refined Literal Indeterminacy, Quadruple Neutrosophic Algebraic Structures, Multiplication Law of SubIndeterminacies, and Neutrosophic Quadruple Numbers of the form $a + bT + cI + dF$,
<https://arxiv.org/ftp/arxiv/papers/1512/1512.00047.pdf>
<http://fs.unm.edu/SymbolicNeutrosophicTheory.pdf>
 - 5- Introduction of the SubIndeterminacies of the form $I_0^K = \frac{K}{0}$, for $k \in \{0, 1, 2, \dots, n-1\}$, into the ring of modulo integers Z_n - called natural Neutrosophic indeterminacies (Vasanth-Smarandache),
<http://fs.unm.edu/MODNeutrosophicNumbers.pdf>
 - 6- Introduction of Neutrosophic Topology (Salama & Smarandache) ,
<http://fs.unm.edu/NeutrosophicCrispSetTheory.pdf>
- 2016:**
- 1- Introduction of Neutrosophic Multisets (as generalization of classical multisets)
<http://fs.unm.edu/NeutrosophicMultisets.htm>
 - 2- Introduction of Neutrosophic Triplet Structures and m-valued refined Neutrosophic triplet structures [Smarandache – Ali] <http://fs.unm.edu/NeutrosophicTriplets.htm>
 - 3- Introduction of Neutrosophic Duplet Structures, <http://fs.unm.edu/NeutrosophicDuplets.htm>
- 2017:**
- 1- Neutrosophic Score, Accuracy, and Certainty Functions form a total order relationship on the set of (single-valued, interval-valued, and in general subset-valued) Neutrosophic triplets (T, I, F) ; and these functions are used in MCDM (Multi-Criteria Decision Making),
<http://fs.unm.edu/NSS/TheScoreAccuracyAndCertainty1.pdf>
 - 2- In biology Smarandache introduced the Theory of Neutrosophic Evolution: Degrees of Evolution, Indeterminacy or Neutrality, and Involution, <http://fs.unm.edu/neutrosophic-evolution-PP-49-13.pdf>
-
- 3- Introduction by F. Smarandache of Plithogeny (as generalization of Yin-Yang, Dialectics, and Neutrosophy_ (as generalization of fuzzy, intuitionistic fuzzy, Neutrosophic set/logic/probability/statistics)
 - 4- Enunciation of the Law that: It Is Easier to Break from Inside than from Outside a Neutrosophic Dynamic System (Smarandache - Vatuui)
- 2018:**
- 1- Generalization of the Soft Set to Hyper Soft Set,
<http://fs.unm.edu/NSS/ExtensionOfSoftSetToHypersoftSet.pdf>
 - 2- Introduction to Neutrosophic Psychology (Neutropsyche, Refined Neutrosophic Memory: conscious, a conscious, unconscious, Neutropsychic Personality, Eros / Aoristos / Thanatos, Neutropsychic Crisp Personality) , <http://fs.unm.edu/NeutropsychicPersonality-ed3.pdf>
- 2019:**
- 1- Theory of Spiral Neutrosophic Human Evolution (Smarandache - Vatuui),
<http://fs.unm.edu/SpiralNeutrosophicEvolution.pdf>
 - 2- Introduction to Neutrosophic Sociology (Neutrosociology) [neutrosophic concept, or (T, I, F) -concept, is a concept that is $T\%$ true, $I\%$ indeterminate, and $F\%$ false]
<http://fs.unm.edu/Neutrosociology.pdf>
 - 3- Refined Neutrosophic Crisp Set, <http://fs.unm.edu/RefinedNeutrosophicCrispSet.pdf>
 - 4- Generalized of the classical Algebraic Structures to NeutroAlgebraic Structures (or NeutroAlgebras) {whose operations and axioms are partially true, partially indeterminate, and partially false} as extensions of Partial Algebra, and to AntiAlgebraic Structures (or AntiAlgebras) {whose operations and axioms are totally false}. And, in general, he extended any classical Structure, in no matter what field of knowledge, to a NeutroStructure and an AntiStructure.
 - 5- Extension of HyperGraph to n-SuperHyperGraph

2020 –

Introduction to Neutrosophic Genetics ,<http://fs.unm.edu/NeutrosophicGenetics.pdf>

2021

1- As alternatives and generalizations of the Non-Euclidean Geometries, Smarandache introduced in 2021 the NeuroGeometry & AntiGeometry. While the Non-Euclidean Geometries resulted from the total negation of only one specific axiom (Euclid's Fifth Postulate), the AntiGeometry results from the total negation of any axiom and even of more axioms from any geometric axiomatic system (Euclid's, Hilbert's, etc.), and the NeuroAxiom results from the partial negation of one or more axioms [and no total negation of no axiom] from any geometric axiomatic system.

2- Real Examples of NeuroGeometry and AntiGeometry .

3- Introduction of Plithogenic Logic as a generalization of MultiVariate Logic.

4- Introduction of Plithogenic Probability and Statistics as generalizations of MultiVariate Probability and Statistics respectively

2022:

1- SuperHyperAlgebra & Neutrosophic SuperHyperAlgebra

2- SuperHyperGraph, Neutrosophic SuperHyperGraph

3- SuperHyperFunction, SuperHyperTopology

4- IndetermSoft Set, IndetermHyperSoft Set

5- TreeSoft Set

2023 - Symbolic Plithogenic Algebraic Structures built on the set of Symbolic Plithogenic Numbers of the form $a_0 + a_1P_1 + a_2P_2 + \dots + a_nP_n$ where the multiplication $P_i \cdot P_j$ is based on the prevalence order and absorbance law.

d. Applications in:

Artificial Intelligence, Information Systems, Computer Science, Cybernetics, Theory Methods, Mathematical Algebraic Structures, Applied Mathematics, Automation, Control Systems, Big Data, Engineering, Electrical, Electronic, Philosophy, Social Science, Psychology, Biology, Biomedical, Genetics, Engineering, Medical Informatics, Operational Research, Management Science, Imaging Science, Photographic Technology, Instruments, Instrumentation, Physics, Optics, Economics, Mechanics, Neurosciences, Radiology Nuclear, Medicine, Medical Imaging, Interdisciplinary Applications, Multidisciplinary Sciences etc. [Xindong Peng and Jingguo Dai, A bibliometric analysis of neutrosophic set: two decades review from 1998 to 2017, Artificial Intelligence Review, Springer, 18 August 2018 .

e. Important Neutrosophic Researchers:

There are about 7,000 neutrosophic researchers, within 7489 countries around the globe, that have produced about 2,000 publications within more than two decades. Many neutrosophic researchers got specialized into various fields of neutrosophics:

Xiaohong Zhang & Yingcang Ma (neutrosophic triplet and quadruple algebraic structures), Yanhui Guo (neutrosophic image processing), Jun Ye & Peide Liu & Jianqiang Wang (neutrosophic optimization), Xindong Peng & Jingguo Dai (neutrosophic bibliometrics), Jianqiang Wang, Guiwu Wei, Donghai Liu, Xiaohong Chen, Dan Peng, Jiongmei Mo, Han-Liang Huang, Victor Chang, Hongjun Guan, Shuang Guan, Aiwu Zhao, Wen-Hua Cui, Xiaofei Yang, Xin Zhou, G.L. Tang, W.L. Liu, Wen Jiang, Zihan Zhang, Xinyang Deng, Changxing Fan, Sheng Feng, En Fan, Keli Hu, Xingsen Li, Xin Zhou, Ping Li;

Rajab Ali Borzooei & Young Bae Jun (neutrosophic BCK/BCI-algebras), Arsham Borumand Saeid (neutrosophic structures), Saied Jafari (neutrosophic topology), Prem Kumar Singh (Neutrosophic MCDM), Maikel Leyva-Vazquez (neutrosophic cognitive maps);

Amira S. Ashour, Muhammad Aslam (neutrosophic statistics), Nguyen Xuan Thao (neutrosophic similarity measures), Le Hoang Son, Vakkas Ulucay & Memet Sahin (neutrosophic quadruple structures), Irfan

Deli, Madad Khan (neutrosophic algebraic structures), Said Broumi & Muhammad Akram (neutrosophic graphs), Mohamed Abdel-Baset (neutrosophic linear and non-linear programming), Ahmed Mostafa Khalil, Ahmed Salama (neutrosophic crisp topology), etc.

f. Neutrosophic Journals:

1- Neutrosophic Sets and Systems (NSS) international journal started in 2013 and it is indexed by Scopus, Web of Science (ESCI), DOAJ, Index Copernicus, Redalyc - Universidad Autonoma del Estado de Mexico

(IberoAmerica), Publons, CNKI (Beijing, China), Chinese Baidu Scholar, etc, Submit papers on neutrosophic set/logic/probability/statistics, Simulation, etc. and their applications through our OJS, [14 – 19]

1- International Journal of Neutrosophic Science (IJNS, in SCOPUS) , Submit papers on neutrosophic, inventory management, Linear Programming , dynamic programming, Decision – Making , Machine learning, Queue Theory , etc , [20-29]

2- Neutrosophic Computing and Machine Learning (NCML), in Spanish
<http://fs.unm.edu/NCML/>

3- Neutrosophic Knowledge (NK), in English and Arabic: <http://fs.unm.edu/NK/>

4- Journal of Neutrosophic and Fuzzy Systems (JNFS), Submit papers on neutrosophic Machine learning, Queue Theory , etc , [30 – 33]

5- Prospects for Applied Mathematics and Data Analysis (PAMDA) , Submit papers on neutrosophic Machine learning , Neutrosophic Simulation , etc, [34-36]

6- Encyclopedia of Neutrosophic Researchers, To certify the names of authors who have published or presented research on Neutrosophic,[37-40]

Note : The authors who have published or presented papers on neutrosophics and are not included in the Encyclopedia of Neutrosophic Researchers (ENR), vols. 1, 2, 3, and 4 are pleased to send their CV, photo, and List of Neutrosophic Publications to smarand@unm.edu in order to be included into the next volume of ENR.

3. Conclusion and results:

There is no absolute truth, there is nothing certain that any data presented to conduct a study in any field of science contains some kind of indeterminacy that affects the desired results of this study, which made neutrosophic science and the basic concepts of neutrosophic science the focus of attention of scholars and researchers who wish to obtain results Perfect and accurate, far from taking risks, they achieve the desired goal

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