Neutrosophic AHP for the prioritization of requirements for a computerized facial recognition system

Nelson Patricio Becerra Arévalo[1], Marco Fernando Calles Carrasco[2], John Luis Toasa Espinoza[3] and Miguel Velasteguí Córdova[4]

[1]Professor, Universidad Regional Autónoma de Los Andes, Ecuador. E-mail: up.nelsonbecerra@uniandes.edu.ec
[2] Professor, Universidad Regional Autónoma de Los Andes, Ecuador. E-mail: sp.marcofcc66@uniandes.edu.ec
[3] Professor, Universidad Regional Autónoma de Los Andes, Ecuador. E-mail: up.johntoasa@uniandes.edu.ec
[4] Professor, Universidad Regional Autónoma de Los Andes, Ecuador. E-mail: up.miguelvelastegui@uniandes.edu.ec

Abstract. The Cooperative of Taxis and Vans of Puyo in Ecuador is dedicated to the transportation of people and minor loads. Due to the considerable number of members of this cooperative, it is difficult to determine the presence of each of the participants in the meetings. That is why it was decided to implement a facial recognition system that allows identifying the presence of members in each moment. However, in order to apply this system, certain requirements are needed for guaranteeing its success. This paper aims to apply the neutrosophic Analytic Hierarchy Process (NAHP) technique for analyzing the prioritization of requirements necessary to implement a facial recognition system in the cooperative. Neutrosophic AHP permits including the indetermination incorporated in neutrosophic models and additionally experts can provide their evaluations based on linguistic terms, which results in greater ease and effectiveness to evaluate.

Keywords: prioritization of software requirements, facial recognition system, neutrosophic AHP, multicriteria-decision making

1 Introduction

The Cooperative of Taxis and Vans of Puyo in Ecuador is an organization whose main activity is the transportation of passengers and minor loads. They provide this service since the year 1972 to the city of Puyo. With almost 50 years of service the number of members in this cooperative has grown to 79. The entity periodically summons a meeting of members either for accountability, approval of financial statements, sessions for sporting events, among others.

Due to the large number of members of the cooperative, there have been inconveniences in the process of making the calls. Although calls are made approximately 5 days in advance either by the delivery of the summons of minutes in person or by sending Whatsapps or emails, not always all members attend the meetings.

Attendance is taken by the secretary of the institution in a period of 15 to 30 minutes only once at the beginning of the meeting. This implies difficulties in maintaining the history of the attendees to each one of the convocations, due to the fact that many of the members present at the sessions do not sign the payroll because of the lack of time or delays. In addition these meetings are prolonged ending, many times after midnight.

In order to solve this difficulty, it is proposed to implement a computerized facial recognition system, obtaining many benefits, such as security and reliability in the attendance registry, since this system will identify the faces of the members, thus discarding any type of impersonation at the time of registration and will allow a better management of time in the convocations, see [1].

However, this solution leads to new challenges such as, the high cost of implementing a system like this, the training or hiring of personnel to manage the system, the cost of maintenance or updating, among others. Therefore, we propose in this paper to yield a process of prioritization of requirements, see [2].

Software engineers are involved in complex decisions that require multiple points of view. A specific case is the requirements prioritization process. This process is used to decide what software requirement to develop in a given iteration from a group of candidate requirements. The criteria involved in this process can be of different nature so that they must be evaluated in different domains and the results can be shown in a linguistic domain.

Multiple models of prioritization of requirements have been proposed in the literature; see [2-9]. However, there are two fundamental limitations to these proposals:

- Lack of management of information with different nature.
- The results are shown quantitatively and are difficult for understanding by the software engineers.

This paper fills a research gap, when it is affirmatively answered the question about if there exists a tool that overcomes the aforementioned limitations. Thus, the motivation of this paper is to apply an efficient tool, such that those drawbacks are surmounted. Hence, this paper aims to identify and select the requirements necessaries for implementing an effective computerized facial recognition system in the Cooperative of Taxis and Vans of Puyo, Ecuador. This is not a straightforward problem, because its solution needs of financial, human and technological considerations.

For this end, we apply the Neutrosophic Analytic Hierarchy Process technique NAHP . Saaty's Analytic Hierarchy Process (AHP) technique ([10]), which is a multicriteria-decision technique used to evaluate a set of criteria-based alternatives by a group of experts in the field. This technique starts from a tree, where the upper level leaf represents the goal, the leaves at the next lower level represent the criteria to evaluate such a goal, at the lower level there are the leaves that represent the sub-criteria on the criteria and so on. The lowest level contains the leaves representing the alternatives.

In this method the elements of the same level in the tree are pair-wise compared, as to the importance rate of each other, this gives a score to each criterion and sub-criterion with respect to their peers. These scores influence the evaluation of the alternatives.

In this paper the neutrosophic AHP (NAHP) is used, which is the AHP technique defined in the neutrosophic framework, see [11-13]. One advantage of using neutrosophy is that experts can evaluate the choices by means of linguistic terms, thus they can assess the alternatives more accurately than by using numerical scales. On the other hand, many researchers have dedicated their research subjects to design and implement face recognition systems, moreover, the scientific literature have many examples of face recognition systems based on several points of view, e.g., see [14]. Multicriteria decision-making is successfully modeled in neutrosophic environments, see for example [15, 16].

This paper is organized as follows; Section 2 describes the main concepts of neutrosophic AHP technique. Section 3 describes the technique applied to solve the problem of prioritization of the requirements for the design of the facial recognition software in the taxi base of Puyo. To finish the conclusions are given in the last Section.

2 Neutrosophic Analytic Hierarchy Process

We start with some preliminaries from both, the classical AHP in subsection 2.1, and the neutrosophic AHP in subsection 2.2,

2.1 Introduction to the AHP Technique

Analytic Hierarchy Process (AHP) starts from a hierarchical structure represented by a tree, such that there is an upper unique leaf representing the goal. This leaf is the parent of other leaves of criteria, which are the parents of the leaves of sub-criteria and so on. The bottom level contains the leaves of alternatives, see Figure 1.

This schematic representation is used by a group of experts in assessing the alternatives based on pair-wise comparison matrices according to certain scale. Saaty proposed the scale that he considered is the better to evaluate decisions; it can be seen in Table 1.

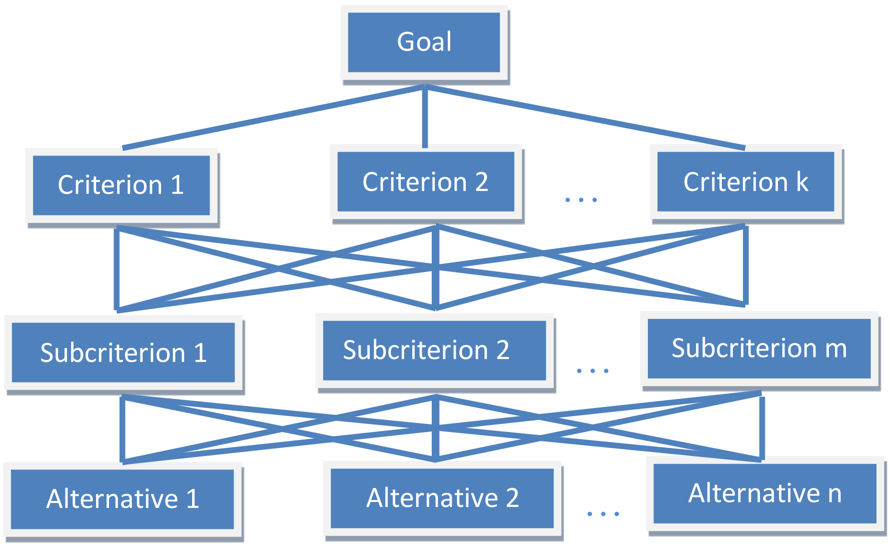

Figure 1: Scheme of a generic tree representing an Analytic Hierarchy Process

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments.	When comprise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*.	

Table 1: Intensity of importance according to the classical AHP

Other detail to consider when applying this technique is the calculus of the *Consistency Index* (CI), which is function depending on λ_{max}, the maximum eigenvalue of the matrix. Saaty establishes that consistency of the evaluations can be determined by equation$CI = \frac{\lambda_{max} - n}{n-1}$, where n is the order of the matrix. Also, the *Consistency Ratio* (CR) is defined by equation CR = CI/RI, where RI is given in Tab. 2.

Order (n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Table 2: RI associated to every order.

If CR≤0.1 we can consider that experts' evaluation is sufficiently consistent and hence we can proceed to use AHP.

AHP aims to score criteria, sub-criteria and alternatives, and to rank every alternative according to these scores. For more details about this technique [10] can be consulted.

AHP can also be used in group assessment. In such a case, the final value is calculated by the weighted geometric mean, see Equations 1 and 2. Weights are utilized to measure the importance of each expert's criteria, where some factors are considered like expert's authority, knowledge, effort, among others.

$$\bar{x} = \left(\prod_{i=1}^{n} x_i^{w_i}\right)^{1/\sum_{i=1}^{n} w_i} \quad (1)$$

If expert's weights sum up one, i.e. $\sum_{i=1}^{n} w_i = 1$., Equation 1 converts to Equation 2,

$$\bar{x} = \prod_{i=1}^{n} x_i^{w_i} \quad (2)$$

2.2 Basic concepts of the Neutrosophic AHP

Definition 1: ([17-19]) The *Neutrosophic set* N is characterized by three membership functions, which are the truth-membership function T_A, indeterminacy-membership function I_A, and falsity-membership function F_A, where U is the Universe of Discourse and $\forall x \in U$, $T_A(x), I_A(x), F_A(x) \subseteq]^-0, 1^+[$, and $^-0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+$.

See that according to the definition, $T_A(x)$, $I_A(x)$ and $F_A(x)$ are real standard or non-standard subsets of $]^-0, 1^+[$ and hence, $T_A(x)$, $I_A(x)$ and $F_A(x)$ can be subintervals of [0, 1].

Definition 2: ([17-19]) The *Single-Valued Neutrosophic Set* (SVNS) N over U is $A = \{<x; T_A(x), I_A(x), F_A(x)>: x \in U\}$, where $T_A: U \to [0, 1]$, $I_A: U \to [0, 1]$, and $F_A: U \to [0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

The *Single-Valued Neutrosophic* (SVNN) number is symbolized by N = (t, i, f), such that $0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Definition 3: ([12-13, 18-19]) The *single-valued trapezoidal neutrosophic number*,

$\tilde{a} = \langle (a_1, a_2. a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, whose truth, indeterminacy and falsity membership functions are defined as follows:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}}, & a_2 \leq x \leq a_3 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_3 \leq x \leq a_4 \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, & a_2 \leq x \leq a_3 \\ \frac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_3 \leq x \leq a_4 \\ 1, & \text{otherwise} \end{cases} \quad (4)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a}}, & a_2 \leq x \leq a_3 \\ \frac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_3 \leq x \leq a_4 \\ 1, & \text{otherwise} \end{cases} \quad (5)$$

Where $\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \in [0,1]$, $a_1, a_2, a_3, a_4 \in \mathbb{R}$ and $a_1 \leq a_2 \leq a_3 \leq a_4$.

Definition 4: ([12-13, 18-19]) Given $\tilde{a} = \langle (a_1, a_2, a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3, b_4); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued trapezoidal neutrosophic numbers and λ any non null number in the real line. Then, the following operations are defined:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
2. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
3. Inversion: $\tilde{a}^{-1} = \langle (a_4^{-1}, a_3^{-1}, a_2^{-1}, a_1^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, where $a_1, a_2, a_3, a_4 \neq 0$.
4. Multiplication by a scalar number:
$$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3, \lambda a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_4, \lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases}$$
5. Division of two trapezoidal neutrosophic numbers:
$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle \left(\frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 > 0 \; and b_4 > 0 \\ \langle \left(\frac{a_4}{b_4}, \frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 < 0 \; and b_4 > 0 \\ \langle \left(\frac{a_4}{b_1}, \frac{a_3}{b_2}, \frac{a_2}{b_3}, \frac{a_1}{b_4}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 < 0 \; and b_4 < 0 \end{cases}$$
6. Multiplication of two trapezoidal neutrosophic numbers:
$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1 b_1, a_2 b_2, a_3 b_3, a_4 b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 > 0 \; and b_4 > 0 \\ \langle (a_1 b_4, a_2 b_3, a_3 b_2, a_4 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 < 0 \; and b_4 > 0 \\ \langle (a_4 b_4, a_3 b_3, a_2 b_2, a_1 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 < 0 \; and b_4 < 0 \end{cases}$$

Where, $\wedge$ is a t-norm and $\vee$ is a t-conorm.

Let us remark that if $a_2 = a_3$ in Definitions 3 and 4, we say the single-valued trapezoidal neutrosophic number is a *single-valued triangular neutrosophic number*, see [20].

The second step of the model is to apply the NAHP. The proposed linguistic scale is based on triangular neutrosophic numbers summarized in Table 3, according to the scale defined [12].

The hybridization of AHP with neutrosophic set theory was used in [12-13]. This is a more flexible approach to model the uncertainty in decision making. Indeterminacy is an essential component to be assumed in real world organizational decisions.

The neutrosophic pair-wise comparison matrix is defined in Equation 6.

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \quad (6)$$

$\tilde{A}$ satisfies the condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, according to the inversion operator defined in Definition 4.

Authors in [12] defined two indices to convert a neutrosophic triangular number in a crisp number. They are the equations of score and accuracy in Equations 7 and 8, respectively:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (7)$$

$$\mathbf{A}(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (8)$$

Saaty scale	Definition	Neutrosophic Triangular Scale
1	Equally influential	$\tilde{1} = \langle(1,1,1); 0.50, 0.50, 0.50\rangle$
3	Slightly influential	$\tilde{3} = \langle(2,3,4); 0.30, 0.75, 0.70\rangle$
5	Strongly influential	$\tilde{5} = \langle(4,5,6); 0.80, 0.15, 0.20\rangle$
7	Very strongly influential	$\tilde{7} = \langle(6,7,8); 0.90, 0.10, 0.10\rangle$
9	Absolutely influential	$\tilde{9} = \langle(9,9,9); 1.00, 1.00, 1.00\rangle$
2, 4, 6, 8	Sporadic values between two close scales	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$
		$\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$
		$\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$
		$\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

Table 3:Saaty's scale translated to a neutrosophic triangular scale.

Given the criteria and sub-criteria tree and the neutrosophic triangular scale in Table 3, the NAHP consists in the following:

1. To design an AHP tree. This contains the selected criteria, sub-criteria and alternatives from the first stage.
2. To create matrices per level from the AHP tree, according to experts' criteria expressed in neutrosophic trapezoidal scales associated with linguistic terms, and with regard to the matrix scheme in Equation 6.
3. To evaluate the consistency of these matrices. Abdel-Basset et al. make reference to Buckley, see [21, 22], who demonstrated that if the crisp matrix $A = [a_{ij}]$ is consistent, then the neutrosophic matrix $\tilde{A} = [\tilde{a}_{ij}]$ is also consistent. Thus, $\tilde{A}$ is converted to the crisp matrix A applying formulas 7 or 8, such that it fulfils the condition $a_{ij} = 1/a_{ji}$. See that for simplicity we preferred to evaluate in form of single-valued triangular neutrosophic number.
4. To follow the other steps of a classical AHP.

3 Results

Here we expose the result for applying the neutrosophic AHP to the problem we are solving, which is a real-life example. Then, we specify the steps we followed to achieve this end.

1. To establish prioritization framework: Experts, criteria and requirements are selected in order to prioritize the latter. The framework is defined as follows:
   - $E = \{E_1, E_2, ..., E_n\}$ with $n \geq 2$, is the group of experts who will participate in the process.

- $C=\{C_1,C_2,...,C_k\}$ with $k\geq 2$, is the set of criteria to be evaluated.
- $R=\{R_1,R_2,...,R_m\}$ with $m\geq 2$, is the set of requirements to be prioritized.

These elements are used to design the tree that represents the AHP that has the structure shown in Figure2 for each expert:

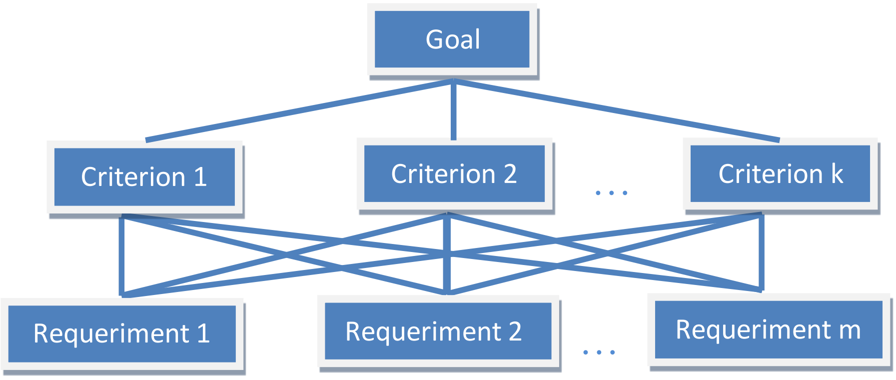

Figure 2: Scheme of the tree representing an Analytic Hierarchy Process for the prioritization of requirements to design a computerized facial recognition system by each expert.

2. Collection of information: The neutrosophic pair-wise comparison matrices are obtained as in Equation 6, given by each expert E_i.
3. The AHP neutrosophic technique is applied for each of the trees corresponding to each expert. For each requirement and expert we obtain the importance that each requirement has according to each criterion with respect to the others.
4. The calculated value of the importance of each requirement is aggregated with respect to the group of experts, using Formulas 1 or 2. To apply these equations a weight must be assigned to each expert, in this paper we will assign the same weight for everyone.
5. Numbers are ordered by each requirement, giving priority to those with the highest values.

There were three experts to carry out the evaluations, which will be denoted from now on by E_1, E_2 and E_3.

The criteria for evaluating are the following three:

C_1. The requirement feasibility and efficiency respect to the user.

C_2. Cost: It is the criterion to determine the cost of implementing the requirement for each individual candidate.

C_3. Technical Complexity: It is the technical level of the software and hardware needed to implement the requirement.

The requirements to be evaluated are as follows:

The system has to be able to:

R_1: Record all calls made in the cooperative.

R_2: Store the information of each member including photographs of their front faces.

R_3: Capture images by means of a webcam with the possibility of saving it later.

R_4: Detect faces of people within the camera field of vision.

R_5: Identify the members registered in the system and record their attendance at the meetings of the cooperative.

R_6: Generate reports with the attendance list for each call.

R_7: The graphical interface should be user-friendly.

R_8: Quickly process the images captured by the camera.

R_9: The system must provide ease of maintenance to the person in charge.

R_{10}: Login to the system must be validated by the user name and password.

The three obtained pair-wise matrices corresponding to criteria, one per expert are summarized in Tables 4, 5, and 6. Let us note that the values are expressed in form of the scale given in Table 1.

Criteria	C_1	C_2	C_3
C_1	$\tilde{1}$	$\tilde{3}$	$\tilde{5}$
C_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{2}$
C_3	$\tilde{5}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$

Table 4:Pair-wise matrix corresponding to criteria given by Expert 1.

Criteria	C_1	C_2	C_3
C_1	$\tilde{1}$	$\tilde{3}$	$\tilde{4}$
C_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{3}$

C_3	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}$

Table 5:Pair-wise matrix corresponding to criteria given by Expert 2.

Criteria	C_1	C_2	C_3
C_1	$\tilde{1}$	$\tilde{3}$	$\tilde{4}$
C_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{2}$
C_3	$\tilde{4}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$

Table 6:Pair-wise matrix corresponding to criteria given by Expert 3.

Tables 7, 8 and 9, contain the average evaluation for the total of experts corresponding to the Requirements, one per each criterion.

Requirement	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
R_1	1	0.29242	0.26495	0.20653	0.97872	1.98851	1.76250	2.24351	3.41980	3.41980
R_2	3.41980	1	0.82786	0.82786	2.24351	2.94214	2.53120	2.94214	4.38707	4.38707
R_3	3.77431	1.20793	1	0.97872	2.94214	3.41980	2.94214	3.97500	4.38707	5.34380
R_4	4.84186	1.20793	0.97872	1	3.41980	3.77431	3.77431	3.96332	5.08434	5.08434
R_5	0.97872	0.44573	0.33989	0.29242	1	2.31135	2.31135	2.94214	3.77431	3.97500
R_6	0.50289	0.33989	0.29242	0.26495	0.43265	1	0.70026	1.98851	2.24351	1.98851
R_7	0.56738	0.39507	0.33989	0.26495	0.43265	1.42805	1	1.61117	1.98851	2.31135
R_8	0.44573	0.33989	0.25157	0.25231	0.33989	0.50289	0.62067	1	0.93750	1.42805
R_9	0.29242	0.22794	0.22794	0.19668	0.26495	0.44573	0.50289	0.93750	1	1.20793
R_{10}	0.29242	0.22794	0.18713	0.19668	0.25157	0.50289	0.43265	0.70026	0.82786	1

Table 7: Average crisp pair-wise matrix corresponding to requirements given by the experts according to criterion C_1.

Requirement	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
R_1	1	2.00054	2.00054	2.23001	0.67640	0.50899	0.44454	0.33734	0.26564	0.29462
R_2	0.49986	1	1.45842	0.93750	0.58114	0.44843	0.34504	0.33734	0.25235	0.25157
R_3	0.49986	0.65963	1	0.79717	0.42682	0.29462	0.25157	0.22682	0.19717	0.18713
R_4	0.44843	0.93750	1.25445	1	0.49986	0.29462	0.26960	0.22682	0.19717	0.23020
R_5	1.41310	1.65539	2.34289	2.00054	1	0.56738	0.44454	0.39507	0.26564	0.34504
R_6	1.96466	2.23001	3.39417	3.39417	1.76250	1	0.95035	0.29462	0.20755	0.26564
R_7	2.24953	2.89821	3.97500	3.70926	2.24953	1.00576	1	0.44843	0.29462	0.34504
R_8	2.96435	2.96435	4.40876	4.40876	2.53120	3.39417	2.23001	1	0.84365	0.84365
R_9	3.76455	3.96274	5.07170	5.07170	3.76455	4.81804	3.39417	1.18533	1	0.98082
R_{10}	3.39417	3.97500	5.34380	4.34401	2.89821	3.76455	2.89821	1.18533	0.98082	1

Table 8: Average crisp pair-wise matrix corresponding to requirements given by experts according to criterion C_2.

Requirement	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
R_1	1	0.28805	0.26960	0.20450	0.98082	2.00054	1.76250	2.23001	3.39417	3.39417
R_2	3.47163	1	0.84365	0.79717	2.27074	2.96435	2.53120	2.96435	4.40876	4.40876
R_3	3.70926	1.18533	1	0.95035	2.96435	3.47163	2.96435	3.97500	4.40876	5.34380
R_4	4.88986	1.25445	1.00576	1	3.47163	3.85047	3.85047	4.05318	5.14729	5.14729
R_5	0.98082	0.44039	0.33734	0.28805	1	2.34289	2.34289	2.96435	3.76455	3.97500
R_6	0.49986	0.33734	0.28805	0.25971	0.42682	1	0.65963	2.00054	2.27074	2.00054
R_7	0.56738	0.39507	0.33734	0.25971	0.42682	1.45842	1	1.60396	2.00054	2.34289
R_8	0.44843	0.33734	0.25157	0.24672	0.33734	0.49986	0.59592	1	0.93750	1.41310
R_9	0.29462	0.22682	0.22682	0.19428	0.26564	0.44039	0.49986	0.93750	1	1.18533
R_{10}	0.29462	0.22682	0.18713	0.19428	0.25157	0.49986	0.42682	0.67640	0.84365	1

Table 9: Average crisp pair-wise matrix corresponding to requirements given by experts according to criterion C_3.

We supported the calculus with the aid of the software Octave 4.2.1, specially the function *eig* to estimate the maximum eigenvalue of the crisp pair-wise matrices, see [23]. Thus, let us remark that we shall apply formula 8 for converting the pair-wise matrices in crisp matrices. The obtained CRs were 0.0034808, 0.024394,and 0.0014231for Expert 1, Expert 2 and Expert 3, respectively, which are smaller than 0.1. Whereas, for the matrices of Requirements we obtained the CRs are smaller than 0.1 respect to every expert and every criterion.

Table 10 summarizes the priority vectors of the three experts for the criteria, applying Equation 2 with weights $w_i = 1/3$ for i = 1, 2, 3.

Criteria	Average over experts of Criteria Priority Vectors	Order
C_1	0.61143	1
C_2	0.25372	2
C_3	0.13375	3

Table 10: Average of priority vectors obtained for every criterion over the experts and their order.

Table 11 summarizes the weights for every requirement and the final order.

Requirement\Criterion	C_1(0.61143)	C_2(0.25372)	C_3(0.13375)	Requirements Priority Vector	Order
R_1	0.084669	0.058097	0.084123	0.077761	6
R_2	0.167878	0.041460	0.167974	0.135631	3
R_3	0.199339	0.030708	0.198023	0.156159	2
R_4	0.218413	0.034742	0.221580	0.171995	1
R_5	0.102241	0.063551	0.102015	0.092282	4
R_6	0.057777	0.084364	0.057414	0.064411	10
R_7	0.062954	0.101726	0.062809	0.072702	9
R_8	0.041391	0.168992	0.041086	0.073680	7
R_9	0.034464	0.217979	0.034189	0.080951	5
R_{10}	0.030875	0.198381	0.030788	0.073329	8

Table 11: The requirements priority vectors and the final order of requirements.

According to the results summarized in Table 11 the requirements are ordered as follows:

$R_4 \succ R_3 \succ R_2 \succ R_5 \succ R_9 \succ R_1 \succ R_8 \succ R_{10} \succ R_7 \succ R_6$.

Conclusion

This paper was devoted to study the prioritization of requirements for a computerized facial recognition system of the Cooperative of Taxis and Vans of Puyo, Ecuador, with the aim to record the presence of the members to the meetings. For this end, we applied the neutrosophic AHP technique with three experts' criteria, having as an advantage that experts' assessment are given in form of linguistic terms, which is the most natural human manner to evaluate. The three criteria are viz., efficiency of the system, cost, and technical complexity. Moreover, evidently the indeterminacy modelled by neutrosophy is also incorporated. The results were that the requirements that should be prioritized are the following in that order of preference, the system must be able to:

- Detect faces of people within the camera field of vision.
- Capture images by means of a webcam with the possibility of saving it later.
- Store the information of each member including photographs of their front faces.
- Identify the members registered in the system and record their attendance at the meetings of the cooperative.

This paper contributed to solve a real-life complex problem by using NAHP. It illustrates the applicability of this technique in a field like the decision making for the prioritization of requirements for a computerized facial recognition system.

References

[1] Calles-Carrasco, M. F. (2019). *Informatics System for Facial Recognition for the Record and Control of the Members' Presense of the Puyo Cooperative of Taxis and Vans (Sistema Informático de Reconocimiento Facial para el Registro y Control de Asistencia de Socios de la Cooperativa de Taxis y Camionetas Puyo)(In Spanish).* Bachelor Thesis, Regional Autonomous University of Los Andes, Puyo, Ecuador

[2] Aurum, A. and Wohlin, C. (2005). *Engineering and Managing Software Requirements*. New York: Springer.

[3] Azar, J., Smith, R. K., and Cordes, D. (2007). Value-oriented requirements prioritization in a small development organization. *IEEE software, 24*(1), 32-37.

[4] Iqbal, M. A., Zaidi, A. M. and Murtaza, S. (2010). *A New Requirement Prioritization Model for Market Driven Products Using Analytical Hierarchical Process.* Paper presented at the International Conference on Data Storage and Data Engineering.

[5] Otero, C. E., Dell, E., Qureshi, A. and Otero, L. D. (2010). *A Quality-Based Requirement Prioritization Framework Using Binary Inputs*. Paper presented at the Fourth Asia International Conference on Mathematical/Analytical Modelling and Computer Simulation.

[6] Betancourt-Vázquez, A., Pérez-Teruel, K., Ramírez-Domínguez, J. and Leyva-Vázquez, M. (2015). Prioritization of software requirements by means of a multi-expert multi-criteria model with heterogeneous information (Priorización de requisitos de software mediante un modelo multi-experto multi-criterio con información heterogénea)(In Spanish). *Revista Digital Sociedad de la Información, 2015*(52), 1-11.

[7] Barriga-Dias, R., Ortiz-Choez, W., Martillo-Alcivar, I. and Ortiz-Aguilar, W. (2017). Neutrosophy for software requirement prioritization *Neutrosophic Sets and Systems, 17*, 93-98.

[8] Chindapornsopit, A. and Samanchuen, T. (2016). Requirement Prioritization for Software Release Planning Based on Customer Value with Analytic Hierarchy Process. *ITMSOC Transactions on Innovation & Business Engineering, 1*, 21-27.

[9] Sasank, V. V., Praveen, D., Suresh, V. and Vakkalanka, S. (2019). Issues with Requirements Prioritization in MDRE. *International Journal of Management, Technology And Engineering, 9*(1), 867-877.

[10]Aczél, J. and Saaty, T. L. (1983). Procedures for Synthesizing Ratio Judgments. *Journal of Mathematical Psychology, 27*(1), 93-102.

[11]Wei, C. C., Chien, C. F. and Wang, M. J. (2005). An AHP-based approach to ERP system selection. *International Journal of Production Economics, 96*(1), 47-62.

[12]Abdel-Basset, M., Mohamed, M. and Smarandache, F. (2018). An Extension of Neutrosophic AHP-SWOT Analysis for Strategic Planning and Decision-Making. *Symmetry, 10*(4), 116.

[13]Abdel-Basset, M., Mohamed, M., Zhou, Y. and Hezam, I. (2017). Multi-criteria group decision making based onneutrosophic analytic hierarchy process. *Journal of Intelligent & Fuzzy Systems33(6), 4055–4066.*

[14]Biosys. (2018). Biometry of the facial recognition (Biometria de reconocimiento facial)(In Spanish) Available at the Biosys web site URL: http://www.biosys.es/sistemas-biometricos/facial/

[15]Estupiñan Ricardo, J., Llumiguano Poma, M. E., Argüello Pazmiño, A. M., Albán Navarro, A. D., Martín Estévez, L., and Batista Hernandez, N. (2019) Neutrosophic model to determine the degree of comprehension of higher education students in Ecuador *Neutrosophic Sets & Systems*, 26, 55-61.

[16]Leyva Vázquez, , Batista Hernández, N., and Smarandache, F.,(2018) *Multicriteria methods for determining the effectiveness of the public administration and the analysis of the transparency* (*Métodos multicriterios para determinación de la efectividad de la gestión pública y el análisis de la transparencia)(In Spanish)*, Infinite Study.

[17]Haibin, W., Smarandache, F., Zhang, Y., and Sunderraman, R. (2010) *Single valued neutrosophic sets*, Infinite Study.

[18]Biswas, P., Pramanik, S. and Giri, B. C. (2016). Value and ambiguity index based ranking method of single-valued trapezoidal neutrosophic numbers and its application to multi-attribute decision making. *Neutrosophic Sets and Systems, 12*, 127-138.

[19]Ye, J. (2015). Trapezoidal neutrosophic set and its application to multiple attribute decision-making. *Neural Computing and Applications, 26*(5), 1157-1166.

[20]Abdel-Basset, M., Mohamed, M., Hussien, A. N. and Sangaiah, A. K. (2018). A novel group decision-making model

based on triangular neutrosophic numbers. *Soft Computing, 22*(20), 6629-6643.
[21]Buckley, J. J. (1985). Fuzzy hierarchical analysis. *Fuzzy Sets and Systems, 17*, 233-247.
[22]Buckley, J. J., Feuring, T. and Hayashi, Y. (2001). Fuzzy hierarchical analysis revisited. *European Journal of Operational Research, 129*, 48-64.
[23]Eaton, J. W., Bateman, D., Hauberg, S. and Wehbring, R. (2017). GNU Octave: A high-level interactive language for numerical computations version 4.2.1. Available at: http://www.gnu.org/software/octave/doc/interpreter.

Received: October 01st, 2019. Accepted: February 22nd, 2020