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# Neutrosophic Evaluation of Depression Severity

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**Abstract.** Among the mental illnesses, depression is a very common manifestation today. Various methods have been approached in the scientific literature to quantify depression, among which we may find the Hamilton scale. However, depression has a degree of uncertainty in its manifestation conditioned by the severity of the diagnosis. Problems of this nature have been addressed by science from neutrosophic modeling. Based on the scenario described above, the present research proposes a neutrosophic method for evaluating the level of depression. The method bases its operation on the adaptation of the Hamilton scale with neutrosophic numbers to quantify depressive disorder. The method uses the range to indicate the levels of severity of depression recognized by the American Psychiatric Association by means of neutrosophic numbers.

**Keywords:** neutrosophic numbers; mental diseases; Hamilton scale; depression

## 1. Introduction

Depressive disorder or depression represents a mental illness that currently affects more than 350 million people in the world, according to the World Health Organization [1]. Depression is characterized by a group of conditions, such as: pathological sadness, decay, apathy, irritability, feeling of discomfort and helplessness towards the vicissitudes of life. Cognitive processes can also generate physical manifestations such as vomiting, loss weight, cardiac ischemia, diabetes, cerebrovascular diseases, cancer, among others [2].

Guaranteeing the identification and diagnosis of patients from the beginning would allow the implementation of antidepressant and opportune psychotherapeutic treatments that avoid aggravating these manifestations [3]. Rating scales for depression and its response to treatment have been proposed in various studies. The proposed scales are intended to evaluate the patient's symptoms in a given time [4].

Hetero-evaluated scales are those in which the evaluator asks about each of the items and evaluates them [5]. Self-assessing scales or questionnaires can be read by the interviewer or by the patient himself, who chooses the items that best reflect his state; the most used are: Beck Depression Inventory (BDI), Hamilton Rating Scale for Depression (HAM-D) and Montgomery Asberg Depression Rating Scale (MADRS) [6].

The symptoms of the patients represent the evaluation criteria to which a weight is matched. The result of the method returns a numerical value that must be previously supplemented with the clinical interview and its respective psychopathological information to determine the diagnosis [7]. The scientific literature describes problems of this nature through multi-criteria modeling for the evaluation of medical diagnosis. Based on the problems raised above, this research proposes a neutrosophic method for the evaluation of depression levels.

## 2. Preliminaries

This section describes the main theoretical references on the object of study; and the different concepts that facilitate the understanding of the research. A description of the mental illnesses is made and an approximation of the way to measure depression is introduced, specifically the Hamilton scale as a way to measure the severity of depression.

## 2.1. Mental disorders

Depression is a very common mental illness today. It means knocked down or beaten down; formerly it was called melancholy. Depressive disorder or depression is defined as the grouping of affective, cognitive, volitional and somatic symptoms that entails a great psychological and physical affectation to the person who suffers from it [8].

Depression is often associated with anxiety, with organic brain diseases or with systemic organic diseases [9]. It is also associated with the abuse of alcohol and illegal substances, with alterations in eating behavior and alterations of the personality; also depressive disorder has a direct relationship with chronic physical diseases, which can increase depression and this, in turn, adversely affects the course of the physical disease [10]. People who suffer from depression present signs and symptoms together that affect both the mood, the behavior and the organic part.

## 2.2. Hamilton scale

The Hamilton rating scale for the evaluation of depression is a hetero-applied scale, designed to be used in patients previously diagnosed with depression. The scale is applied in order to quantitatively assess the severity of the symptoms and assess the changes in the depressed patient [11]. It is valued according to the information obtained in the clinical interview and accepts complementary information from other secondary sources [12]. Different evaluations have made it possible to verify the discriminant validity, reliability and sensitivity to change, both in hospitalized and outpatient populations. [13].

It is a scale to assess the intensity or severity of depressive disorder both in clinical practice and in research. It is used to monitor how symptoms progress in patients. The assessment of the various symptoms corresponds to the moment in which it is applied, with the exception of some items that strictly refer to the previous two days, such as the items about sleep.

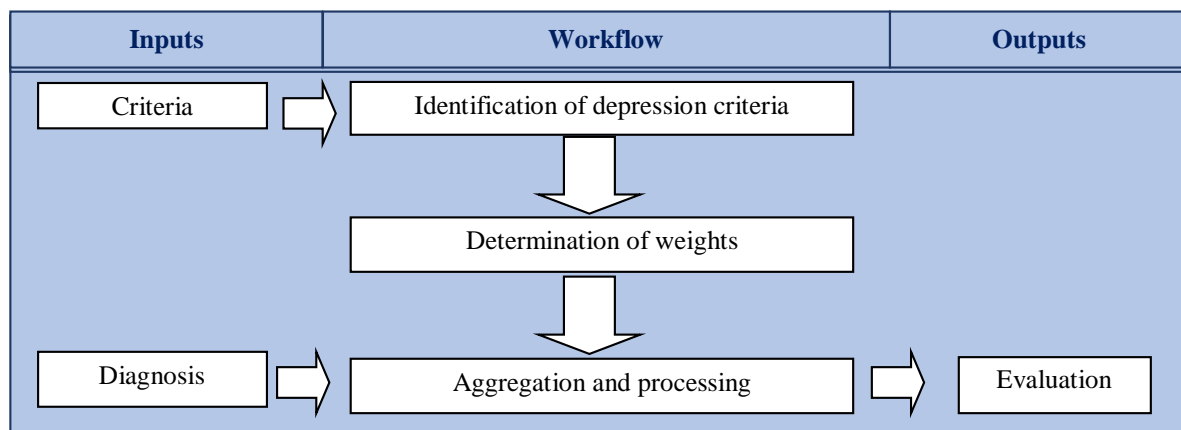
## 2. Materials and Methods

This section describes the structure and operation of the method for evaluating depression. The method models the uncertainty by using neutrosophic numbers to represent it. The inference process is managed from the use of operators for the aggregation of information [14, 15].

The method proposal is structured to ensure the management of the workflow for the evaluation of depression. It uses a multi-expert multi-criteria approach based on defined qualitative indicators to assess this condition. The indicators represent the basis of inference for the evaluation of depression.

It has an aggregation and processing stage that processes the information for the evaluation of depression. The end result of the method is the evaluation of depression.

Figure 1 shows a representation of the structure and operation of the proposed method.



**Figure 1:** General operation of the proposed method.

The method for the evaluation of depression is made up of three basic activities (determination of the criteria to quantify depression, definition of the weights associated with the depression criteria, aggregation and information processing). The main activities are described below:

*Activity 1 identification of depression criteria:*

In the activity of identifying the criteria to quantify depression, a multi-criteria approach is used; bases its operation by using the criteria of the Hamilton scale that quantify depression [12].

*Activity 2 determination of the weights associated with the depression criteria:*

Based on the criteria obtained from the previous activity, they are evaluated to determine the weight vectors associated with each criterion. The activity of determining the weights associated with the depression criteria is carried out through a multi-expert approach, for which the use of 7 to 13 experts who intervene in the process is proposed.

*Activity 3 aggregation and processing of information:* The activity of aggregation and processing of information represents the fundamental nucleus of the inference of the method. The activity represents the pathway used in the decision support process. The activity starts from the information obtained in the previous activities. It consists of the transformation of a data set into a single element using aggregation operators [16-18].

**Definition 1: T-norm operator.** An operator  $T: [0,1] * [0,1] \rightarrow [0,1]$  is a T-norm operator if it meets the following properties:

$$1. \text{ Commutative } T(x,y) = T(y,x). \quad (1)$$

$$2. \text{ Associative } T(x,T(y,z)) = T(T(x,y),Z). \quad (2)$$

$$3. \text{ Increasing monotone } T(x,y) > T(x',y) \text{ si } x \geq x' \cap y \geq y'. \quad (3)$$

$$4. \text{ Neutral element } T(x,1) = x. \quad (4)$$

The activity is based on the aggregation process using the Ordered Weighted Average (OWA) information aggregation operator. The operator allows the aggregation of information according to predefined parameters, obtaining a representative value. A decision maker can aggregate the information based on the desired degree of optimism or pessimism [15, 19, 20].

**Definition 2: OWA operator.** A function  $F: R^n \rightarrow R$ , is an OWA operator of dimension  $n$  if it has an associated vector  $W$  of dimension  $n$  such that its components satisfy [21]:

$$1) W_j \in [0,1], \quad (5)$$

$$2) \sum_{j=1}^n W_j = 1, \text{ and} \quad (6)$$

$$3) F(a_1, a_2, \dots, a_n) = \sum_{j=1}^n W_j b_j \quad (7)$$

Where  $b_j$  is the  $j$ -th largest of the  $a_j$ .

The aggregation operator can be expressed using a vector notation as represented in equation 8:

$$F(a_1, a_2, \dots, a_n) = W^t B \quad (8)$$

Where:

$W$ : is the OWA weight vector associated with the aggregation.

$B$ : is the ordered aggregate vector, where the  $j$ -th largest component of  $B$  is  $b_j$  this being the  $j$ -th largest of the  $a_i$ .

Neutrosophic numbers can be expressed in neutrosophic logic as shown in [14, 22, 23]:

Given

$$N = \{(T, I, F) : T, I, F \subseteq [0, 1]\}, \quad (9)$$

A neutrosophic value is a mapping of a group of formulas proportional to  $N$ , from each  $p$  sentence we have [24-26]:

$$v(p) = (T, I, F) \quad (10)$$

Where:

$T$ : represents the dimension of the space that represents the truth,

$I$ : represents falsehood,

$F$ : represents indeterminacy.

Mathematically, a Neutrosophic OWA operator can be defined as a 2-tuple  $(W, B)$  as represented by equation 11.

$$F(a_1, a_2 \dots a_n) = W_{(T,I,F)} {}^t B_{(T,I,F)} \quad (11)$$

Where:

W: is the OWA weight vector associated with the aggregation that has a space of truth, falsehood and indeterminacy (T, I, F).

B: is the ordered aggregate vector, where the j-th largest component of B is  $b_j$  this being the j-th largest of the  $a_i$ , which has a space of truth, falsehood and indeterminacy (T, I, F).

The proposed method performs the aggregation process using the OWA operator for neutrosophic numbers.

### 3. Results

This section describes the implementation of the proposed method through a case study. The study is carried out on a patient who was hospitalized in the Internal Medicine area of the Latacunga General Hospital in Ecuador. The example presents the fundamental elements for the analysis of the proposal.

The main elements of the implemented method are described below:

*Activity 1 identification of depression criteria.*

During the process of obtaining information for the definition of the depression criteria, the result was 15 criteria that make up the Hamilton scale. Table 1 shows the criteria obtained.

Criteria	Depression
C <sub>1</sub>	Depressed mood
C <sub>2</sub>	Feeling guilty
C <sub>3</sub>	Idea of suicide
C <sub>4</sub>	Early insomnia
C <sub>5</sub>	Medium insomnia
C <sub>6</sub>	Problems at work and activities
C <sub>7</sub>	Inhibition
C <sub>8</sub>	Agitation
C <sub>9</sub>	Psychic Anxiety
C <sub>10</sub>	Somatic anxiety
C <sub>11</sub>	Somatic Gastrointestinal Symptoms
C <sub>12</sub>	General somatic symptoms
C <sub>13</sub>	Genital symptoms
C <sub>14</sub>	Hypochondria
C <sub>15</sub>	Weight loss

**Table 1:** Criteria for depression.

*Activity 2 determination of the weights associated with the depression criteria.*

To determine the weight associated with the depression criteria, 9 experts were used who participated in the process. Each criterion has a set of indicators that represent the way to assess the criteria. The indicators have been modeled using neutrosophic numbers. As a final result, the weight vectors associated with each criterion were obtained. Table 2 shows the results of the indicators that correspond to each criterion in a neutrosophic domain.

Criteria	Indicators	Neutrosophic scale
C <sub>1</sub>	Absent	[ 0,1,1 ]
	These sensations are indicated only when interrogate	[ 0.10,0.90,0.90 ]
	These sensations are reported orally and spontaneously	[ 0.20,0.85,0.80 ]
	Sensations not communicated verbally, but by facial expression, posture, voice or tendency to cry	[ 0.30,0.75,0.70 ]
	The patient manifests these sensations in his verbal and non-verbal communication spontaneously	[ 0.40,0.65,0.60 ]
C <sub>2</sub>	Absent	[ 0,1,1 ]
	Blames himself, thinks he has let people down	[ 0.10,0.90,0.90 ]

Criteria	Indicators	Neutrosophic scale
	Ideas of guilt, or meditation on past mistakes or bad actions	[ 0.20,0.85,0.80 ]
	The current illness is a punishment. Delusions of guilt	[ 0.30,0.75,0.70 ]
	Hears accusing or denouncing voices and / or experiences threatening visual hallucinations	[ 0.40,0.65,0.60 ]
C <sub>3</sub>	Absent	[ 0,1,1 ]
	It seems to her that life is not worth living.	[ 0.10,0.90,0.90 ]
	Wish you were dead or have thoughts about dying	[ 0.20,0.85,0.80 ]
	Ideas or threats of suicide	[ 0.30,0.75,0.70 ]
	Suicide attempts	[ 0.40,0.65,0.60 ]
C <sub>4</sub>	Absent	[ 0,1,1 ]
	occasional difficulty falling asleep, for example more than half an hour	[ 0.10,0.90,0.90 ]
	difficulty falling asleep every night	[ 0.20,0.85,0.80 ]
C <sub>5</sub>	Absent	[ 0,1,1 ]
	The patient complains of being restless at night	[ 0.10,0.90,0.90 ]
	You are awake at night; any occasion of getting out of bed is scored as 2, unless justified (urinating, taking or giving medication)	[ 0.20,0.85,0.80 ]
C <sub>6</sub>	Absent	[ 0,1,1 ]
	Wakes up in the early hours of the morning but falls asleep again	[ 0.10,0.90,0.90 ]
	You can't go back to sleep if you get out of bed	[ 0.20,0.85,0.80 ]
C <sub>7</sub>	Absent	[ 0,1,1 ]
	Ideas and feelings of incapacity. Fatigue or weakness related to your job, activity, or hobbies	[ 0.10,0.90,0.90 ]
	Loss of interest in their activity, hobbies or work, manifested directly by the patient or indirectly by inattention, indecision and hesitation	[ 0.20,0.85,0.80 ]
	Decrease in time dedicated to activities or decrease in productivity	[ 0.30,0.75,0.70 ]
	Stopped working for the present illness	[ 0.40,0.65,0.60 ]
C <sub>8</sub>	Normal word and thought	[ 0,1,1 ]
	Slight delay in dialogue	[ 0.10,0.90,0.90 ]
	Obvious delay in dialogue	[ 0.20,0.85,0.80 ]
	Difficult dialogue	[ 0.30,0.75,0.70 ]
	Absolute clumsiness	[ 0.40,0.65,0.60 ]
C <sub>9</sub>	None	[ 0,1,1 ]
	He "plays" with his, hands, hair, etc.	[ 0.10,0.90,0.90 ]
	He wrings his hands, bites his nails, his lips, he pulls his hair.	[ 0.20,0.85,0.80 ]
C <sub>10</sub>	No difficulty	[ 0,1,1 ]
	Subjective tension and irritability	[ 0.10,0.90,0.90 ]
	Worry about little things	[ 0.20,0.85,0.80 ]
	Apparent apprehensive attitude in expression or speech	[ 0.30,0.75,0.70 ]
	Terrors expressed without asking	[ 0.40,0.65,0.60 ]
C <sub>11</sub>	Absent	[ 0,1,1 ]
	Light	[ 0.10,0.90,0.90 ]
	Moderate	[ 0.20,0.85,0.80 ]
	Serious	[ 0.30,0.75,0.70 ]

Criteria	Indicators	Neutrosophic scale
	Unable	[ 0.40,0.65,0.60 ]
C <sub>12</sub>	None	[ 0,1,1 ]
	Loss of appetite, but eats without being stimulated. Feeling of heaviness in the abdomen	[ 0.10,0.90,0.90 ]
	Difficulty eating if you don't insist. Request or need laxatives or intestinal medication or for your gastrointestinal symptoms	[ 0.20,0.85,0.80 ]
C <sub>13</sub>	None	[ 0,1,1 ]
	Heaviness in the extremities, back or head. Back pain, headache, myalgia. Fatigue and loss of energy	[ 0.10,0.90,0.90 ]
	Any of the above symptoms is scored as 2 if it is very well defined	[ 0.20,0.85,0.80 ]
C <sub>14</sub>	Absent	[ 0,1,1 ]
	Weak	[ 0.10,0.90,0.90 ]
	Serious	[ 0.20,0.85,0.80 ]
	Unable	[ 0.30,0.75,0.70 ]
C <sub>15</sub>	None	[ 0,1,1 ]
	Self-conscious (bodily)	[ 0.10,0.90,0.90 ]
	Concerned about your health	[ 0.20,0.85,0.80 ]
	He constantly regrets. Ask for help.	[ 0.30,0.75,0.70 ]
	Hypochondriacal delusions	[ 0.40,0.65,0.60 ]

**Table 2:** Neutrosophic scale of the criteria and their measurement indicators.

From the work with the group of experts that intervened in the process, the weight vectors associated with each depression criterion were obtained. Table 3 shows the result of the weight vectors associated with the criteria.

Criteria	W
C <sub>1</sub>	[ 0.1620,0.85,0.80 ]
C <sub>2</sub>	[0.2014,0.85,0.80]
C <sub>3</sub>	[0.1520,0.85,0.80]
C <sub>4</sub>	[0.1620,0.85,0.80]
C <sub>5</sub>	[0.3110,0.83,0.80]
C <sub>6</sub>	[0.1716,0.83,0.80]
C <sub>7</sub>	[0.1801,0.82,0.80]
C <sub>8</sub>	[0.1534,0.85,0.80 ]
C <sub>9</sub>	[0.1718,0.83,0.80]
C <sub>10</sub>	[0.1820,0.82,0.80]
C <sub>11</sub>	[0.1012,0.90,0.80]
C <sub>12</sub>	[0.1110,0.98,0.80 ]
C <sub>13</sub>	[0.1522,0.85,0.80]
C <sub>14</sub>	[0.1910,0.81,0.80]
C <sub>15</sub>	[0.1830,0.86,0.80]

**Table 3:** Neutrosophic vectors of weights associated with the evaluative criteria.

#### *Activity 3 aggregation and processing of information.*

From the data set obtained in the previous activities, the information is processed. The aggregation process is carried out from the set of neutrosophic vectors of associated weights of the depression criteria and the

preferences obtained from the diagnosis that represents an input parameter using equation 11. Table 4 presents the result of the values obtained during the aggregation process.

Criteria	Weights	Diagnosis	Aggregation
C <sub>1</sub>	[ 0.1620,0.85,0.80 ]	[1,0,0]	[0.0626, 0.85,0.90 ]
C <sub>2</sub>	[0.2014,0.85,0.80]	[0.70,0.25,0.30]	[0,0545,0.85,0.90]
C <sub>3</sub>	[0.1520,0.85,0.80]	[0.9, 0.1, 0.1]	[0,0528,0.85,0.90]
C <sub>4</sub>	[0.1620,0.85,0.80]	[1,0,0]	[0,0626,0.85,0.90]
C <sub>5</sub>	[0.3110,0.83,0.80]	[0.30,0.75,0.70]	[0,0360,0.85,0.90]
C <sub>6</sub>	[0.1716,0.83,0.80]	[0,1,1]	[0,1,1]
C <sub>7</sub>	[0.1801,0.82,0.80]	[0.9, 0.1, 0.1]	[0,0629,0.85,0.90]
C <sub>8</sub>	[0.1534,0.85,0.80 ]	[0.70,0.25,0.30]	[0,0415,0.85,0.90 ]
C <sub>9</sub>	[0.1718,0.83,0.80]	[1,0,0]	[0,0664,0.85,0.90]
C <sub>10</sub>	[0.1820,0.82,0.80]	[0.30,0.75,0.70]	[0,0211,0.85,0.90 ]
C <sub>11</sub>	[0.1012,0.90,0.80]	[0,1,1]	[0,1,1]
C <sub>12</sub>	[0.1110,0.98,0.80 ]	[0.9, 0.1, 0.1]	[0,0386,0.85,0.90]
C <sub>13</sub>	[0.1522,0.85,0.80]	[1,0,0]	[0,0587,0.85,0.90 ]
C <sub>14</sub>	[0.1910,0.81,0.80]	[0.30,0.75,0.70]	[0,0221,0.85,0.90]
C <sub>15</sub>	[0.1830,0.86,0.80]	[1,0,0]	[0,0707,0.85,0.90 ]
Evaluation			[0,6510,0.35,0.40]

**Table 4:** Result of the aggregation process.

From the result of the aggregation process, the evaluation referred to the proposed case study is obtained. An evaluation of the level of depression of a [0, 6510,0.35, 0.80] was obtained. To conclude the evaluation process, the result is interpreted according to the Hamilton scale as: Severe depression.

## Conclusions

This investigation proposed a neutrosophic method for the evaluation of depression. It based its operation using the Hamilton scale with neutrosophic numbers to quantify depressive disorder from the modeling of uncertainty. The method used the range to indicate the levels of severity of depression recommended by the American Psychiatric Association through neutrosophic numbers.

The proposed method was implemented for a case study on a patient who was hospitalized in the Internal Medicine area of the Latacunga General Hospital in Ecuador. With the case study the applicability of the method could be verified. The evaluation obtained allows classifying the degree of depression in patients, fulfilling the objective proposed for the present investigation.

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