Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 46 No. 3
March 2025

Analysis Of Neutrosophic Cognitive Map and Fuzzy Cognitive Map

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Abstract
In this paper, we suggest employing a Neutrosophic fuzzy environment to represent Cognitive Maps. Neutrosophic Cognitive Maps (NCM) are defined and their creation explained in this work. Moreover, a comparison is made using Fuzzy Cognitive Maps (FCM). Here, we've examined the elements that are the main contributors to mobile phone hacking using the NCM method. A numerical example is provided to illustrate the applicability and soundness of the suggested approach.
Keywords: NCMs, FCMs, indeterminate, relation, node.

1. Introduction

The concept of neutrosophic logic is becoming increasingly important for solving real-world issues in fields like commerce, law, IT, and medical, among others. Fuzzy theory is alone responsible for membership grade. But it fails when the problem has relations between nodes i.e. indeterminate. The idea of indeterminateness with fuzzy, which forms the basis of neutrosophic logic, is actually present in the problem.

A fuzzy cognitive map application to variables influencing slurry rheology has been provided by Banini (1). The cognitive maps have been compiled by Bougon (2) into a unified dynamic theory of organizations and strategy. An attempt has been made by Brannback et al. (3) to track and focus on decision making in cognitive maps. Repertory grids and cognitive mapping have been introduced by Brown (4) for use in qualitative survey research. Neural nets have been applied to fuzzy cognitive maps by Caudill (5). Chen (6) has examined the NPN logics cognitive map-based decision analysis. Model inferences, fuzzy cognitive maps, and causal structure have all been briefly stated by Craiger (7). According to Diamond et al. (8), referential neuronal architectures in fuzzy cognitive systems are examined. Sophia Porchelvi and Vanitha (9) have used FCM to analyze a symptom disease model. Eden (10) has been discussed about the nature of cognitive maps. Kosko (11) has given the fuzzy cognitive maps with illustrative example. Using FCM models, Amal and Lillies Thivagar (12) examined the issues faced by poor rural students enrolled in Chennai city colleges. Smarandache (13) has given the definitions derived from Neutrosophic set. For situation analysis, Aasim Zafar (14) introduced the Neutrosophic Cognitive Maps. The differences between Neutrosophic and adaptive fuzzy cognitive maps have been analyzed and explored by Banerjee et al. (15). To tackle the critical path problem, Sudha et al.[16] used triangular intuitionistic fuzzy numbers.

The composition of the paper is organised as follows:

- The preliminary matters are covered in Section 2.
- In section 3, the difference between NCMs and FCMs is covered.
- Section 4 offers the problem-solving process along with an example for clarity.
- Finally, the conclusion is found in section 5.

2. Preliminaries

Definition 2.1: With ideas like policies, events, etc. as nodes and causalities or the unknown as edges, a Neutrosophic Cognitive Map (NCM) is a directed network that is neutrosophically oriented. It illustrates the connection of causation between concepts.

Definition 2.2: Simple NCMs are those that have an edge weight in the range of {-1, 0, 1, I}.

Definition 2.3: Assume that an NCM consists of the nodes $H_1, H_2, \dots, H_n$. Let the neutrosophic matrix $N_m(D)$ be defined as $N_m(D) = (d_{ij})$ where d_{ij} is the weight of the directed edge H_iH_j, where $d_{ij} \in \{0, 1, -1, I\}$. $N_m(D)$ is called the neutrosophic adjacency matrix of the NCM.

Definition 2.4: Let NCM consists of the nodes $H_1, H_2, \ldots, H_n$. Let A = $\{a_1, a_2, \ldots, a_n\}$ where $a_i \in \{0, 1, I\}$. A is known as the neutrosophic vector of the instantaneous state. and it denotes the off – on – indeterminate state position of the node at an instant

a_i = 0 if a_i is off (no effect)

a_i = 1 if a_i is on (has effect)

a_i = I if a_i is indeterminate (effect cannot be determined)

for i = 1,2,…,n.

3. Comparison of Neutrosophic and Fuzzy Cognitive Maps

- The existence of causal relation between any two concepts were measured by FCMs and if doesn't have any relation then 0 is used to represent it.
- NCMs provide a representation of the indeterminacy of relationships between two conceptions in addition to measuring the causal relationship between any two concepts.
- All unsupervised data doesn't need to apply NCMs. There should be relation between at least two concepts H_i and H_j are indeterminate to apply NCMs.
- By substituting I with 0 in the connection matrix, any NCM can become an FCM.
- NCMs have the following entries: 0, 1, 1, and I.

4. Single Valued PNF De-Fuzzification Functions

4.1 Problem Procedure

- Construct a problem
- Analysis the feature of a defined problem
- Feature relationship is formulated based on degree of truth, indeterminacy and falsehood.
- Based on the relationship graph, Neutrosophic Cognitive Maps are formed.
- Then adjacency matrix is formulated.
- Best features which contribute for a problem is identified.

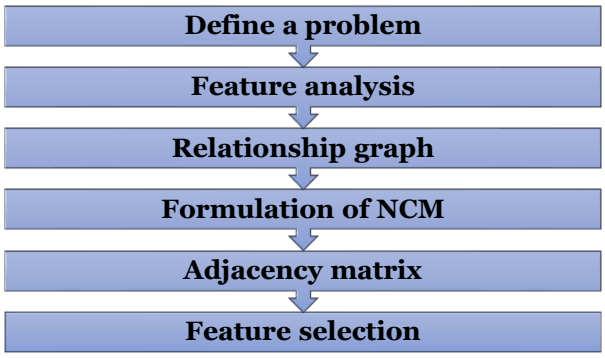

Figure 1: Flow chart of NCM model

4.2 Illustrative Example

In this section, we analysed the hacking of mobile by unknown persons. It's the major problem facing by all over the world. There are several reasons one could hack someone else's cell phone. To examine the elements that are the main source of mobile hacking. We employ the NCM methodology. Considered to be conceptual nodes are the ones listed below.

H_1	•Professional rivalry
H_2	•Jealousy
H_3	•Curiosity
H_4	•Fun
H_5	•Sexual satisfaction
H_6	•Breach of trust
H_7	•Needs
H_8	•To Satisfy Ego

Figure 2: Flow chart for the conceptual nodes.

The directed graph and the neutrosophic directed graph are given in figure 3 and 4 by an investigator.

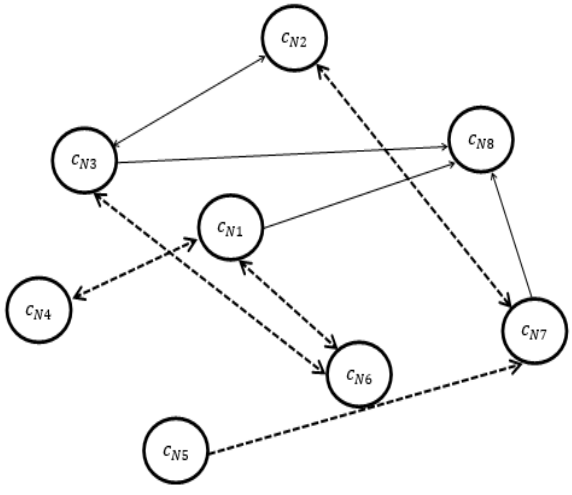

Figure 3: Neutrosophic Directed Graph

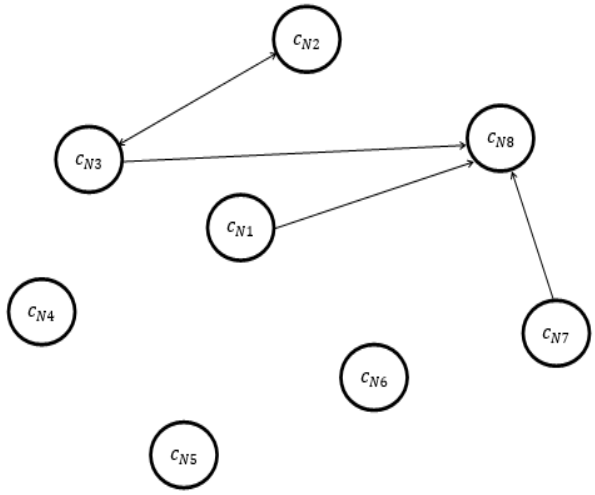

Figure 4: Directed Graph

The corresponding neutrosophic connection matrix N(D) is given below

$$N(D) = \begin{bmatrix} 0 & 0 & 0 & I & 0 & I & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & I & 0 \\ 0 & 1 & 0 & 0 & 0 & I & 0 & 1 \\ I & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ I & 0 & I & 0 & 0 & 0 & 0 & 0 \\ 0 & I & 0 & 0 & I & 0 & 0 & 1 \\ -1 & 0 & -1 & 0 & 0 & 0 & -1 & 0 \end{bmatrix}$$

Suppose, Let's obtain the current state vector instantaneously. c_{N1}= (0 0 0 0 0 0 1 0), "Needs" node is in the on state.

Hence, the effect of c_{N1} of N(D) is as follows

$$c_{N1}N(D) = (0\ \mathrm{I}\ 0\ 0\ \mathrm{I}\ 0\ 0\ 1) \rightarrow (0\ I\ 0\ 0\ I\ 0\ 1\ 1) = c_{N2}$$

$$c_{N2}N(D) = (-1\ \mathrm{I}\ \mathrm{I} - 1\ 0\ \mathrm{I}\ 0\ I^2 - 1\ 1) \rightarrow (0\ I\ 0\ 0\ I\ 0\ 1\ 1) = c_{N3} = c_{N2}$$

Hence, while the node "Needs" is in the on state; "Professional Rivalry", "Curiosity", "Fun" and "Breach of Trust" are in the off state. "Jealousy" and "Sexual Satisfaction" are an indeterminate. "To satisfy ego" is in the on state.

When the Indeterminates (I's) are taken out, the outcome will be in FCM. Here N(D) is used as a usual FCM matrix then the effect F1= (0 0 0 0 0 0 1 0) in the on state when passed through the system we get F = (0 0 0 0 0 0 1 1) which implies "To Satisfy Ego" is in on state and other states are in the off state.

H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8
OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
0	0	0	0	0	0	1	0

EFFCTS

H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8
OFF	IND	OFF	OFF	IND	OFF	ON	ON
0	I	0	0	I	0	1	1

REMOVAL OF I

H_1	H_3	H_4	H_6	H_7	H_8
OFF	OFF	OFF	OFF	ON	ON
0	0	0	0	1	1

Suppose, let us take the instantaneous state vector c_{N1}= (1 0 0 0 0 0 0 0), "Professional Rivalry" node is in the on state. Hence, the effect of c_{N1} of N(D) is as follows

$$c_{N1}N(D) = (0\ 0\ 0\ \mathrm{I}\ 0\ \mathrm{I}\ 0\ 1) \rightarrow (1\ 0\ 0\ I\ 0\ I\ 0\ 1) = c_{N2}$$

$$c_{N2}N(D) = (0\ I\ 0\ 0\ I\ 0\ 1\ 1) = c_{N3} = c_{N2}$$

Hence, while the node "Professional Rivalry" is in the on state; "Fun" and "Breach of Trust" are an indeterminate. "To Satisfy Ego" is in the on state and other states are in the off state.

H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8
ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF
1	0	0	0	0	0	0	0

EFFCTS

H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8

ON	OFF	OFF	IND	OFF	IND	OFF	ON
1	0	0	I	0	I	0	1

Suppose, let us take the instantaneous state vector c_{N1}= (0 1 0 0 0 0 0 0), "Jealousy" node is in the on state. Hence, the effect of c_1 of N(D) is as follows

$$c_{N1}N(D) = (0\,0\,1\,0\,0\,0\,\mathrm{I}\,0) \rightarrow (0\,1\,1\,0\,0\,0\,I\,0) = c_{N2}$$

$$c_{N2}N(D) = (0\,1\,1\,0\,I\,I\,I\,1) = c_{N3}$$

$$c_{N3}N(D) = (0\,1\,I\,0\,I\,I\,0\,1) = c_{N4}$$

$$c_{N4}N(D) = (0\,1\,I\,0\,0\,I\,0\,I) = c_{N5}$$

$$c_{N5}N(D) = (0\,1\,1\,0\,0\,I\,0\,I) = c_{N6}$$

$$c_{N6}N(D) = (0\,1\,1\,0\,0\,I\,0\,1) = c_{N7}$$

$$c_{N7}N(D) = (0\,1\,I\,0\,0\,I\,0\,I) = c_{N8}$$

$$c_{N8}N(D) = (0\,1\,I\,0\,0\,I\,0\,I) = c_{N9} = c_{N8}$$

Hence, while the node "Jealousy" is in the on state; "Curiosity" and "Breach of Trust" are an indeterminate. "To Satisfy Ego" is in the on state and other states are in the off state.

The reader is expected to evaluate with other coordinates and compare with fuzzy cognitive map.

5. Conclusion

In this paper, the NCM model we compared with a FCM model. All unsupervised data doesn't need to apply NCMs. Only data which necessary to have relations between the two nodes to be an indeterminate can modelled by NCMs. If not, FCMs itself will do the best job.

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