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Neutrosophic Statistics applied in Social Science

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Abstract. Social Science deals with the study of phenomena related to the social status of human beings. The importance of such sciences lies in the fact that they make it possible to know, predict, modify and improve the functioning of human societies today. Due to the great complexity of modern societies, it is virtually impossible to have accurate data or knowledge about any contemporary society. That is why neutrosophic theory is suitable for representing and modeling the data from studies on any social sciences. They may contain data that is contradictory, incomplete, inaccurate, vague, and so on. In particular, neutrosophic statistics generalizes classical statistics to interval-valued data. Since classical statistics are of great importance for the study of Social Sciences, in this paper, we compile, define and illustrate some statistical methods typical of classical statistics generalized to neutrosophic statistics. We will emphasize the Legal Sciences in our approach.

Keywords: Social Sciences, Neutrosophy, Neutrosociology, Neutrosophic Statistics.

1 Introduction

Social Sciences are a generic name for the disciplines or fields of knowledge that claim for themselves the condition of sciences, which analyze and treat different aspects of social groups and human beings in society, dealing with their material and immaterial manifestations [1]. According to the intention of the one who uses them, other convergent or differentiated names are those of human sciences or humanities (terms that are differentiated by diverse epistemological and methodological considerations). Different combinations of these terms are also used, such as Human and Social Science. Social Science studies the origin of individual and collective behavior, seeking to discover the social rules that determine them and are expressed in the set of human institutions and societies.

In the classification of sciences, they are distinguished from the Natural Sciences and the Formal Sciences. They deal with the behavior and activities of humans, generally not studied in the Natural Sciences. The Social Sciences present methodological problems that do not appear in the Natural Sciences. Within the Natural Sciences, there is little discussion about what constitutes a Natural Science and what does not. However, in Social Sciences, there has historically been greater discussion about what genuinely constitutes a Social Science and what does not. Although they involve rational reasoning and discussion, some disciplines or social studies are not considered Social Sciences.

In general, there is no reasonable agreement on which disciplines should be considered part of the Social Sciences and for the Natural Sciences, although the traditional division between them is doubtful in some cases. Thus, for example, if the study of the language had been considered almost universally a Social Science, the modern approach that started with the generative grammar of Noam Chomsky suggests that the language is not so much of the social interaction but should be seen as a part of psychology, or evolutionary biology, as in the operation of the languages and their temporal evolution of the consciousness of the speakers or their representations psychological not seem to play any role. For this reason, some authors consider that languages are a natural object that is generated spontaneously and not by the deliberate intention of human beings [2-5].

In general, and without being overly rigorous, the following disciplines have been considered examples of Social Sciences by a large number of authors:

Sciences related to social interaction: Anthropology, History, Human Geography, Economics, Social Psychology, Sociology, and Political Science.

Sciences related to the human cognitive system: Linguistics, Psychology.

Sciences related to the evolution of societies: Archaeology, Demography, and Human Ecology.

On the other hand, Neutrosophy studies the neutralities that are contained in the lack of knowledge, contradictions, paradoxes, and imprecision, among others. Neutrosophic sets generalize fuzzy sets, and fuzzy intuitionist sets, among others, [6]. This theory has been applied in many real-life problems.

An approach of Neutrosophy to sociology is Neutrosophic Sociology (or Neutrosociology), which is the study of sociology using neutrosophic scientific methods [7]. The massive amount of social data we face in sociology is usually vague, incomplete, contradictory, hybrid, biased, ignorant, redundant, superfluous, meaningless, ambiguous, unclear, etc.

That is why some neutrosophic research tools and methods should be involved, such as Neutrosophy (a new branch of philosophy), neutrosophic set, neutrosophic logic, neutrosophic probability, and neutrosophic statistics, neutrosophic analysis, neutrosophic measure, and so on.

Specifically, Neutrosophic Statistics refers to a set of data and the methods used to analyze them when the data or at least a part of them are indeterminate to some degree [8]. In Classical Statistics, all data are determined; this is the main distinction between neutrosophic statistics and classical statistics. Some researches on Neutrosophic Statistics can be read in [9-17].

When indeterminacy is zero, neutrosophic statistics coincide with classical statistics. Therefore, we can use the neutrosophic measure for assessing indeterminate data. The neutrosophic statistical methods will enable us to interpret and organize data that may have some indeterminacies to reveal underlying patterns.

The purpose of this paper is to compile, define and illustrate the use of neutrosophic statistics methods in Social Sciences because these disciplines often present imprecise, inconsistent, insufficient, and unknown data. Specifically, we will emphasize the field of Legal Sciences within the Social Sciences, where this type of data is very common, despite precise decisions that can affect people's lives need to be made, hence its importance. Some papers on Neutrosophy applied to the Social and Legal Sciences can be found in [9, 18-24].

This article is divided into the following sections; section 2 exposes the main concepts of neutrosophic statistics. Section 3 contains the classical and neutrosophic statistical methods that we recommend applying and defining for Social Sciences, particularly in Legal Sciences. Finally, the paper ends with the conclusions.

2 Neutrosophic Statistics

This section contains some basic concepts of neutrosophic sets and neutrosophic statistics [25-46].

Definition 1: ([6]) Let X be a universe of discourse. Three membership functions characterize a Neutrosophic Set (NS), $u_A(x), r_A(x), v_A(x) : X \rightarrow]-0, 1^+[$, which satisfy the condition $-0 \leq inf\ u_A(x) + inf\ r_A(x) + inf\ v_A(x) \leq sup\ u_A(x) + sup\ r_A(x) + sup\ v_A(x) \leq 3^+$ for all $xX.$ $u_A(x), r_A(x)$ and $v_A(x)$ are the membership functions of truthfulness, indeterminacy, and falseness of x in A, respectively, and their images are standard or non-standard subsets of $]-0, 1^+[$.

Definition 2: ([6]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is a set of the form:

$$A = \{\langle x, u_A(x), r_A(x), v_A(x) \rangle : x \in X\} \qquad (1)$$

Where $u_A, r_A, v_A : X \rightarrow [0,1]$, satisfy the condition $0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ for all$xX.$ $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indeterminate, and falseness of x in A, respectively. For convenience, a *Single-Valued Neutrosophic Number* (SVNN) will be expressed as $A = (a, b, c)$, where a, b, c [0,1] and satisfy $0 \leq a + b + c \leq 3$.

Neutrosophic Statistics extends classical statistics such that we can deal with set values rather than crisp values [8].

Neutrosophic Descriptive Statistics is comprised of all techniques to summarize and describe the neutrosophic numerical data.

Neutrosophic Inferential Statistics consists of methods that allow the generalization from a neutrosophic sampling to a population from which the sample was selected.

Neutrosophic Data is the data that contains some indeterminacy. Similarly to classical statistics, it could be classified as:

- *Discrete neutrosophic data*, if the values are isolated points.
- *Continuous neutrosophic data*, if the values form one or more intervals.

Another classification is the following:

- *Quantitative (numerical) neutrosophic data*; for example, a number in the interval (we do not know exactly), 46, 53, 68, or 70, not knowing exactly;
- *Qualitative (categorical) neutrosophic data*; for example: blue or red (we don't know exactly), white, black or green, or yellow (not knowing exactly).

The *univariate neutrosophic data* is neutrosophic data that consists of observations on a neutrosophic single attribute.

Multivariable neutrosophic data is neutrosophic data that consists of observations on two or more attributes.

A *Neutrosophic Statistical Number* N has the form $N = d + I$, [47], where d is called *determinate part* and I is called *indeterminate part.*

A *Neutrosophic Frequency Distribution* is a table showing the categories, frequencies, and relative frequencies with some indeterminacy. Most often, indeterminacies occur due to incomplete, imprecise, or unknown data related to frequency. As a consequence, relative frequency becomes imprecise, incomplete, or unknown too.

Neutrosophic Survey Results are results from a survey that contains indeterminacy.

A *Neutrosophic Population* is a population not well determined at the membership level where we are not sure if some individuals belong or do not belong to the population).

A *simple random neutrosophic sample* of size n from a classical or neutrosophic population is a sample of n individuals such that at least one of them has some indeterminacy.

A *stratified random neutrosophic sampling* is the pollster groups of the (classical or neutrosophic) population by a stratum according to a classification; afterward, the pollster takes a random sample of appropriate size according to a criterion from each group. If there is indeterminacy, we deal with neutrosophic sampling.

Additionally, we describe concepts of interval calculus, which shall be useful in this paper.

Given $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$ two neutrosophic numbers, some operations between them are defined as follows, [47]:

$N_1 + N_2 = a_1 + a_2 + (b_1 + b_2)I$ (Addition),

$N_1 - N_2 = a_1 - a_2 + (b_1 - b_2)I$ (Difference),

$N_1 \times N_2 = a_1 a_2 + (a_1 b_2 + b_1 a_2 + b_1 b_2)I$ (Product),

$\frac{N_1}{N_2} = \frac{a_1 + b_1 I}{a_2 + b_2 I} = \frac{a_1}{a_2} + \frac{a_2 b_1 - a_1 b_2}{a_2(a_2 + b_2)} I$ (Division).

Additionally, given $I_1 = [a_1, b_1]$ and $I_2 = [a_2, b_2]$ we have the following operations between them (see [48]):

1. $I_1 \leq I_2$ if and only if $a_1 \leq a_2$ and $b_1 \leq b_2$.
2. $I_1 + I_2 = [a_1 + a_2, b_1 + b_2]$ (Addition);
3. $I_1 - I_2 = [a_1 - b_2, b_1 - a_2]$ (Subtraction),
4. $I_1 \cdot I_2 = [min\{a_1 b_1, a_1 b_2, a_2 b_1, a_2 b_2\}, max\{a_1 b_1, a_1 b_2, a_2 b_1, a_2 b_2\}]$ (Product),
5. $I_1/I_2 = I_1(1/I_2) = \{a/b \colon aI_1, bI_2\}$, always that 0□$I_2$ (Division).
6. $\sqrt{I} = [\sqrt{a}, \sqrt{b}]$, always that $a \geq 0$ (Square root).
7. $I^n = I \cdot I \cdot \cdots \cdot I \cdot I\underbrace{}_{n\ times}$

3 Neutrosophic statistics applied in Social Sciences

This section covers the neutrosophic statistics methods that can be used in Social Sciences. Especially, correlation methods like Contingency Tables, Pearson's correlation coefficient, and Spearman's correlation coefficient are introduced.

3.1 Contingency Tables

In classical statistics, contingency tables are used to record and analyze the relationship between two or more variables, usually of a qualitative nature (nominal or ordinal) [49]. This table is based on the frequency of cases that satisfy the characteristics that each cell in the table represents. However, in many cases, this frequency of cases cannot be defined with a single number due to differences of opinion among several experts in the Social Sciences. Some sciences are based on various theories, some of them can partially contradict each other, and therefore the cases that are studied may have different meanings depending on the theory that is applied. On the other hand, there may be unknown or unclassifiable cases, because there is insufficient data, one investigator classifies the case in one way, and another considers it in another, and so on. Therefore, instead of numerical frequencies, it is recommendable to perform the calculations with frequency intervals.

A contingency table is important in the social sciences because it allows the representation of qualitative values, which are data widely used in this type of science.

Definition 3: We define a *neutrosophic contingency table* as a contingency table such that at least one cell element is an interval rather than a crisp value.

Let us note that when the range of the intervals contains the same limit values, it is a crisp value and the neutrosophic contingency table becomes a classical contingency table. Additionally, according to the authors' knowledge, the neutrosophic contingency table is defined for the first time here.

The coefficient (also called quadratic contingency coefficient), on which the contingency coefficient is based, is a measure of the "intensity" of the relationship between the observed characteristics. In *neutrosophic contingency tables*, the same formula as in classical statistics is maintained, using the interval-valued operators of the quadratic contingency. This formula is the following:

$$\frac{N\chi^2}{n} = \frac{1}{n}\sum_{i=1}^{k} \sum_{j=1}^{m} \frac{\left(I_{ij} - \frac{I_{i.}I_{.j}}{n}\right)^2}{\frac{I_{i.}I_{.j}}{n}} \qquad (2)$$

Where, $\frac{N\chi^2}{n}$ is the neutrosophic mean quadratic contingency, I_{ij} is the interval value of the cell in the i-th row and the j-th column. $I_{i.}$ is the sum for columns of the i-th row, $I_{.j}$ is the sum for rows of the jth column. n is the interval sampling size, while k is the number of rows and m is the number of columns of the table.

The greater this measure, the more intense is the relationship between the two analyzed characteristics. If both characteristics (variables) are independent, then each of the summands is 0, as a result of which the numerator of the fraction is 0 and with it the measure itself as well. In the case of a 2x2 contingency table, the measurement is normalized and assumes values in the interval [0, 1].

$N\chi^2$ can assume very large values in principle and is not limited to a subinterval of [0, 1]. To exclude the dependence of the contingency coefficient on the sample size, the contingency coefficient NC extends the contingency coefficient C. The case of interval values is calculated based on $N\chi^2$, based on the following formula:

$$NC = \sqrt{\frac{N\chi^2}{N\chi^2 + n}} \qquad (3)$$

Where n is the interval size of the sample. In this case, the division is defined as follows:

$$\frac{I_1}{I_2} = \left[\frac{a_1}{b_1}, \frac{a_2}{b_2}\right] \qquad (4)$$

An example is used below to illustrate the method:

Example 1:

Suppose that in Ecuadorian City X an average of 35 women's rapes is reported during a year. This crime is highly sensitive because it involves psychological, social, moral, and family damage to the woman that is a victim of the crime. That is why some women do not report it and the crime goes unpunished, which gives the rapist confidence to continue committing it, and then it becomes a judicial problem for the city. Experts estimate that in reality, this crime rate must be 10% higher. They know by reference some women who have been raped and have not reported the incident to the police. In other cases, friends or relatives have reported the incident, but the woman has refused to give details of the incident out of shame and therefore, the prosecutor has not been able to do anything about it.

Another important aspect has to do with the delivery of justice. Table 1 represents the neutrosophic contingency table that relates the number of rapes that occurred in the year 2020 in city X with the number of these crimes in which the guilty party has been punished. Unreported violations are included in this statistic, which of course is considered among the crimes that have gone unpunished.

Rapes reported in one year\Outcome of	Punished	Not punished	Total
Reported	[22, 24]	[11, 13]	[33, 37]
Not reported	[0, 0]	[1, 9]	[1, 9]
Total	[22, 24]	[12, 22]	[34, 46]

Table 1. Neutrosophic contingency table representing denounced and non-denounced rapes against punished and not punished rapes in city X during 2020.

See that the table considers the reported crimes in the form of intervals, this has to do with the fact that some reported crimes are still in the judicial phase. Therefore, there is also imprecision in the reported crimes; however, it has been decided to maintain this imprecision for greater accuracy.

The obtained result is the following:

$N\chi^2 = [1.8487, 137.2568]$ and $NC = [0.22709, 0.89006]$ which indicates that the correlation of punished cases and reported cases can be from very correlated with C H 0.89 to little correlated with C H 0.23.

3.2 Pearson's correlation coefficient

In classical statistics, Pearson's correlation coefficient is a measure of the linear relationship between two quantitative random variables. Unlike covariance, Pearson's correlation is independent of the measurement scale of the variables.

Less formally, we can define the Pearson correlation coefficient as an index that can be used to measure the degree of relationship of two variables as long as both are quantitative.

In the case that two random variables x and y are being studied on a population; the Pearson correlation coefficient is represented with the letter ρ_{XY}, and the expression that allows us to calculate it is [49]:

$$\rho_{XY} = \frac{\sigma_{XY}}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y} \tag{5}$$

Where:

- σ_{XY} is the covariance of (X, Y),
- σ_X is the standard deviation of variable X,
- σ_Y is the standard deviation of variable Y.

Similarly, we can calculate this coefficient on a sample statistic, denoted as r_{xy}:

$$r_{xy} = \frac{\sum \quad x_i y_{i-n\underline{x}\underline{y}}}{n s_X s_Y} \tag{6}$$

In both formulas, Equation 4 of the division is used. Formulas 5 and 6 are converted into neutrosophic equations when the data (X, Y) or $\{(x_i, y_i)\}$ are intervals more than crisp values, respectively. Let us denote the generalizations of formulas 5 and 6 to the neutrosophic framework by $N\rho_{XY}$ (which we will call *neutrosophic Pearson' correlation coefficient*) and Nr_{xy}, respectively. The explanation for using interval data instead of crisp data is the same as in the previous subsection.

The value of Nr_{xy} is a subinterval of [-1, 1]:

- If $1 \in Nr_{xy}$, there are cases with a perfect positive correlation. The index designates a total dependence between the two variables called a direct relationship: when one of them increases, the other also increases in constant proportion.
- If $(0, 1) \subseteq Nr_{xy}$, there is a positive correlation.
- If $0 \in Nr_{xy}$, there are cases where there is no linear relationship. But this does not necessarily imply that the variables are independent: there may still be nonlinear relationships between the two variables.
- If $(-1, 0) \subseteq Nr_{xy}$, there is a negative correlation.
- If $-1 \in Nr_{xy}$, there are cases with a perfect negative correlation. The index designates a total dependence between the two variables called an inverse relationship: when one of them increases, the other decreases in constant proportion.

Below we illustrate the use of this coefficient by an example:

Example 2:

Tax evasion is an illegal activity and is usually regarded as an administrative offense in most legal systems. It is an illegal act of concealing property or income to pay fewer taxes. "Black money" is anyone who has evaded the payment of taxes. They are profits obtained in illegal or legal activities, but that are not declared to the Treasury to evade taxes. The intention is to keep it in cash, and not to deposit it with financial institutions so that it is not recorded in bank movements and the State is not aware of its existence.

Suppose that we want to study the relationship between the numbers in millions of dollars deposited in tax havens by citizens living in 21 cities of the territory of a country X, concerning the cost of living, measured in Consumer Price Index (CPI). In this way, both the economic and social impacts of tax evasion in each studied city are related. Hence, this phenomenon has economic, political, social, and legal significance.

However, it is difficult to have an exact figure of the millions of dollars that are in tax havens and that should be used in public expenditures of the city, because this illegal practice is hidden, therefore the most accurate way to represent it is in the form of an interval.

So, the data are summarized in Table 2:

Number of the City	Millions of dollars in tax havens	Consumer Price Index (CPI) (%)
1	[2.60, 3.40]	2.9
2	[5.30, 5.88]	7.9
3	[8.60, 9.52]	1.7
4	[7.40, 7.73]	7.7
5	[1.40, 1.81]	6.5
6	[5.40, 6.29]	3.8
7	[0.40, 0.88]	1.8
8	[1.90, 2.46]	6.9
9	[3.40, 3.59]	8.8
10	[7.30, 8.22]	4.1

11	[7.40, 7.81]	7.9
12	[8.00, 8.20]	1.4
13	[7.70, 8.55]	4.3
14	[5.80, 6.01]	8.5
15	[7.80, 8.21]	1.1
16	[2.50, 3.25]	7.1
17	[4.20, 4.39]	5.7
18	[0.80, 0.88]	8.9
19	[5.00, 5.69]	7.4
20	[9.90, 10.53]	4.7
21	[7.40, 7.53]	8.2

Table 2: Data from 21 cities that relate estimated amounts of millions in tax havens vs. CPI.

The result of applying Formula 6 to the data in Table 2 is $Nr_{xy} = [-0.27838, -0.23236]$, which indicates that in this case, the correlation is negative and quite small. Let us note that the data in the second column could be given as intervals and still formulas 5 and 6 remain applicable. This indicates that in this case the estimated amount of dollars in tax havens of citizens of the city does not significantly influence the standard of living of citizens.

3.3 Spearman's correlation coefficient

In classical statistics, Spearman's correlation coefficient, ρ is a measure of the correlation (association or interdependence) between two continuous random variables, [49]. To calculate ρ, the data are sorted and replaced by their respective order.

The statistic ρ is given by the following expression:

$$\rho = 1 - \frac{6\sum D^2}{N(N^2-1)} \qquad (7)$$

Where:

- D is the difference between the corresponding X-Y order statistics.
- N is the number of pairs.

The existence of identical data has to be considered when ordering them, although if these are few, this circumstance can be ignored.

For samples larger than 20 observations, we can use the following approximation by the t-Student distribution:

$$t = \frac{\rho}{\sqrt{\frac{(1-\rho^2)}{(n-2)}}} \qquad (8)$$

The interpretation of Spearman's coefficient is the same as that of Pearson's. It oscillates between -1 and +1, indicating negative or positive associations respectively, 0 means no correlation but no independence.

As for contingency table and Pearson's correlation coefficient, it is possible and useful to extend ρ to the neutrosophic framework, denoting by $N\rho$ when $\{(x_i, y_i)\}$ are intervals rather than crisp values. Similarly, Equation 8 becomes Nt when ρ is replaced by $N\rho$. Neutrosophic Spearman's correlation coefficient is a crisp value because orders are crisp values when interval values are compared, using the interval-value order definition.

The use of this coefficient will be illustrated with the following example:

Example 3:

Let us revisit Example 2 and apply Spearman's correlation coefficient in it. In this case, we wish to confirm whether there is a correlation among the standard of living of citizens of the 21 cities, concerning the order (not the number of millions) in tax havens of citizens investigated by the courts.

Thus, Table 2 becomes the following Table 3 of ordered data:

Number of the City	Order of millions of dollars	Order of Consumer Price	D
1	6	5	1
2	10	16	-6
3	20	3	17
4	14.5	15	-0.5
5	3	11	-8
6	11.5	6	5.5
7	1	4	-3
8	4	12	-8
9	7	20	-13
10	14.5	7	7.5
11	14.5	17	-2.5
12	17.5	2	15.5
13	17.5	8	9.5

14	11.5	19	-7.5
15	19	1	18
16	5	13	-8
17	8	10	-2
18	2	21	-19
19	9	14	-5
20	21	9	12
21	14.5	18	-3.5

Table 3: Order of data from the 21 cities that relate the estimated dollar amounts in tax havens vs. CPI, and D.

Table 3 shows that the 11th, 13th, and 17th cases are considered repeated because they cannot be compared by the order between intervals. For example, it is not $[5.40, 6.29] \npreceq [5.80, 6.01]$ nor $[5.80, 6.01] \npreceq [5.40, 6.29]$ in Table 2, therefore they are considered to have the same order, the 11th one, which is converted into $\frac{11+12}{2} = 11.5$. The result is $N\rho = -0.32857$, which is consistent with Neutrosophic Pearson's correlation coefficient.

Let us note that in this case the amount of millions in tax havens does not matter, only the order.

Conclusion

This paper covered the definition, illustration, and proposition of neutrosophic statistics methods in Social Sciences. On many occasions, the data available in Social Sciences contain inconsistencies due to inaccuracies, contradictions in the sources of information and knowledge, lack of objectivity in some opinions, among other factors. That is why in these cases, data represented in the form of intervals may be necessary. Specifically, in this paper, we define and illustrate the use of contingency tables, Pearson's correlation coefficient, and Spearman's correlation coefficient generalized to the neutrosophic framework. Three examples of the use of each of them served to show how and why to use neutrosophic statistics in these cases, where the examples used are mainly based on hypothetical problems of Legal Sciences. In future research, we will propose to generalize other methods of classical statistics to the framework of Neutrosophy, so that they will be helpful to solve problems of Social Sciences.

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