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Static analysis in neutrosophic cognitive maps

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Abstract.
Static analysis is developed in neutrosophic cognitive maps to define the importance of each node based on centrality measures. In this paper a framework static analysis of neutrosophic cognitive maps is presented. The analysis results are given in the form of neutrosophic numbers. Variables are classified and a de-neutrosophication process gives an interval number for centrality. Finally the nodes are ordered. An illustrative example based on critical success factor of customer relationship management (CRM) systems implementation is provided to show the applicability of the proposal. The paper ends with conclusion and future research directions.

Keywords: mental model, neutrosophic Logic, neutrosophic cognitive maps, static analysis

1 Introduction

Neutrosophic Cognitive Maps (NCM) [1] was introduced as a generalization of Fuzzy Cognitive Maps (FCM) [2]. A special feature of NCMs is their ability to handle indeterminacy in relations between two concepts, which is denoted by 'I'. NCM are capable of giving results with greater sensitivity than the FCM . It also allows a larger liberty for expert to express not just the positive, negative and absence of relations but also the indeterminacy of causal relations.
Static analysis is develop to define the importance of each node based on centrality measures [3].In this paper, we propose the use of an innovative technique for static analysis in neutrosophic cognitive maps.
The outline of this paper is as follows: Section 2 is dedicated to neutrosophic cognitve maps and static anlysis. The proposed framework is presented in Section 3. An illustrative example is discussed in Section 4. The paper closes with concluding remarks, and discussion of future work in Section 5.

2 Neutrosophic cognitive maps

Neutrosophic logic is a generalization of fuzzy logic based on neutrosophy [4]. A neutrosophic matrix is a matrix where the elements $a = (a_{ij})$ have been replaced by elements in $\langle R \cup I \rangle$, where $\langle R \cup I \rangle$ is the neutrosophic integer ring [5]. A neutrosophic graph is a graph in which at least one edge or one vertex is neutrosophic [6]. If indeterminacy is introduced in cognitive mapping it is called Neutrosophic Cognitive Map (NCM) [7].
NCM are based on neutrosophic logic to represent uncertainty and indeterminacy in cognitive maps [4]. A NCM is a directed graph in which at least one edge is an indeterminacy denoted by dotted lines [8].
In [9] a static analysis of mental model in the form of NCM is presented. The result of the static analysis result is in the form of neutrosophic numbers (a+bI, where I = indeterminacy) [10]. Finally, a de-neutrosophication process as proposed by Salmeron and Smarandache [11] is applied to give the final ranking value In this paper this model is extended and detailed to deal with nodes classification.

3 Proposed Framework

The following steps will be used to establish a framework static analysis in NCM (Fig. 1).

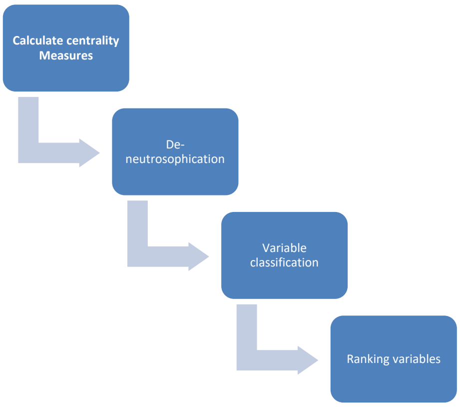

Figura 1Proposed framework

- **Calculate centrality Measures**

The following measures are calculated [12] with absolute values of the NCM adjacency matrix [13]:

1. Outdegree $od(v_i)$ is the row sum of absolute values of a variable in the neutrosophic adjacency matrix. It shows the cumulative strengths of connections (a_{ij}) exiting the variable.

2. Indegree $id(v_i)$ is the column sum of absolute values of a variable. It shows the cumulative strength of variables entering the variable.

3. The centrality (total degree $td(v_i)$), of a variable is the summation of its indegree (in-arrows) and outdegree (out-arrows)

$$td(v_i)= od(v_i)+ id(v_i) \quad (1)$$

- Variable classification

Variables are classified according to the following rules:

a) Transmitter variables have a positive or indeterminacy outdegree, $od(v_i)$ and zero indegree, $id(v_i)$.

b) Receiver variables have a positive indegree or indeterminacy, $id(v_i)$, and zero outdegree, $od(v_i)$.

c) Ordinary variables have both a non-zero indegree and outdegree. Ordinary variables can be more or less receiver or transmitter variables, based on the ratio of their indegrees and outdegrees.

- Ranking variables

A de-neutrosophication process gives an interval number for centrality. Finally the nodes are ordered.

The contribution of a variable in a cognitive map can be understood by calculating its degree centrality, which shows how connected the variable is to other variables and what the cumulative strength of these connections are. The median of the extreme values [14] is used :

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

Then

$$A > B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2} \quad (3)$$

Finally a ranking of variables is given.

4 Illustrative example

In this section, we present an illustrative example in order to show the applicability of the proposed framework. We selected a critical sucess factor(CSF) of custumer relationship managemente (CRM)sytems implementation [15] for modeling interdependencies in the form of NCM [16]. Building a NCM allows dealing with indeterminacy, making easy the elicitation of interdependencies CSF [17].

Node	Description
A	Market orientation
B	Flexibility
C	Managers support
D	Organizational changes inclusion
F	Users' commitment and presence.
G	Time

TABLE I. NCM NODES

The NCM is developed integrating knowledge. The NCM with weighs is represented in tale II.

0	0	0.4	0	0	0
I	0	0	0	0	-0.7
0	0	0	0	I	-0.5
0	I	0	0	0	0
0	0	0	0	0	-0.7
0	0	0.6	0	0	0

TABLE II. ADJACENCY MATRIX

The centralities measures are presented.

A	0.4
B	0.7+I
C	0.5+I
D	I
E	0.7
F	0.6

TABLE III. OUTDEGREE

A	I
B	I
C	1
D	0
E	I
F	1.4

TABLE III. INDEGREE

A	0.4+I
B	0.7+2I
C	1.5+I
D	I
E	0.7+I
F	2.0

TABLE III. TOTAL DEGREE

Later nodes are clasified. In this case node D: "Organizational changes inclusion" is Transmitter, the rest of the nodes are Ordinary.

The next step is the de-neutrosophication process as proposes by Salmeron and Smarandache [11]. I ∈[0,1] is repalaced by both maximum and minimum values.

A	[0.4, 1.4]
B	[0.7, 2.7]
C	[1.5, 2.5]
D	[0, 1]
E	[0.7, 1.7]
F	2.0

TABLE III. DE-NEUTRIFICATION

Finally we work with the median of the extreme values [14] (3) .

A	0,9
B	1,7
C	2.0
D	0.5
E	1.2
F	2.0

TABLE III. MEDIAN OF THE EXTREME VALUES

The ranking is as follows:

$$C \sim F \succ B \succ E \succ A \succ D$$

"Managers support" and "Users commitment and presence "are the more important factors in his model.

5 Conclusions

In this paper, we propose a new framework for processing uncertainty and indeterminacy in static analysis of NCM. A case study was presented showing the applicability of the proposal. The analysis results are given in the form of neutrosophic numbers. Variables are classified and a de-neutrosophication process gives an interval number for centrality allowing the ranking of the variables.

Future research will focus on conducting further real life experiments and the development of a tool to automate the process. The calculation of other metrics is another area of future research.

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