



Prioritization of non-functional requirements in a mobile application for panic button system using neutrosophic decision maps

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Abstract. Several countries around the world have implemented systems to preserve public safety. Taking advantage of technological advances that are available to all citizens, in Ecuador it has been implemented a system called panic button, which consists of a cell phone network with geo-location, which can assist every citizen who needs to ask for help and the authorities will respond efficiently. This research proposes to improve this system in order to increase its efficiency and effectiveness. This requires the use of prioritization of non-functional requirements. In this paper we use the static analysis of Neutrosophic Cognitive Maps to determine, evaluate, and compare non-functional requirements. Neutrosophic Cognitive Maps allow establishing causal relationships among different criteria, with the objective of determining an order of preference. In this investigation we have three experts who provided the evaluations.

Keywords: Non-functional requirements, requirement engineering, neutrosophic logic, neutrosophic cognitive maps.

1 Introduction

Article 23 of the Public Security and State Law in Ecuador refers to citizen security and justice, through which some institutions such as the National Police among others, seek to guarantee citizens' security by the implementation of infrastructure, as well as the necessary equipment within the linked institutions.

Several countries have implemented measures aimed at preventing the safety of citizens, such as the ERSOS application that has been developed in Chile, using the technological resources currently available, in this case by means of geo-location, which seeks to provide alternatives that facilitate interaction between control authorities and citizens in case of inconveniences or emergencies that threaten their integrity.

In conjunction with the National Police and the Ministry of the Interior, the country has developed an alarm system that operates since the Community Police Units (CPU), which uses the panic button, a security strategy implemented by the National Police. This is based on an alert generated from the user's cellular network, having as its main reference the address to the home that has been registered, to which the aid personnel are directed in the event of an emergency, see [1].

The project in [1] is significant because it proposes the development of an option that allows for a better response to citizen emergencies, trying to find new technological alternatives that will improve the response time for responding to emergency calls in the CPU of the National Police.

The objective of such project was to develop a mobile application that would optimize the panic button system supported by geo-location to achieve a better response time in the CPU of the National Police, as a prototype in the parish of Caranqui, taking advantage of the great usefulness of technological resources currently available.

This paper aims to order by importance the quality criteria of the software applications that will be used in the system. Thus, our purpose is to analyse the prioritization of non-functional requirements of the software applied

in the cell-phone applications and computer servers.

In order to determine the prioritization of non-functional requirements to implement such a system, the Neutrosophic Cognitive Maps technique is used, see [2]. Non-functional requirement (NFR) refers to global properties and frequently to quality of functional requirements. This is an important and complex part of the requirement engineering process. It is essential for studying the quality of software, and constitutes a critical problem; see [3-10]. Non-functional requirements are difficult to evaluate, particularly because they are subjective, relative and interdependent.

To analyze NFR, uncertainty arises, making desirable to compute with qualitative information. In software development projects analyst must identify and specify relationships between NFR. Current approaches differentiate three types of relationships: negative (-), positive (+) or null (no contribution). The opportunity to evaluate NFR depends on the type of these relationships. Softgoal Interdependency Graphs ([6]) is a technique used for modeling non-functional requirements and interdependencies among them. Bendjenna in [3] proposed the use of fuzzy cognitive maps (FCM) relationships among NFRs and the weight of these relationships expressed with fuzzy weights in the range 0 to 1; see [11] [1] for Cognitive Maps and [12][2] for FCM. This model lacks additional techniques for analyzing the resulting FCM.

Neutrosophic logic generalizes fuzzy logic and is based on neutrosophy, see [13-14]. When indeterminacy is introduced in cognitive map it is called Neutrosophic Cognitive Map (NCM), see [2, 15]. NCMs are based on neutrosophic logic to represent uncertainty and indeterminacy in cognitive maps ([11]) extending FCM ([12]). A NCM is a directed graph in which at least one edge is indeterminate and is denoted by dotted lines. To utilize a NCM permits dealing with indeterminacy, making easy the elicitation of interdependencies among NFR.

This paper is divided in the following sections; Section 2 contains the definitions and theories that will be applied to solve the proposed problem. Section 3 consists in the exposition of the results of the problem solution. The last section contains the conclusions.

2 Basic Concepts

This section contains the main definitions of neutrosophic logic, in addition of neutrosophic numbers, neutrosophic cognitive maps and their static indices. All these are theories, methods and techniques that will serve to solve the problem addressed in this article.

Definition 1. ([13, 15]) 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 $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indeterminacy and falseness of x in A , respectively, and their images are standard or non-standard subsets of $]^{-0}, 1^{+}[$.

The *Single-Valued Neutrosophic Set*, which is defined below, was created to apply NS to real problems.

Definition 2. ([13, 15]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is an object of the form:

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

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 $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indeterminacy 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 satisfies $0 \leq a + b + c \leq 3$.

Neutrosophic Logic (NL), was proposed in 1995 by Florentin Smarandache, and is a generalization of fuzzy logic. According to this theory, a proposition P is characterized by three components; see [13-14][3]:

$$NL(P) = (T, I, F) \quad (2)$$

Where component T is the degree of truthfulness, F is the degree of falsity and I is the degree of indeterminacy. This degree of indeterminacy is proposed for the first time as an independent component.

The results of the static analyses in neutrosophic theory are given in the form of neutrosophic numbers, which are numbers with the algebraic structure $a+bI$, where I = indeterminacy. The formal definitions of these concepts are given below.

Definition 3. Let R be a ring. The *neutrosophic ring* $\langle R \cup I \rangle$ is also a ring, generated by R and I under the operation of R , where I is a neutrosophic element that satisfies the property $I^2 = I$. Given an integer n , then, $n \cdot I$ and nI are neutrosophic elements of $\langle R \cup I \rangle$ and in addition $0 \cdot I = 0$. Also, I^{-1} , the inverse of I is not defined.

An example of a neutrosophic ring is $\langle \mathbb{R} \cup I \rangle$ generated by \mathbb{R} .

Other operations on I are the following:

$$I + I = 2I \text{ and in general } I + I + \dots + I = nI.$$

Definition 4. A *neutrosophic number* N is defined as a number as follows ([16-18][4]):

$$N = d + I \quad (3)$$

Where d is the *determined part* and I is the *indeterminate part* of N .

Example 1. $N = 4.7 + I$, has 4.7 as the determined part and I as the indeterminate part, such that if $I = [0, 1]$ then, $N = [4.7, 5.7]$.

Let $N_1 = a_1 + b_1I$ and $N_2 = a_2 + b_2I$ be two neutrosophic numbers, then some operations between them are defined as follows:

5. $N_1 + N_2 = a_1 + a_2 + (b_1 + b_2)I$ (Addition),
6. $N_1 - N_2 = a_1 - a_2 + (b_1 - b_2)I$ (Difference),
7. $N_1 \times N_2 = a_1a_2 + (a_1b_2 + b_1a_2 + b_1b_2)I$ (Product),
8. $\frac{N_1}{N_2} = \frac{a_1+b_1I}{a_2+b_2I} = \frac{a_1}{a_2} + \frac{a_2b_1-a_1b_2}{a_2(a_2+b_2)}I$ (Division).

A *neutrosophic matrix* is a matrix whose components are elements of $\langle R \cup I \rangle$. From this, it is possible to generalize the operations between vectors and matrices on R to the ring $\langle R \cup I \rangle$. An example is the following:

Example 2. Given two matrices, $A = \begin{pmatrix} -1 & 2 & -I \\ 3 & I & 0 \end{pmatrix}$ and $B = \begin{pmatrix} I & 1 & 2 & 4 \\ 1 & I & 0 & 2 \\ 5 & -2 & 3I & -I \end{pmatrix}$, $AB = \begin{pmatrix} -6I + 2 & -1 + 4I & -2 - 3I & I \\ 4I & 3 + I & 6 & 12 + 2I \end{pmatrix}$.

A *neutrosophic graph* is a graph with at least one neutrosophic edge linking two nodes, i.e. an edge where there is indetermination about its connection of two nodes.

A *neutrosophic cognitive map* (NCM) is a neutrosophic graph used to represent causal reasoning.

This is a generalization of cognitive maps and fuzzy cognitive maps, since it includes the possibility of indetermination. See an example in Figure 1, where the connections of nodes v_4 to v_2 , v_5 to v_2 and v_1 to v_5 are represented by dashed lines, which mean that there is an indeterminacy in these connections.

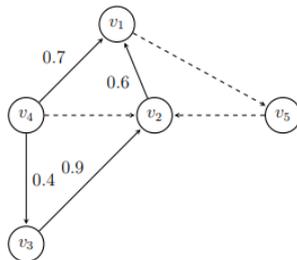


Figure 1. Example of Neutrosophic Cognitive Map.

To build a NCM we have to gather the evaluations of k experts. The *collective adjacency matrix* of the experts is calculated as follows:

$$E = \mu(E_1, E_2, \dots, E_k) \tag{4}$$

Where μ is an aggregation operator, usually the arithmetic mean.

Centrality measures are calculated as neutrosophic numbers obtained from the adjacency matrix of the NCM. These measures are:

Outdegree, denoted by $od(v_i)$, is calculated as the sum by rows of the absolute values of a variable in the neutrosophic adjacency matrix. It measures the degree of accumulated force of the existing connections of the variable. See Equation 5:

$$od(v_i) = \sum |c_{ij}| \tag{5}$$

Indegree, denoted by $id(v_i)$, is calculated as the sum by columns of the absolute values of a variable in the neutrosophic adjacency matrix. It measures the degree of accumulated force of the variables that arrive at the given variable. See Equation 6:

$$id(v_i) = \sum |c_{ji}| \tag{6}$$

The *Total Degree*, which is denoted by $td(v_i)$, is calculated by the sum of indegree and outdegree. See Equation 7:

$$td(v_i) = od(v_i) + id(v_i) \tag{7}$$

A de-neutrosophication process was proposed by Salmeron and Smarandache ([19]) and can be applied to give a final order. This process provides a range of numbers for centrality using as a base the maximum and minimum

values of $I = [a_1, a_2] \subseteq [0, 1]$, based on Equation 8, see [19]:

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \tag{8}$$

Once the previous numeric value is calculated, an order can be established between $A = [a_1, a_2]$ and $B = [b_1, b_2]$, as it is shown below:

$$A > B \Leftrightarrow \lambda(A) > \lambda(B) \tag{9}$$

In other words, A is preferred over B if and only if $\lambda(A) > \lambda(B)$.

3 Results

This section is devoted to describe the calculus for applying NCM to determine and sort the main attributes to consider in the mobile application for the panic button system. The study is carried out respect to the software application necessary to install in the cell phones, as well as the software of data store in the computer servers. For this end, we begin with the non-functional requirements attributes selected by three experts, which are the following:

- A₁. Portability,
- A₂. Reliability,
- A₃. Efficiency,
- A₄. Security,
- A₅. Initial and Life-cycle cost,
- A₆. Usability by users' community,
- A₇. Stability,
- A₈. Extensibility, or capacity to incorporate new additives to the system,
- A₉: Maintainability,
- A₁₀: Response time,
- A₁₁: Data integrity.

The three experts evaluated the strength of the causal relationships between every pair of attributes using a scale of integers in 0-10. We established this scale because it is more understandable for them, than a continuous scale in $[0, 1]$. Here, 0 means that there is not any causal relationship, 10 means the strength is total and 5, it is medium. We informed to experts that they can use symbol I to indicate indetermination. Additionally, we asked them to settle on if every relationship is direct or inverse.

These evaluations were processed as follows:

1. The strength of the assessed causalities are aggregated over the set of the three experts, using the median, if they are numeric. In case that at least one of experts assesses with symbol I, then I is the final aggregation value and the steps below do not proceed.
2. These aggregated evaluations are divided by 10 and it is the numeric strength of the relationships.
3. If the majority of the three experts consider the relationship is direct, then, we associate sign + to the obtained strength in step 2, otherwise we associate sign -.

Table 1 contains the calculations obtained by experts' evaluations. Let us note we use the notation A₁, A₂, ..., A₁₁ to represent the attributes associated with these notations.

Attribute	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉	A ₁₀	A ₁₁
A ₁	0	I	0.7	I	-0.4	0.9	-0.3	0.4	-0.6	I	I
A ₂	0	0	0.1	0.8	-0.5	0.4	0.6	0	0	0	0.8
A ₃	0	0	0	I	0.7	0.6	I	0.6	I	0.9	0.4
A ₄	0	0	0	0	0.3	0.4	0	-0.3	0	-0.2	0.8
A ₅	0	0	0	0	0	0.5	0.6	I	0.6	0.4	0.3
A ₆	0	0	0	0	0	0	0	0	0	0	0
A ₇	0	0	0	0.4	0	0.5	0	0	0	-0.3	I
A ₈	0	-0.4	0	0	0	0.6	-0.5	0	-0.3	-0.3	-0.3
A ₉	0	0.5	0	0	0	0.3	0.5	0	0	0	0
A ₁₀	0	0.5	0	0	0	0.8	0	0	0	0	I
A ₁₁	0	0	0	0	0	0.1	0	0	0.3	0	0

Table 1: Obtained aggregated relationships between every pair of attributes.

We supported our calculations by using Octave 4.2.1, see [20]. Table 2 summarizes the results of indegree, outdegree and total degree corresponding to Table 1. Whereas Table 3 contains the interval-valued total degree, the de-neutrosophicated values and order number of the attributes.

Attribute	$id(A_i)$	$od(A_i)$	$td(A_i)$
A ₁	0	3.3+4I	3.3+4I
A ₂	1.4+I	3.2	4.6+I
A ₃	0.8	3.2+3I	4+3I
A ₄	1.2+2I	2	3.2+2I
A ₅	1.9	2.4+I	4.3+I
A ₆	5.1	0	5.1
A ₇	2.5+I	1.2+I	3.7+2I
A ₈	1.3+I	2.4	3.7+I
A ₉	1.8+I	1.3	3.1+I
A ₁₀	2.1+I	1.3+I	3.4+2I
A ₁₁	2.6+3I	0.4	3+3I

Table 2: Indegree, outdegree, and total degree of the neutrosophic adjacency matrix.

Attribute	Interval A _i	$\lambda(A_i)$	Order
A ₁	[3.3, 7.3]	5.3	2
A ₂	[4.6, 5.6]	5.1	3
A ₃	[4, 7]	5.5	1
A ₄	[3.2, 5.2]	4.2	9
A ₅	[4.3, 5.3]	4.8	5
A ₆	5.1	5.1	3
A ₇	[3.7, 5.7]	4.7	6
A ₈	[3.7, 4.7]	4.2	9
A ₉	[3.1, 4.1]	3.6	11
A ₁₀	[3.4, 5.4]	4.4	8
A ₁₁	[3, 6]	4.5	7

Table 3: Interval-valued total degree, de-neutrosophicated values and order number of the attributes.

Thus, according to the results in Table 3, we have that the order of the attributes sorted in descended order is the following:

$$A_3 > A_1 > A_2 \sim A_6 > A_5 > A_7 > A_{11} > A_{10} > A_4 \sim A_8 > A_9.$$

Conclusion

The mobile application for panic button system is a way to guarantee the public security of the Ecuadorian citizens. This paper aimed to study the possibility to improve the quality of its software application. Thus, it is necessary to sort by importance the different attributes of software quality, i.e. the non-functional requirements of the software. We applied the technique of neutrosophic cognitive maps, where three experts assessed the pair-wise causal relationships between eleven attributes. Then, we arrived to the conclusion that “Efficiency” is the most important of the attributes, followed by “Portability”, and after there are both, “Reliability” and “Usability by users’ community”.

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