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Application of neutrosophic cognitive maps in the jurisprudence of the National Court of Justice of Ecuador

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Abstract. This research analyzes the use of neutrosophic cognitive maps in the jurisprudential examination of divorce in the National Court of Justice of Ecuador. The suggested technique intends to simulate the links between legal reasons and the psychological and emotional ramifications of divorce, therefore enhancing judicial decision-making. Resolution No. 0071 - 2018 - 38420 is evaluated to determine its influence on the protection of individual rights, presenting an original viewpoint on family law. The results gathered from the study underline the necessity to examine both the legal reasons and the psychological and emotional ramifications of divorce when making court judgments in this area. The findings reveal the important importance of variables such as legal and psychological assistance, family dynamics, and domestic violence in the divorce process. Furthermore, the efficiency of the neutrosophic cognitive mapping approach was proved to model complex and diverse interactions in this context, thus giving a helpful tool to increase the quality and depth of research in legal studies connected to divorce.

Keywords: neutrosophic cognitive map, legal analysis, divorce, neutrosophic model of legal relationships.

1 Introduction

The jurisprudential examination of divorce in the Ecuadorian legal system is an important field of research in modern legal practice. In recent years, divorce has acquired increased importance in Ecuadorian culture, indicating substantial changes in family dynamics and cultural beliefs toward marriage and the breakup of marital partnerships. In this regard, research on information fusion approaches is becoming more relevant in a deep understanding of court cases connected to divorce. The capacity to combine diverse sources of data and information, such as legislation, judicial precedents and socioeconomic elements, becomes a vital ingredient to successfully handle the problems and complexity unique to jurisprudential analysis in this subject. Analyzing jurisprudence connected to divorce has become a difficult and comprehensive undertaking that demands novel and sophisticated analytical techniques. Information fusion approaches provide significant tools to handle this complexity by allowing the integration and coherent analysis of a broad variety of data and elements essential to judicial decision-making. Jurisprudential analysis entails reviewing and assessing a broad variety of legal material and evidence to achieve educated judicial judgments and decisions. However, the information supplied might be varied, fragmented, and frequently inconsistent, making it difficult for judges and attorneys to comprehend and administer the law.

In this sense, information fusion approaches give strong tools and strategies to efficiently combine and evaluate diverse sources of data and knowledge relevant to a specific legal issue. Information fusion enables data from multiple kinds and sources, such as legislation, legal precedents, expert testimony, and forensic evidence, to be merged to generate a fuller and more accurate picture of the issue at hand. By combining data logically and systematically, information fusion approaches may assist in eliminating ambiguity and uncertainty in jurisprudential analysis, so providing a firmer foundation for judicial decision-making [1].

Furthermore, information fusion approaches may also enable the detection of hidden patterns, trends, and linkages in data [2], which can help judges and attorneys better comprehend the nature and context of a certain legal issue. This may be particularly valuable in complicated, multiple instances, where understanding the interconnections between numerous aspects and variables might be vital to obtaining a fair and equitable verdict [3].

In this context, the implementation of methods such as Cognitive Maps appears as a viable way to enhance the comprehension and analysis of legal opinions linked to divorce. However, the use of cognitive maps to describe and simulate complex systems may lead to the introduction of ambiguity and indeterminacy [4]. This ambiguity may develop owing to the subjective character of the data and the difficulty in correctly defining causal links between various aspects of the system. [5]

Likewise, the intrinsic complexity of many phenomena examined in scientific and technical sectors may lead to uncertainty owing to the necessity to make conclusions based on partial or incomplete evidence [6]. In this setting, obtaining accuracy and perfect certainty may be problematic, leading to the need to create ways that can effectively manage and express ambiguity [7]. The complex interplay between various components that influence divorce situations, encompasses legal and jurisprudential concerns as well as emotional and social considerations [8, 9].

A potential method to remedy this dilemma is the introduction of fuzzy cognitive mapping (FCM). FCMs are an extension of classic cognitive maps that enable modeling the ambiguity and vagueness present in many real-world issues [10]. Unlike traditional cognitive maps, which describe causal links as binary (i.e., there is a connection between two items or there is not), FCMs enable the depiction of the strength and direction of interactions in a more flexible and graded [11]. This is performed by giving numerical values in the range [- 1, 1] to represent the strength of the causal relationship between the nodes in the map. Additionally, FCMs may manage uncertainty by enabling connection values to be imprecise or fuzzy, thereby representing the subjective or ambiguous nature of causal linkages in many complex systems. [12]

On the other hand, the introduction of Neutrosophic in the area of representation of complex systems gives an extra layer of depth and flexibility in the management of uncertainty and indeterminacy. Neutrosophic, a philosophical theory created by Romanian philosopher Florentin Smarandache in the 1990s, presents a more complete way of handling uncertainty that goes beyond typical fuzzy logic [12] . In the context of the representation of complex systems, Neutrosophic enables us to analyze not only the truth or falsity of a statement but also indeterminacy, that is, the inability to identify whether a proposition is true or untrue. [13, 14]. Neutrosophic presents a manner of describing the degree of indeterminacy or neutrosophic of a statement. This permits the underlying ambiguity of many real-world issues to be recorded more exactly and thoroughly than fuzzy logic. While fuzzy logic focuses on describing uncertainty via fuzzy sets and membership values, neutrosophic logic goes a step further by acknowledging the possibility that a statement might be true, false, or indeterminate [15].

In fuzzy cognitive maps, connections are essentially numerical, which restricts the depiction of non-linear interactions between events. However, Neutrosophic emerges as an alternative capable of managing ambiguous and inconsistent information, features that are not well handled by fuzzy sets and intuitive fuzzy sets [16]. Neutrosophic cognitive maps form an extension of fuzzy cognitive maps that contain indeterminacy in their conceptualization, providing a more exact and full depiction of reality. [17]. His study explores and analyzes the potential of Neutrosophic Cognitive Maps in the specific context of divorce jurisprudence in Ecuador. The research aims not only to examine the applicability and effectiveness of NCM to understand judicial decisions related to divorce but also to analyze the legal, social and human impact of these techniques on the interpretation and application of the law. By integrating quantitative and qualitative approaches, as well as jurisprudential and conceptual data, a comprehensive and enriching perspective is provided on the jurisprudential analysis of divorce and its implications for the protection of fundamental rights and the evolution of family law in Ecuador.

1. Related work

Definition 1 [18]. Let N = {(T, I, F): T, I, F $\in$[0 ,1]}C be a *neutrosophic evaluation set* . v: $\boldsymbol{P} \rightarrow N$is a mapping of a group of propositional formulas in N, that is, each sentence $p \in \boldsymbol{P}$is associated with a value in N, as stated in Equation 1, that is, p is T% true, I% indeterminate and F% false.

$$v(p) = (T, I, F) \quad (1)$$

Therefore, neutrosophic logic is an extension of fuzzy logic, rooted in the principles of neutrosophic according to.

Definition 2 . Let K be the ring of real numbers. The ring generated by $K \cup I$is called a neutrosophic ring whenever it encompasses the element of indeterminacy within it, where I satisfies $I^2 = I$, $I + I = 2I$, and generally $I + I + \ldots + I = nI$,. If $k \in K$., then $k * I = kI$, and $0I = 0$. The neutrosophic ring is symbolized by K(I), which is generated by $K \cup I$, i.e. $K(I) = \langle K \cup I \rangle$, where $\langle K \cup I \rangle$denotes the ring generated by K and I.

Definition 3 . A *neutrosophic matrix* is a matrix $A = \left[a_{ij}\right]_{ij}$ $i = 1, 2, \ldots, m$and $j = 1, 2, \ldots, n$; $m, n \geq 1$, so that each $a_{ij} \in K(I)$, where K(I) is a neutrosophic ring, see [19].

It is worth noting that an element of the matrix can take the form $a + bI$, where "a" and "b" are real numbers, while (I) represents the indeterminacy factor. The standard operations of neutrosophic matrices can be extended

from classical matrix operations. This representation allows us to capture the uncertain nature of some elements of the matrix, which can be crucial for modeling and understanding complex phenomena in various fields of study.

Manipulation and analysis of data that includes both certainty and uncertainty is allowed. This facilitates the application of matrix tools in situations where uncertainty plays an important role, thus expanding the scope and usefulness of matrices in various scientific and technological fields. For example.

$$\begin{pmatrix} -1 & \mathrm{I} & 5\mathrm{I} \\ \mathrm{I} & 4 & 7 \end{pmatrix}\begin{pmatrix} \mathrm{I} & 9\mathrm{I} & 6 \\ 0 & \mathrm{I} & 0 \\ -4 & 7 & 5 \end{pmatrix} = \begin{pmatrix} -21\mathrm{I} & 27\mathrm{I} & -6+25\mathrm{I} \\ -28+\mathrm{I} & 49+13\mathrm{I} & 35+6\mathrm{I} \end{pmatrix}$$

Furthermore, a neutrosophic graph is defined as a graph containing at least one edge or node characterized by indeterminacy, as shown in Figure 1. The neutrosophic adjacency matrix, an extension of the traditional adjacency matrix in graph theory, serves to represent the relationships between nodes. In this matrix, $a_{ij} = 0$it indicates that nodes i and j are not connected, $a_{ij} = 1$ means a connection between these nodes, and $a_{ij} = I$denotes an indeterminate connection state, where it is unknown whether a connection exists or not. In particular, fuzzy set theory lacks such distinctions and representations.

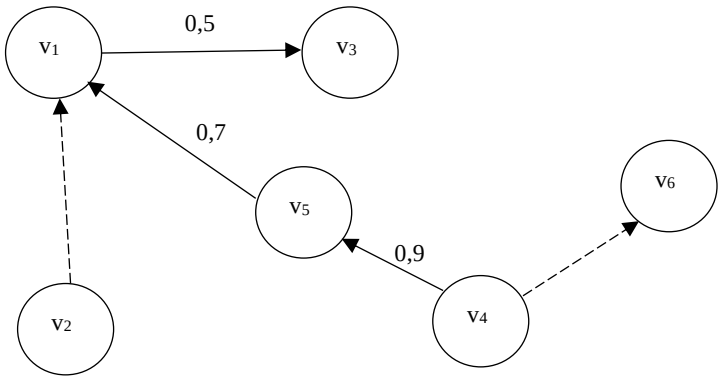

Figure 1. Neutrosophic graph

In contrast, when indeterminacy is incorporated into a cognitive map, the resulting map is called a neutrosophic cognitive map, which is particularly advantageous for representing causal knowledge. Its formal definition is provided in Definition 4.

Definition 4 [20]. A *Neutrosophic Cognitive Map* (NCM) is a directed neutrosophic graph with concepts such as policies and events, among others, as nodes and causalities or indeterminate as edges. It represents the causal relationship between concepts.

2. Material end Methods

As a first step, a Neutrosophic Cognitive Map (NCM) is created by obtaining expert information, which is then used to calculate centrality measures for static analysis.

The measures described below are used in the proposed model, they are based on the absolute values of the adjacency matrix[21].

- The degree is the sum of the row elements in the neutrosophic adjacency matrix. It reflects the strength of the salient relations of the variable.
  $od(v_i) = \sum_{i=1}^{n} c_{ij}$ (2)
- In degree is the sum of the elements of the column. It reflects the strength of the relationships that come out of the variable.
  $id(v_i) = \sum_{i=1}^{n} c_{ji}$ (3)
- The total centrality (total degree td (i)), is the sum of the entry degree and the exit degree of the variable.
  $td(v_i) = od(v_i) + id(v_i)$ (4)

The application of static analysis involves using the adjacency matrix considering the absolute values of the weights. In neutrosophic cognitive maps, as described in [22], static analysis is initially characterized by neutrosophic numbers in the form of $a + bI$, where I represent indeterminacy. This requires a deneutrosofization process, as suggested in, in which $I \in [0, 1]$,and is replaced by its maximum and minimum values.

Is used, calculated using Equation 5 as described in [23]. This calculation is beneficial to obtain a singular value, which helps identify the characteristics to prioritize based on the factors obtained in our case study.

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \quad (5)$$

So,

$$A \succ B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2} \quad (6)$$

3. Results and discussion

Resolution No. 0071 - 2018 - 38420 plays a crucial role in the Ecuadorian legal system by establishing a regulatory framework for divorce procedures, impacting both legal and emotional aspects of marital breakdowns. This research highlights the importance of this resolution in addressing various reasons for divorce, such as infidelity and unjustifiable desertion, while also considering the significant psychological effects on the spouses, including sadness, anxiety, and post-traumatic stress disorder. To thoroughly analyze these complexities, a Neutrosophic Cognitive Map (NCM) was developed, incorporating ten key variables that represent the legal and emotional dimensions of divorce. Expert input was used to assign neutrosophic values to the relationships between these variables, resulting in an adjacency matrix that provides a detailed mathematical foundation for understanding the intricate interrelationships involved in divorce. This approach offers a comprehensive perspective on the legal, emotional, familial, and societal factors at play, contributing to a more nuanced analysis of the divorce process.

Table 1. Selected critical factors to analyze during the study.

Coding	Factor	Description
F1	Legal causes of divorce	It is essential to understand the legal causes of divorce according to the current legal framework, as these establish the legal basis for the divorce process and can influence judicial decisions.
F2	Psychological and emotional impact	Assess the psychological and emotional impact of divorce on spouses and children, as these repercussions can affect the ability to make informed decisions and the well-being of the parties involved.
F3	Family dynamics	Assess the psychological and emotional impact of divorce on spouses and children, as these repercussions can affect the ability to make informed decisions and the well-being of the parties involved.
F4	Legal and Psychological Support	Consider the availability of legal and psychological support for the parties involved in the divorce process, as this may affect their ability to defend their rights and make informed decisions.
F5	Domestic violence	Identify and address cases of domestic violence, as these can have a significant impact on the divorce process and court decisions related to the safety and well-being of the parties involved.

Coding	Factor	Description
F6	Economic Aspects	Evaluate the financial aspects of divorce, including the division of marital assets and debts, as well as the determination of alimony and child support, as these aspects may influence court decisions related to the distribution of financial resources.
F7	Agreements and commitments	Consider the ability of the parties to reach mutual agreements and compromises regarding the divorce, as this can facilitate the judicial decision-making process and promote an amicable and equitable resolution of the conflict.
F8	Professional evaluations	Assess the need for professional evaluations, such as psychological evaluations and expert reports, to inform court decisions in divorce cases, as these evaluations can provide relevant information about the well-being and needs of the parties involved.
F9	Regulations and legal precedents	Consider relevant legal rules and precedents in divorce cases, as they can provide guidance on the interpretation of the law and the application of legal principles in specific situations.
F10	Minors' interests	Prioritize the interests and well-being of the children in the divorce process, as they must be considered a primary consideration in judicial decisions related to the custody, care, and support of children.

The NCM is developed through the capture and representation of relevant knowledge. The resulting adjacency matrix, based on the neutrosophic values assigned by the experts, is detailed in Table 2 as a key tool for the analysis and understanding of causal relationships within the context of the study.

Table 2. Adjacency matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	0	1	0.5	0	0	0.4	I	0.3	0	0
F2	I	0	I	0.2	0	0	0	0	0	0
F3	0.1	0	0	1	0	0	0	0	0	0
F4	0	0.8	0.7	0	0	0	0	0	0	I
F5	1	0.7	1	I	0	0	I	0	0	0
F6	0.6	0.1	1	I	0	0	0	0	0.2	0.8
F7	0	0.5	0	0.9	I	0	0	0.1	0	0
F8	0	0.5	0	0.9	I	0	0	0.1	0	0
F9	1	0	0	1	0	0	I	0.5	0	I
F10	0	0	1	I	0.5	0	0	0.2	1	0

Based on this approach, the centrality measures that have been calculated are presented below. These metrics provide a quantitative assessment of the relative importance of nodes within the context of the network, which is essential to understanding the dynamics and influence of different elements in the system studied.

Table 3: Calculated centrality measures

Factors	$od(v_i)$	$id(v_i)$	$td(v_i)$
F1	2.2+I	2.7+I	4.9+I
F2	0.2+2I	3.6	3.8+2I
F3	1.1	4.2+I	5.3+I
F4	1.5+I	4+3I	5.5+3I
F5	2.7+2I	0.5+2I	3.2+4I
F6	2.7+I	0.4	3.1+I
F7	1.5+I	0+3I	1.5+3I
F8	1.5+I	1.2	2.7+i
F9	2.5+2I	1.2	3.7+2I
F10	2.7+i	0.8+2I	3.5+2I

The static analysis in NCM initially returns neutrosophic values that include the indeterminacy variable. Therefore, it is necessary to apply a deneutrosification process, as suggested by Salmerón and Smarandache, where the parameter I belonging to the interval [0,1] is replaced by its corresponding maximum and minimum values. This procedure is essential to obtain clearer and more precise results that facilitate the interpretation of the relationships within the context of the analysis. See Table 4.

Table 4: Deneutrosophization

Factors	$td(v_i)$
F1	4.9+5.9I
F2	3.8+5.8I
F3	5.3+6.3I
F4	5.5+8.5I
F5	3.2+7.2I
F6	3.1+4.1I
F7	1.5+4.5I
F8	2.7+3.7I
F9	3.7+5.7I
F10	3.5+5.5I

Finally, equation (5) is used to calculate the corresponding values for comparison. This approach allows obtaining a quantitative measure that synthesizes the relevant information, thus providing a more complete and precise perspective of the aspects considered in the analysis.

Table 5: Median of extreme values

Factors	$td(v_i)$
Legal causes of divorce	5.25
Psychological and emotional impact	4.8
Family dynamics	5.8
Legal and Psychological Support	7
Domestic violence	5.2
Economic Aspects	3.6
Agreements and commitments	3
Professional evaluations	3.2
Regulations and legal precedents	4.7
Minors' interests	4.5

The research highlights the importance of "Legal and Psychological Support" as the most influential factor in the legal study of divorce, with the highest centrality value in the neutrosophic map, followed by "Family Dynamics" and "Domestic Violence." These findings emphasize the need to prioritize legal and psychological assistance, family dynamics, and domestic violence prevention in divorce proceedings. While factors like "Economic Aspects" and "Agreements and Commitments" are significant, they are less central. The study demonstrates the effectiveness of neutrosophic cognitive maps in capturing the complexity and ambiguity of divorce-related legal and emotional issues, providing a comprehensive framework for analysis. Resolution No. 0071 - 2018 - 38420 serves as a crucial reference in addressing these elements within Ecuador's legal framework, offering a solid foundation for informed decision-making and policy development that supports justice and well-being in family law.

Conclusion

The current research offered a full investigation of the legal grounds and the psychological, emotional, and social ramifications of divorce, utilizing the approach of neutrosophic cognitive maps as the major instrument. Through this strategy, it was feasible to simulate the complicated interactions between aspects associated with divorce, giving a useful tool to enhance judicial decision-making in this sector. The insights collected from the research underline the need to address both the legal reasons and the psychological and emotional ramifications of divorce when making judicial judgments in this area.

The findings reveal the important importance of variables such as legal and psychological assistance, family dynamics, and domestic violence in the divorce process. Likewise, the efficacy of the neutrosophic cognitive mapping approach was proven to model complicated and multidimensional interactions in this context, giving a beneficial tool to increase the quality and depth of research in legal studies connected to divorce.

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