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Neutrosophy for Survey Analysis in Social Sciences

Carlos Rosero Martínez[1], German Acurio Hidalgo[2], Marvelio Alfaro Matos[3] and Florentin Smarandache[4]

[1] Universidad Regional Autónoma de los Andes (UNIANDES), Troncal de la Sierra, Tulcán, CP 040103, Ecuador.
E-mail: ut.carlosrosero@uniandes.edu.ec
[2] Universidad Regional Autónoma de los Andes (UNIANDES), Avenida La Lorena, CP 230150, Santo Domingo de los Tsáchilas, Ecuador.
E-mail: us.germanacurio@uniandes.edu.ec
[3] Universidad Regional Autónoma de los Andes (UNIANDES), Avenida La Lorena, CP 230150, Santo Domingo de los Tsáchilas, Ecuador.
E-mail: us.marvelioalfaro@uniandes.edu.ec
[4] Department of Mathematics, University of New Mexico705 Gurley AVE Gallup, NM 87301, USA, E-mail:smarand@unm.edu

Abstract. The survey is a research procedure used in sociology to determine the thoughts and feelings of a social group at a given time and context. Within the survey, the questionnaire is considered as a very useful instrument used to measure the state of opinions of social groups. Although it has been demonstrated that fuzzy responses to questionnaires are more appropriate than crisp ones, there may be indeterminacy and thus fuzzy processing does not accurately capture the thought that the respondent wants to express, due to doubts, unclear and vague thoughts, among others. Modeling such scenario by means of neutrosophic sets provides respondents a greater range of possible responses and hence it is more appropriate. In this paper, we propose a method to design single-valued neutrosophic sets from questionnaires to social groups. This method, inspired by another fuzzy one, allows us to create membership functions of truthfulness, indeterminacy and falseness through experimental data, which will let us find the essence of the thought of the human group under study to be captured with greater accuracy.

Keywords: Neutrosociology, survey, questionnaire, single-valued neutrosophic set.

1 Introduction

Sociology is the social science that studies the collective phenomena produced by the social activity of human beings, within the historical-cultural context in which they are immersed. In sociology, multiple interdisciplinary research techniques are used to analyze and interpret from different theoretical perspectives the causes, meanings and cultural influences that motivate the appearance of various behavioral trends in the human being, especially when it is in social coexistence and within a shared habitat. One of the most widely used research methods is the survey.

A survey is a research procedure, within descriptive research designs (not experimental) in which the researcher seeks to collect data through a previously designed questionnaire or an interview with someone, without modifying the environment or the phenomenon where the information is collected (just like in an experiment), [1]. The data are obtained by carrying out a set of standardized questions addressed to a representative sample or to the total set of the statistical population under study, often made up of people, companies or institutional entities, in order to know states of opinion, ideas, characteristics or facts. The researcher must select the most suitable questions, according to the nature of the investigation.

On the other hand, a questionnaire is a research instrument that consists of a set of questions and other indications to obtain information from those consulted [1,2]. Although they are often designed to allow statistical analysis of responses, this is not always the case. The questionnaire is a document formed by a set of questions that must be drafted in a coherent way. Those questions must be organized, sequenced and structured according to a certain planning, so that answers can offer us all the required information.

The survey is often carried out based on a questionnaire, which is therefore the basic document to obtain information in the vast majority of research and market studies. Questionnaires have advantages over other types of surveys in that they are inexpensive, do not require much effort on the part of the respondent, such as oral or telephone surveys, and often have standardized responses that make data tabulation simpler.

In sociology, surveys are usually designed such that the possible responses to the questionnaires are fixed values. An example of a sociological questionnaire is the opinion on the number of children that an ideal family should have, which can force respondents to answer with a number (2, 3, 4) even though the respondent wishes to answer more exactly, although imprecise as in interval form such as 2 to 4, [3]. Some authors have studied and demonstrated the fuzzy rather than crisp essence of surveys, [3-7]. Fuzzy sets have been proven more effective in dealing with measurements related to human thought than classical sets.

In this paper, we defend the thesis that neutrosophic sets are even more suitable than fuzzy sets to represent the possible responses to questionnaires. The former one allow the surveyed person to be able to express even more accurately and also with greater indeterminacy about their true thoughts and feelings, due to the indeterminacy membership function [8], which allows modeling the lack of knowledge, doubts or contradictions that may exist in the responses of any human being.

Neutrosophic Sociology or Neutrosociology is the study of sociology using neutrosophic scientific methods, [9-13], because the data of sociology can be vague, incomplete, contradictory, hybrid, biased, ignorant, redundant, superfluous, meaningless, ambiguous, and unclear, among others. In this new approach to the study of sociology, the concepts are represented in the form of <A>, which is the primary concept, <Anti A>, which is its opposite, and <Neut A>, which represents those that are neither <A> nor <Anti A>.

In this paper, we are inspired by a method in [4] for the construction of fuzzy membership functions [14,15] to construct neutrosophic sets as a result of the responses of a survey by a group of individuals under study. To design a priori fuzzy membership functions or neutrosophic sets is not sufficient and yet it is of great interest finding a more adequate application of these theories. With the use of neutrosophic sets instead of fuzzy sets, greater accuracy of the results is obtained, since the single-valued neutrosophic sets allow a greater range of expression of the thoughts and feelings of the respondents, since they cannot only express their ideas, but also what they consider false and what they consider indeterminate. This method, like its predecessor, stands out for its simplicity and applicability.

This paper is structured into the following sections: Section 2, which recalls the main concepts of Neutrosophy that will be used in the proposed method. In Section 3, we introduce the method proposed in the paper and we develop two illustrative examples. The last section contains the conclusions.

2 Basic concepts of Neutrosophy

This section describes the main concepts of Neutrosophy, such as neutrosophic sets, single-valued neutrosophic sets, and single-valued neutrosophic numbers, among others. In addition, the main definitions of neutrosophic statistics are described.

Definition 1: ([8]) Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow \,]^-0, 1^+[$, 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 x∈X. $u_A(x), r_A(x)$ 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: (8]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is a set of the form:

$A = \{\langle x, u_A(x), r_A(x), v_A(x)\rangle : x \in X\}c$ (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 x∈X. $u_A(x), r_A(x)$ and $v_A(x)$ denotes 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 $a, b, c \in [0,1]$ and satisfy $0 \leq a + b + c \leq 3$.

Definition 3: (8]) A *neutrosophic number* N is defined as a number in the following expression:

$N = d + I$ (2)

Where d is called *determinate part* and I is called *indeterminate part*.

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:

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

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

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

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

Neutrosophy studies triads, where if <A> is an item or a concept then the triad is (<A>, <neut A>, <anti A>),[9,10]. Neutrosociology is based on triads. E.g., the concept A = imperialist society, has an antiA = communist society, and neutA = neutral society.

Neutrosophic Statistics extends the classical statistics, such that we deal with set values rather than crisp values, [16-22]. Neutrosophic Statistics can be used as a quantitative research method in sociology for testing social hypotheses.

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

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

Neutrosophic Data is the piece of information that contains some indeterminacy. Similar to the classical statistics, it can 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:

- *Quantitative (numerical) neutrosophic data*; for example: a number in the interval [2, 5] (we do not know exactly), 47, 52, 67 or 69 (we do not know exactly);
- *Qualitative (categorical) neutrosophic data*; for example: blue or red (we do not know exactly), white, black or green or yellow (not knowing exactly).

The *univariate neutrosophic data* is a 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 $N = d + i$, like Equation 2.

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

Neutrosophic Survey Results are survey results that contain some indeterminacy.

A *Neutrosophic Population* is a population not well determined at the level of membership (i.e. not sure if some individuals belong or not 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* the researcher groups the (classical or neutrosophic) population by a strata according to a classification; afterwards the researcher takes a random sample (of appropriate size according to a criterion) from each group. If there is some indeterminacy, we deal with neutrosophic sampling.

3 Application of neutrosophic theory in sociological surveys

In the study carried out by Li in [4] about how to measure the people's thoughts, the author acknowledges the existence of possible responses like "1 or 2 (sorry)" with respect to the size of an small family, whereas other answer is "not an exact age" for the question about the exact age of a "young person". Thus, it is necessary to include the indeterminacy like a possible result of a survey. On the other hand, Li deals with indeterminacy when the range of responses is an interval rather than a single value.

In this section, we deal with indeterminacy based on single-valued neutrosophic sets and Neutrosociology concepts. The method consists of the following aspects:

1. Firstly, the sociologist must determine the primary concept he/she wants to measure, e.g., A = "small family". Next, he/she determines anti A, e.g. "big family", and neut A, e.g. "optimal family". In addition, he/she establishes the social group to analyse.
2. He/she asks to the group the questions he/she designed aiming to have information about the triad (<A>, <neut A>, <anti A>). Every question should have three variants, one of them related to one of the three elements of the triad.
   The ambiguous or vague answers like "I don't know", "certain number", and so on are associated with <neut A>, even though they were responses for questions of <A> or <anti A>.
   The interviewer remarks that the responses can be given in form of intervals in case it makes sense or if respondent considers it better corresponds to his/her opinions.
   Questionnaires can also include answers in form of linguistic values.
   The respondent should feel free to write what he/she thinks on the subject of the questions.

Let us denote as $X_j = \{x_i^j\}_{i=1}^{m_j}$ the set of possible responses to question q_j (j = 1, 2,…, n).

The frequency of every possible response is calculated for every element of the triad, let us call them $f_{<A>}(x_i^j)$, $f_{<neut\ A>}(x_i^j)$, and $f_{<anti\ A>}(x_i^j)$.

If N is the size of the social group to study, we calculate the following probabilities:

$$p_{<A>}(x_i^j) = \frac{f_{<A>}(x_i^j)}{N} \quad (3)$$

$$p_{<neut\,A>}(x_i^j) = \frac{f_{<neut\,A>}(x_i^j)}{N} \quad (4)$$

$$p_{<anti\,A>}(x_i^j) = \frac{f_{<anti\,A>}(x_i^j)}{N} \quad (5)$$

The properties of $p_{<A>}(x_i^j)$, $p_{<neut\,A>}(x_i^j)$, and $p_{<anti\,A>}(x_i^j)$ are the following:

- For every X_j then $p_{<A>}(x_i^j), p_{<neut\,A>}(x_i^j), p_{<anti\,A>}(x_i^j) \in [0,1]$.
- For every X_j then $\sum_{i=1}^{m_j}\left(p_{<A>}(x_i^j) + p_{<anti\,A>}(x_i^j)\right) \le 1$.
- For every X_j then $\sum_{i=1}^{m_j}\left(p_{<A>}(x_i^j) + p_{<neut\,A>}(x_i^j) + p_{<anti\,A>}(x_i^j)\right) \ge 1$.

Let us remark that the probabilities $p_{<A>}(x_i^j)$ and $p_{<anti\,A>}(x_i^j)$ should satisfy the property of subjective probability approach, [23], whereas, when $p_{<neut\,A>}(x_i^j)$ is included then the sum can exceed the unity. This is because of $p_{<neut\,A>}(x_i^j)$ and the others two may have common answers for some individuals.

Now, for every concept A the sociologists have a single-valued neutrosophic set defined as follows:

$$A = \left\{\langle x, \min_j\left(p_{<A>}(x_i^j)\right), \max_j\left(p_{<neut\,A>}(x_i^j)\right), \max_j\left(p_{<anti\,A>}(x_i^j)\right)\rangle : x \in \Pi_{j=1}^{n} X_j\right\} \quad (6)$$

Let us note that Π is the Cartesian product and the set A contains the definition of n-norm, [17]. Also, let us remark we are using neutrosophic statistics with neutrosophic data.

The single-valued neutrosophic set A can be de-neutrosophied to a crisp set where the elements of the triad are reduced to numerical values using the scoring function or a precision index.

A scoring function $s: [0,1]^3 \to [0,3]$ is defined in Formula 7, it is an adapted scoring function from the one defined in [24].

$$s(a) = 2 + T - F - I \quad (7)$$

Where a is a SVNN with values (T, I, F).

The definition of precision index is given in Equation 8.

$$a(a) = T - F \quad (8)$$

Where $a: [0,1]^3 \to [-1, 1]$.

Below, we illustrate the method through two examples.

Example 1

Here, we revisit the example appeared in [4]. The survey aims to investigate what people considers is an ideal family size, thus <A> = <ideal family size>, <anti A> = <non- ideal family size>, and <neut A> = <indeterminate ideal family size>. Let us note we are dealing with three variants of the same concept instead of only one of them. Here, we use only one question, which is:

1. Use any number (0, 1,2,...) or any range (1-4, 2-3,...) to indicate your perception of:
   1.1. the ideal family size.
   1.2. you cannot determinate it is neither ideal nor not an ideal family size.
   1.3. non- ideal family size.

Let us assume that the population contains 6 respondents, which answer in the following way, where $R_i = \left(R_i^{<A>}, R_i^{<neut\,A>}, R_i^{<anti\,A>}\right)$, correspond to the responses given by the i-th respondent for the triad $(< A >, < neut\,A >, < anti\,A >)$, respectively:

$$R_1 = (\{1,2,3,4\}, \{5\}, \{0,6,7,8,9,10\})$$

$$R_2 = (\{2\}, \{3,4\}, \{0,1,5,6,7,8,9,10\})$$

$$R_3 = (\{2,3\}, \{1\}, \{0,4,5,6,7,8,9,10\})$$

$$R_4 = (\{1,2\}, \{0\}, \{3,4,5,6,7\})$$

$$R_5 = (\{0\}, \emptyset, \{x: x > 0\})$$

$$R_6 = (\{2,3,4\}, \{5,6\}, \{1,7,8,9,10\}).$$

That means, e.g., the first respondent thinks the ideal family size (number of children) is from 1 to 4, whereas to have not child or more than 6 is not ideal, however, 5 children is indeterminate for him/her. Contrarily, respondent 5 is against to have any child.

Table 1 summarizes the frequency of each possible response in the example:

Responses X_1	$f_{<A>}(x_i^1)$	$f_{<neut\ A>}(x_i^1)$,	$f_{<anti\ A>}(x_i^1)$.
0	1	1	3
1	2	1	2
2	5	0	1
3	3	1	2
4	2	1	3
5	0	1	4
6	0	1	5
7	0	0	6
8	0	0	5
9	0	0	5
10	0	0	5

Table 1: Frequencies of the responses.

The probabilities are obtained dividing the frequencies by N = 6. The truthfulness, indeterminacy and falseness membership functions are depicted in Figure 1.

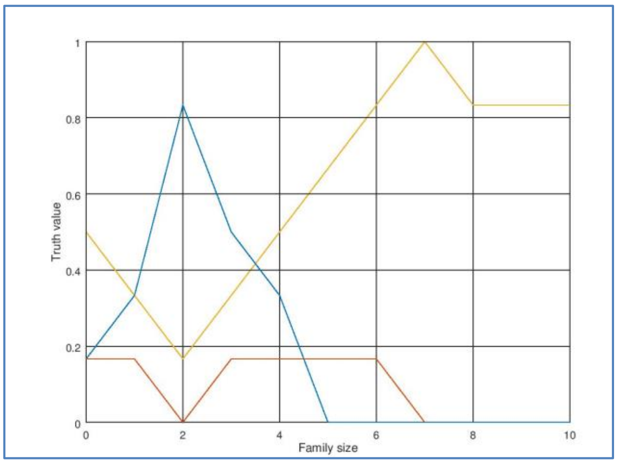

Figure 1: Truthfulness-membership function in blue lines, indeterminacy-membership function in red lines, and falseness-membership function in yellow lines, for the concept "ideal family size".

In Figure 2 shows the scoring function using Equation 7 for the possible responses about the concept "ideal family size".

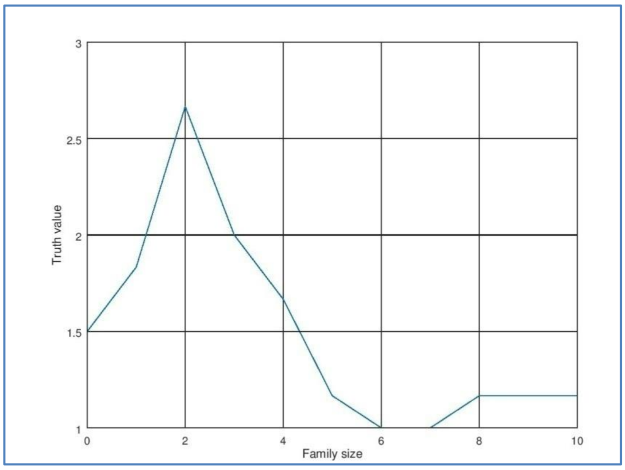

Figure 2: Scoring function of the single-valued neutrosophic set in Figure 1.

Evidently, the ideal family size can be considered equal to 2 for this social group.

Example 2

In a community, sociologists want to know how members perceive two concepts: *young* and *educated*. To do this, they design a questionnaire, one where the triad is that of (<young>, <middle-aged>, <old>), while the second triad is (<instructed>, <borderline instruction>, <unlearned>).

Questions are:

1. How old must a person be to be considered:
   1.1. young?
   1.2. middle-aged?
   1.3. old?
2. ¿What level of education must a person have to be considered:
   2.1. instructed?
   2.2. borderline educated?
   2.3. not educated?

For the first question, the possible answer is an age between 0 and 120 years old, it can also be expressed in the form of intervals, that is, $X_1 = \{G: G \subset [0, 120]\}$.

For the second question, the possible answers are: "primary level of education", "secondary level of education", "upper secondary level of education", "higher level of education", and "MSc. or PhD degrees ", these are the elements of X_2.

Suppose the population of study consists of 180 members. The results are shown in Figure 3:

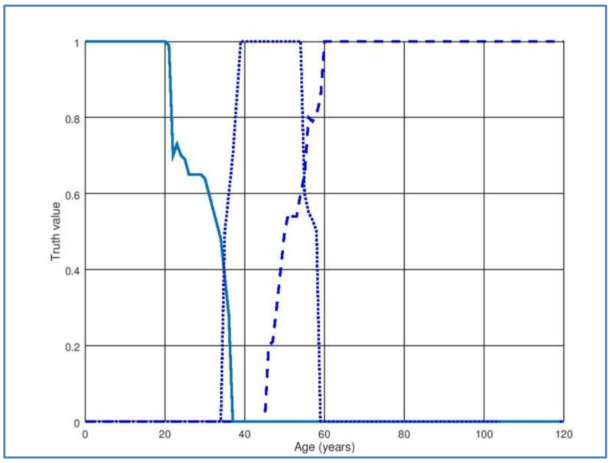

Figure 3: Truthfulness-membership function in solid lines, indeterminacy-membership function in dotted lines, and falseness-membership function in dashed lines, for the concept "young".

In Figure 4 it is depicted the scoring function of the triad related with young people.

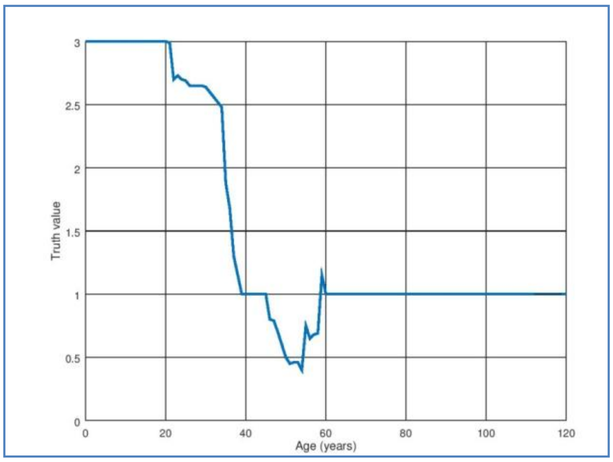

Figure 4: Scoring function for the single-valued neutrosophic set in Figure 3.

Regarding the level of instruction, let us assume that the results were the following:

- Primary level of education has the triple $(0, 0.01, 0.93)$,

- Secondary level of education has the triple (0.1, 0.6, 0.8),
- Upper secondary level of education has the triple (0.6, 0.4,0.1),
- Higher level of education has the triple (1, 0.1, 0), and
- MSc. or PhD degrees has the triple (1,0,0).

Thus, to define the conjunction of young and instructed person, it is necessary to obtain the Cartesian product between the pair age and education level, where the n-norm of the triple of each of them is calculated. E.g., one young 20 years old person AND having a primary level of instruction has a triad value obtained since the n-norm between (1, 0, 0) for young and (0, 0.01,0.93) for educated, which results in (0, 0.01,0.93) for this combination. Calculating the scoring function we have the value -0.94, thus it is very low.

Conclusion

This paper introduces a neutrosophic method for survey analysis in social sciences. The new method is inspired by another one where fuzzy sets were used. The advantage of the neutrosophic approach is that the respondents can express more accurately their thoughts and feelings, because indeterminacy is considered as well as an independent membership function of falseness. The method consists of designing a single-valued neutrosophic set from the collected data. This set serves to evaluate the satisfaction of a concept by a social group. The method is also based on the Neutrosociology theory, where the set A includes the notion of the triad of the aforementioned theory. This neutrosophic approach is applied to questionnaires where both discrete numerical and linguistic responses are possible.

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