Neutrosophic Sets and Systems, Vol. 42, 2021
University of New Mexico

Analysis of Covid-19 via Fuzzy Cognitive Maps and Neutrosophic Cognitive Maps

Sujatha Ramalingam[1,*], Kuppuswami Govindan[2] and Said Broumi[3]

[1*]Department of Mathematics; Sri Sivasubramaniya Nadar College of Engineering; Chennai; India. E.mail:sujathar@ssn.edu.in
[2]Department of Mathematics; Sri Venkateswaraa College of Technology; Chennai; India. E.mail:gkuppuswamiji@gmail.com
[3]Laboratory of Information Processing; Faculty of Science Ben M'Sik, University Hassan II; Casablanca; Morocco. E.mail:broumisaid78@gmail.com

*****Correspondence: sujathar@ssn.edu.in

Abstract: As far world history is concerned, human being faced many problems like world war, terrorist attack, bomb blasters, natural disasters and so on. But all these problems are visible and were able to come across in few months or years. Nowadays situation is entirely different from the past world history, because all the worlds are fighting with an invisible enemy called Novel Corono virus disease (Covid-19). If we compare with other diseases like Swine flu, Ebola virus this disease is very infectious and the death rate is also severe all around the world. The covid-19 pandemic has affected everyone both physically, mentally and changed our life style. Almost all the countries are suffering from this disease and the countries are struggling to control from this epidemic. Researchers in all the disciplines are exploring ways to control this disease and trying to find a vaccine. So this is a correct situation to mathematically analyze the disease covid-19 like symptoms, spreading way and precaution method using Fuzzy cognitive maps and Neutrosophic cognitive maps. Both the methods work on expert's opinion. Since medical field involves uncertainty and indeterminacy, we have chosen fuzzy set and neutrosophic sets for our study.

Keywords: Fuzzy cognitive maps, Neutrosophic cognitive maps, Covid-19, Symptoms, Prediction.

1. Introduction

Each and every human in the universe is looking back to the ever seen killing disease covid-19. All the peoples are living with fear because of severity in spreading and increasing in death rate. This virus was first detected in Wuhan, one of the cities in China in late December 2019 and rapidly

spread in more than 100 countries within few months. It has been declared as a Pandemic by WHO in March 2020. As a precaution, all the countries have declared lock down, working class have been working from home, people are advised to maintain social distance in the public place, continuous hand washing using sanitizer after returning from public place, compulsory wearing mask, avoiding unnecessary outing, online classes for students and so on. But still control of this disease is a challenge. So far there is no prescribed medicine to cure this disease. Various researches is actively going on to study the nature of the virus and to find a vaccine.

On the other hand, all the countries are experiencing an economic downturn because of continuous lockdown. Small merchants, farmers, building contractors and migrant workers are having a hard time. After hundred years, the world is facing a very big disaster because of disease. So we have to put more effort to save from this destruction. As a part of this we have to first create awareness about this disease to the society. To create awareness in the sense this study helps to analysis this disease using fuzzy technique and an extension of fuzzy, called neutrosophic theory. The question is whether this fuzzy techniques is suitable for our study?. The answer is the crisp value 'yes'. Since, for any kind of prediction of (new deadly) diseases or to identify, in the beginning stage there is no crisp answer in the medical field. i.e we cannot say 'yes' or 'no' for the disease during the first examination of the patient. The physician is always in the fuzzy state, because of the complexity of the human body, common or similar symptoms for many disease. We can also say it is indeterminant (extension of fuzzy) to identify the disease for the physician. The doctor wants many parameters like patients medical history, laboratory results, physical examination of the patient body and so on to diagnose the disease. So in comparison to the crisp set, fuzzy set gives gradual membership and also some concepts in the medical term are indeterminant, so it is suitable to use Fuzzy Cognitive Maps (FCMs) and Neutrosophic Cognitive Maps (NCMs) for our study.

This work is constructed as follows: The motivation and background is given in section-2. Necessary basic concepts needed for this study is discussed in section-3. In section-4 analysis of Covid-19 using FCMs and NCMs is presented and the conclusion of the proposed work is given in section-4.

2. Motivation and Background

Decision making in the medical field involves uncertainty and indeterminancy and this motivate us to apply FCMs and NCMs in this work. In the literature FCMs and NCMs are widely applied in many fields, including medical. We will review few here. To study the uncertainty, the concept of fuzzy set was introduced by Zadeh [40]. In 1965, Bart Kosko [20] introduced FCMs as a

combination of fuzzy logic and cognitive maps. To analysis the indeterminacy Florentin Smarandache and Vasantha Kandasamy [35] proposed the new technique called NCMs as an extension of FCMS. As a new approach, for diagnosing process of meniscus injury Antigoni et al.[5] used evolutionary type of FCMs called Dynamic Fuzzy Cognitive Knowledge Networks. In another study to identify pulmonary disease Evangelia et al. [14] applied time dependent FCMs. Gaurav[16] combined two techniques namely NCMs and Genetic algorithm for medical diagnosis.

Neutrosophic environment is more suitable to handle indeterminate situation in medical diagnosis. So, we chosen NCMs for the proposed study. Neutrosophic sets are applied for the analysis of medical imaging. For instance, Abdel-Basset et al.[1] used Plithogenic set as a generalization of neutrosophic set for the identification of Covid-19 using primary symptoms and CT scans. Neutrosophic sets are widely applied in various fields for decision making [2, 25, 26, 27].

For decision making in medical field, Albert William et al.[3] applied FCMs to identify the symptoms of breast cancer. For diagnosing Rheumatoid Arthristis (RAs) Chitra et al. [11] applied Gene selection and Dynamic Neutrosophic Cognitive Map with Bat Algorithm (DNCM-BA). Deepika et al. [12] used neutrosophic sets for medical image identification. For medical diagnosis research, Mumtuz Ali et al. [24] applied algebraic neutrosophic measures, Chao Zhang et al. [8] used single valued neutrosophic probabilistic rough multisets, Masooma et al.[22] proposed m-polar neutrosophic topology and shawkat [34] introduces n-valued refined neutrosophic soft sets. Nowadays most of the people in the globe are affected by diabetes. To identify risk factors caused by diabetes AshrafulAlam [6] used FCMs and Muhammad Aslam et al. [23] applied neutrosophic statistic. Nivetha [29] used decagonal linguistic neutrosophic FCMs to analysis the risk factors of life style disease. In another study, Vasantha Kandasamy et al. [35] applied FCMs by taking concepts as symptoms and disease. For medical decision support, FCMs are applied in [39,40].

FCM architecture is proposed for obstetrics by Chrysostomos [10]. In another application Amirkani at el. [4] Studied taxonomy, methods and applications of FCMs in medicine. For tracking urinary infection Douli et al. [13] applied FCMs using 25 clinical and 13 diagnosis concepts. As a new application Neil et al. [28] introduces FCMs in nursing research. Combining with non-linear Hebbian learning algorithm FCMs can be used for prediction of stroke by Khodadadi et al. [19]. In another study, Papageorgiou et al. [31] applied the concept of FCMs to analysis the risk factor caused by familial breast cancer. To analysis the symptoms of migraine Merlyn Margaret [21] used Induced FCMs.

For medical diagnosis Innocent et al. [18] applied various fuzzy methods like clustering, fuzzy set aggregation and type-2 fuzzy sets. For the treatment of fuzzy disease, fuzzy prototypes used by

Ruben et al. [32]. In another study for decision making in medical diagnosis Palash et al.[30] used an advanced distance measures on intuitionistic fuzzy sets. To diagnose the rare disease , applications in medicine using fuzzy logic and fuzzy logic inference is given in [9,15,36,38]. Type-2 fuzzy sets is used to diagnosis the common disease by Besime et al.[7]. Sundaresan et al. [37] proposed fuzzy membership matrix to identify the different treatment stages in medical diagnosis. Hamidi et al. [17] used the application of Neutro-BCK algebra for the study in covid-19 among country wise.

From this review of literature FCMs and NCMs are widely applied in many medical field and this is another motivation for the current work.

3. Basic things needed for the study

3.1 Definition

A fuzzy weighted directed graph involving concepts like policies, events etc as nodes and the link connecting them represent the casual relationship between the concepts is a FCM. If the nodes of the FCM are fuzzy sets then the nodes are fuzzy nodes. NCM is differ from FCM only when the relation between the concepts is indeterminant and it is denoted by $'I'$.

3.2 Definition

An FCMs is said to be simple if the edge weights are taken from the set$\{-\mathbf{1}, \mathbf{0}, \mathbf{1}\}$ and for simple NCMs it is from $\{-\mathbf{1}, \mathbf{0}, \mathbf{1}, \boldsymbol{I}\}$.

3.3Definition

Let $(\boldsymbol{C_1}, \boldsymbol{C_2}, \dots, \boldsymbol{C_n})$ be the concepts of the FCMs. Using this concept the directed graph is drawn with edge weight $\boldsymbol{e_{ij}} \in \{-\mathbf{1}, \mathbf{0}, \mathbf{1}\}$. Here $\boldsymbol{e_{ij}} = \mathbf{1}$ means positive casuality between the concepts. In otherwayincrease(or decrease) to the corresponding increase(or decrease) in the other and vice-versa for $\boldsymbol{e_{ij}} = -\mathbf{1}$. If the concepts has no relation indicates$\boldsymbol{e_{ij}} = \mathbf{0}$. Define the adjacency matrix $\boldsymbol{E} = (\boldsymbol{e_{ij}})$ where $\boldsymbol{e_{ij}}$ is the weight of the corresponding edge $'\boldsymbol{C_i}\boldsymbol{C_j}'$. This adjacency matrix also known as the connection matrix of the FCMs. Similarly for NCMs using the same concepts of FCMs we can draw the directed graph with edge weight $\boldsymbol{e_{ij}} \in \{-\mathbf{1}, \mathbf{0}, \mathbf{1}, \boldsymbol{I}\}$. Here the adjacency matrix is denoted by $\boldsymbol{N}(\boldsymbol{E}) = (\boldsymbol{e_{ij}})$. If $\boldsymbol{e_{ij}} = '\boldsymbol{I}'$means the relation between the concepts is indeterminate and it is denoted by dotted line in the directed graph. The adjacency matrix $\boldsymbol{N}(\boldsymbol{E})$ is called the neutrosophic adjacency matrix of the NCMs.

3.4 Definition

Let $(\boldsymbol{C_1}, \boldsymbol{C_2}, \dots, \boldsymbol{C_n})$ be the concepts of the FCMs(NCMs).The instantaneous state vector $\boldsymbol{A} = (\boldsymbol{a_1}, \boldsymbol{a_2}, \dots, \boldsymbol{a_n})$ where $\boldsymbol{a_i} \in \{\boldsymbol{0}, \boldsymbol{1}, \boldsymbol{I}\}$ represent the ON-OFF-INDETERMINATE position of the node. If $\boldsymbol{a_i} = \boldsymbol{0}$ means OFF, $\boldsymbol{a_i} = \boldsymbol{1}$ means ON and $\boldsymbol{a_i} = \boldsymbol{I}$ means indeterminate for $\boldsymbol{i} = \boldsymbol{1}, \boldsymbol{2}, \boldsymbol{3}, . . , \boldsymbol{n}$.

3.5 Definition

If the edges form a directed cycle then FCMs (NCMs) is said to be cyclic, otherwise acyclic. An FCMs (NCMs) with cycles is said to have a feedback. If the FCMs (NCMs) has a feedback, then the FCMs (NCMs) is called a dynamical system.

3.6 Definition

Let $\boldsymbol{C_1C_2}, \boldsymbol{C_2C_3}, \dots \boldsymbol{C_mC_n}$(for $\boldsymbol{m} \neq \boldsymbol{n}$) be a cycle. We will say that the dynamical system goes round and round, if the concept $'\boldsymbol{C_i}'$ is ON and if the causality passes through the edges of the cycle and again causes $'\boldsymbol{C_i}'$. This is true for any $'\boldsymbol{C_i'}$ for $\boldsymbol{i} = \boldsymbol{1}, \boldsymbol{2}, \boldsymbol{3}, \dots, \boldsymbol{n}$. The hidden pattern is the equilibrium state of the dynamical system. If the equilibrium state is a unique state vector, then it is fixed point or limit cycle. This is applicable for both FCMs and NCMs.

3.1.1 The pseudo code for the proposed method

1. Collect the concepts or nodes for the covid-19 problem.

2. Construct the directed graph, neutrosophic directed graph and the corresponding adjacency matrix $\boldsymbol{E}$ and $\boldsymbol{N}(\boldsymbol{E})$through experts (Doctors) opinion.

3. Take any concept $\boldsymbol{C_i}(\boldsymbol{i} = \boldsymbol{1}, \boldsymbol{2}, \boldsymbol{3}, \dots, \boldsymbol{n})$ in ON state.

4. To find the hidden pattern of $\boldsymbol{C_i}(\boldsymbol{i} = \boldsymbol{1}, \boldsymbol{2}, \boldsymbol{3}, \dots, \boldsymbol{n})$, the instaneous input vector $\boldsymbol{A_1} = (\boldsymbol{a_1}, \boldsymbol{a_2}, \dots, \boldsymbol{a_n})$ is defined by assigning $\boldsymbol{a_1} = \boldsymbol{1}$for $\boldsymbol{i} = \boldsymbol{1}$ and other $\boldsymbol{a_i's} = \boldsymbol{0}$ if the concept $\boldsymbol{C_1}$ is switch ON and similarly for other concepts.

5. Multiply $\boldsymbol{A_1}$ with $\boldsymbol{E}$ and $\boldsymbol{N}(\boldsymbol{E})$, we get another row vector namely $(\boldsymbol{b_1}, \boldsymbol{b_2}, \dots, \boldsymbol{b_n})$. Here the new operation is introduced called threshold operation and it is denoted by the symbol $'\rightarrow'$. This operation is done by putting $\boldsymbol{b_i}$=1 to the corresponding ON state concept $\boldsymbol{C_i}(\boldsymbol{i} = \boldsymbol{1}, \boldsymbol{2}, \boldsymbol{3}, \dots, \boldsymbol{n})$ and 0 for remaining $\boldsymbol{b_i}$. After this updation we will get another vector called $\boldsymbol{A_2}$.

6. Multiply $\boldsymbol{A_2}$ with $\boldsymbol{E}$ and $\boldsymbol{N(E)}$ and repeat the same procedure to reach the fixed point. Similarly we follow the same procedure to find the hidden pattern and indeterminacy for all the concepts of the disease covid-19. Both FCMs and NCMs will function mainly on expert's opinion. To avoid biasness, it is necessary to consider more than one experts.

4. Reasons and Secure from Novel Coronavirus (covid-19) using FCMs and NCMs

This work concentrates on reasons, transmission mode and precaution method of the coronavirus (Covid-19) using FCMs and NCMs. The different concepts considered for this analysis is identified and is given in the Table-1.

Table-1 Concepts considered for the proposed work

Concepts	Explanation
$\boldsymbol{C_1}$	Fever with cold, cough and difficulty in breathing
$\boldsymbol{C_2}$	No symptoms
$\boldsymbol{C_3}$	Maintaining social distance, wearing mask and continuous hand wash.
$\boldsymbol{C_4}$	High blood pressure, diabetes, tuberculosis, cancer patient, elder people who are violating $\boldsymbol{C_3}$.
$\boldsymbol{C_5}$	Travelling history
$\boldsymbol{C_6}$	Possibility of Covid-19.
$\boldsymbol{C_7}$	High risk factor for getting Covid-19.
$\boldsymbol{C_8}$	Prevention measures from Covid-19.

We are taken the above eight main concepts for this study. First we work on FCMs .In Figure 1 we give the directed graph and the connection square matrix $\boldsymbol{E}$ according to first experts opinion.

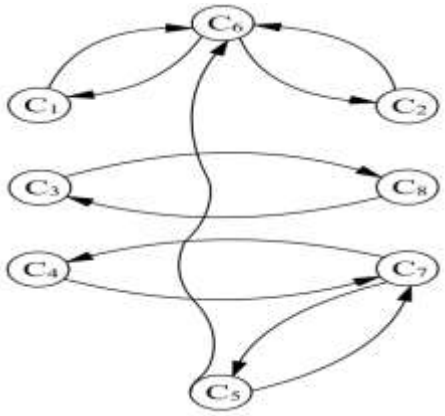

Figure-1 Directed graph given by the first expert for the analysis of covid-19.

The connection matrix $\boldsymbol{E}$ is given by

$$E = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \end{array} \begin{array}{c} \begin{array}{cccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array} \tag{1}$$

Case-1 First we consider the concept C_6 i.e the possibility of covid-19. Take $A_1 = (0,0,0,0,0,1,0,0)$ the effect of A_1 on E is given by

$$\begin{aligned} A_1E &= (1,1,0,0,0,0,0,0) \\ &\rightarrow (1,1,0,0,0,1,0,0) \\ &= A_2. \end{aligned} \tag{2}$$

$$\begin{aligned} A_2E &= (1,1,0,0,0,2,0,0) \\ &\rightarrow (1,1,0,0,0,1,0,0) \\ &= A_3. \end{aligned} \tag{3}$$

Here $A_2 = A_3$.

Case-2 Next we consider the concept C_7 i.e High risk for getting covid-19. Take $A_1 = (0,0,0,0,0,1,0,0)$ the effect of A_1 on E is given by

$$A_1E = (0,0,0,1,1,0,0,0)$$

$$\rightarrow (0,0,0,1,1,0,1,0)$$

$$= A_2. \quad (4)$$

$$A_2E = (0,0,0,1,1,1,2,0)$$

$$\rightarrow (0,0,0,1,1,1,1,0)$$

$$= A_3. \quad (5)$$

$$A_3E = (1,1,0,1,1,1,2,0)$$

$$\rightarrow (1,1,0,1,1,1,1,0)$$

$$= A_4. \quad (6)$$

$$A_4E = (1,1,0,1,1,3,2,0)$$

$$\rightarrow (1,1,0,1,1,1,1,0)$$

$$= A_5. \quad (7)$$

Here $A_4 = A_5$.

Case-3 Now we consider the concept C_3 i.e Maintaining social distance,wearing mask and continuous hand wash i.e Take $A_1 = (0,0,1,0,0,0,0,0)$ the effect of A_1 on E is given by

$$A_1E = (0,0,0,0,0,0,0,1)$$

$$\rightarrow (0,0,1,0,0,0,0,1)$$

$$= A_2. \quad (8)$$

$$A_2E = (0,0,1,0,0,0,0,1)$$

$$\rightarrow (0,0,1,0,0,0,0,1)$$

$$= A_{3.} \quad (9)$$

Here $A_2 = A_3$.

Case-4 Finally we consider the concept C_8.i.e the prevention method from covid-19. Take $A_1 = (0,0,0,0,0,0,0,1)$ the effect of A_1 on E is given by

$$A_1E = (0,0,1,0,0,0,0,0)$$

$$\rightarrow (0,0,1,0,0,0,0,1)$$

$$=A_2 \quad (10)$$

$$A_2E = (0,0,1,0,0,0,0,1)$$

$$\rightarrow (0,0,1,0,0,0,0,1)$$

$$=A_3 \tag{11}$$

$$\text{Here } A_2 = A_3$$

Now the first expert is allow to give the answers concerning the indeterminacy of the concepts. The corresponding neutrosophic graph is given in Figure-2.

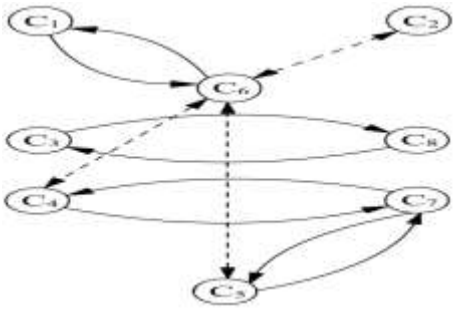

Figure-2 Neutrosophic directed graph given by the first expert for the analysis of covid-19.

The neutrosophic adjacency matrix $N(\boldsymbol{E})$ is given by

$$N(E) = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \end{array} \begin{array}{c} \begin{array}{cccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & I & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & I & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & I & 1 & 0 \\ 1 & I & 0 & I & I & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array} \tag{12}$$

Case-1First we consider the concept C_6 i.e the possibility of covid-19. Take $A_1 = (0,0,0,0,0,1,0,0)$ the effect of A_1 on E is given by

$$A_1N(E) = (1, I, 0, I, I, 0,0,0)$$

$$\rightarrow (1, I, 0, I, I, 1,0,0)$$

$$=A_2 \tag{13}$$

$$\begin{aligned} A_2N(E) &= (1, I, 0, I, I, 1 + 3I^2, 2I, 0) \\ &\rightarrow (1, I, 0, I, I, 1, 2I, 0). \\ &= A_3. \end{aligned} \tag{14}$$

$$\begin{aligned} A_3N(E) &= (1, I, 0, 3I, 2I, 1 + 3I^2, 2I, 0) \\ &\rightarrow (1, I, 0, I, I, 1, 2I, 0). \\ &= A_4. \end{aligned} \tag{15}$$

Here $A_3 = A_4$.

Next we construct the FCMs based on the second expert with the same set of attributes. we give the directed graph in Figure-3 and the connection square matrix $\mathbf{E}$ according to second experts opinion.

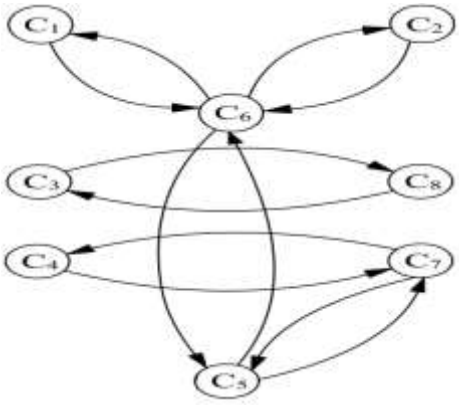

Figure-3 Directed graph given by the second expert for the analysis of covid-19.

The corresponding connection matrix $\boldsymbol{E}$ is given by

$$E = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \end{array} \begin{array}{c} \begin{array}{cccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array} \tag{16}$$

Case-1 we consider the concept C_6 i.e the possibility of covid-19. Take $A_1 = (0,0,0,0,0,1,0,0)$ the effect of A_1 on E is given by

$$A_1E = (1,1,0,0,1,0,0,0)$$

$$\rightarrow (1,1,0,0,1,1,0,0)$$

$$= A_2 \quad (17)$$

$$A_2E = (1,1,0,0,1,3,1,0)$$

$$\rightarrow (1,1,0,0,1,1,1,0)$$

$$= A_3. \quad (18)$$

$$A_3E = (1,1,0,1,2,3,1,0)$$

$$\rightarrow (1,1,0,1,1,1,1,0)$$

$$= A_4. \quad (19)$$

$$A_4E = (1,1,0,1,2,3,2,0)$$

$$\rightarrow (1,1,0,1,1,1,1,0)$$

$$= A_5. \quad (20)$$

Here $A_4 = A_5$.

Now the second expert is allow to give the options concerning the indeterminacy of the concepts. The corresponding neutrosophic graph is given in Figure-4.

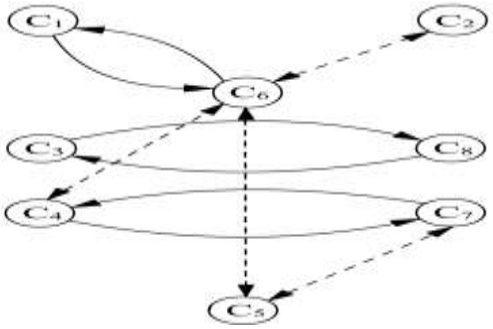

Figure-4 Neutrosophic directed graph given by the second expert for the analysis of covid-19.

The neutrosophic adjacency matrix $N(\boldsymbol{E})$ is given by

$$C_1 \quad C_2 \quad C_3 \quad C_4 \quad C_5 \quad C_6 \quad C_7 \quad C_8$$

$$N(E_1)=\begin{array}{c}C_1\\C_2\\C_3\\C_4\\C_5\\C_6\\C_7\\C_8\end{array}\begin{bmatrix}0&0&0&0&0&1&0&0\\0&0&0&0&0&I&0&0\\0&0&0&0&0&0&0&1\\0&0&0&0&0&I&1&0\\0&0&0&0&0&I&1&0\\1&I&0&I&I&0&0&0\\0&0&0&1&I&0&0&0\\0&0&1&0&0&0&0&0\end{bmatrix} \tag{21}$$

Case-1 Again we consider the concept C_6 i.e the possibility of covid-19. Take $A_1 = (0,0,0,0,0,1,0,0)$ the effect of A_1 on E is given by

$$\begin{aligned} A_1N(E) &= (1, I, 0, I, I, 0,0,0) \\ &\rightarrow (1, I, 0, I, I, 1,0,0) \\ &= \mathrm{A}_2 \end{aligned} \tag{22}$$

$$\begin{aligned} \mathrm{A}_2N(E) &= (1, I, 0,2I, I, 1,2I, 0) \\ &\rightarrow (1, I, 0,2I, I, 1,2I, 0). \\ &= A_3. \end{aligned} \tag{23}$$

$$\begin{aligned} A_3N(E) &= (1, I, 0,3I, 3I, 1,3I, 0) \\ &\rightarrow (1, I, 0,3I, 3I, 1,3I, 0) \\ &= A_4. \end{aligned} \tag{24}$$

Here $A_3 = A_4$.

5. Conclusion

FCMs and NCMs play a very important role in medical field because it involves uncertainty and indeterminacy. This study uses both the techniques for the analysis of covid-19 and we reached many important solutions. First, the results for the various attributes for this covid-19 based on FCMs is discussed.

According to first expert from case-1, the possibility of covid-19 mainly because of fever with cold, cough and difficulty in breathing and no symptoms. From case-2, persons having fever

with cold, cough and difficulty in breathing, without any symptoms, persons having disease mentioned in C_4 violating the precaution methods, travelling from countries to countries are all have to get possibility of getting and high risk of getting this disease. Maintaining social distance, wearing mask and continuous hand washing are the main precaution method and vice-versa for this disease from case-3 and case-4. From the second expert is concern, except the concepts C_3 and C_8 all are main reasons for the possibilities of this disease. Next, we see the indeterminant factor regarding this disease using NCMs.

As far NCMs is concern we are getting the same fixed points for both the experts. Persons having no symptoms, high blood pressure, diabetes, tuberculosis, cancer patients, older people who are not following any precaution method mentioned in C_3,travelling history persons are indeterminant factors for the physician to decide for the possibility and the high risk of getting of this covid-19. The results of this study is suitably matches the current world situation of this disease and we have to strictly follow the precautions mentioned in C_3 to prevent from this invisible disease. The proposed study mathematically analyze the disease using fuzzy and neutrosophic techniques, and it is very useful to all to know the root cause of the epidemic as well as the procedures to be followed to protect from this disease. In future this research can be extended using various fuzzy techniques.

Acknowledgments: The authors thank Sri Sivasubramaniya Nadar College of Engineering and Sri Venkateswaraa College of Technology Management for their support.

Conflicts of Interest: The authors declare no conflict of interest.

References

[1] Abdel-Basset,M.; Mohamed,R.; Elhoseny,M. A model for the effective COVID-19 identification in uncertainty environment using primary symptoms and CT scans. *Health Informatics Journal*, **2020**, pp 1-18.

[2] Abdel-Basset,M.; Nabeeh,N.A.; El-Ghareeb,H.A.; Abelfetouh,A. Utilizing Neutrosophic Theory to Solve Transition Difficulties in IoT-based Enterprises. *Enterprise Information Systems*, **2019**, 14, pp 1-21.

[3] Albert William,M.; Victor Devadoss.A.; Janet Sheeba.A. A Study on the Symptoms of Breast Cancer using Fuzzy Cognitive Maps. *International Journal of Engineering Research & Technology*, **2012**, 1, pp 1-4.

[4] Amirkani,A.; Papageorgiou,E.I.; Mohseni,A.; Mosavi,M.R. A Review of Fuzzy Cognitive Maps in Medicine: Taxonomy, Methods, and Applications. *Computer Methods and Programs in Biomedicine*, **2017**, 142, pp 129-145.

[5] Antigoni.P.Anninou.; Peter,P.Groumpos.; Panagiotis Poulios.; Ioannis.Gkliatis. A New Approach of Dynamic Fuzzy Cognitive Knowledge Networks in Modelling Diagnosing Process of Meniscus Injury. *International Federation of Automatic Control* (IFAC papers online), **2017**, 50-1, pp 5861-5866.

[6] Ashraful Alam,Md. Fuzzy Cognitive Maps Approach to Identify Risk Factors of Diabetes. *Journal of Physical Sciences,* **2017**,22, pp13-21.

[7] Besime,E.; Abiyev,R.H. Diagnosis of Common Diseases Using Type-2 Fuzzy System. *ICMLSC 2019: Proceedings of the 3rd International Conference on Machine Learning and Soft Computing*, **2019**, pp 239–243.

[8] Chao,Z.; Deyu,L.; Said Broumi and ArunKumar,S. Medical Diagnosis based on Single Valued Neutrosophic Probabilistic Rough Multisets over Two Universes. *Symmetry*, **2018**, 10(6), pp 1-16.

[9] Choudhury,B.S. ;Dhara,P.S.; Saha,P. An application of fuzzy logic on importing medicines.*International Journal of Healthcare Management*, **2019**, pp 1-7.

[10] Chrysostomos,D.S.; Voula,C.G. Fuzzy Cognitive Maps Structure for Medical Decision Support Systems. *Studies in Fuzziness and Soft Computing*, **2008**, pp 1-5.

[11] Chitra,B.; Nedunchelian,R. Gene selection and dynamic neutrosophic cognitive map with bat algorithm (DNCM-BA) for diagnose of rheumatoid arthritis (RAs). *International Journal of Engineering & Technology*,**2018**, 7, pp 242-250.

[12] Deepika,K. ; Savita,G.; Sukhwinder, S. Applications of Neutrosophic Sets in Medical Image Denoising and Segmentation. *New Trends in Neutrosophic Theory and Applications*, **2016**, pp *257-275.*

[13] Douali,N.; Papageorgiou,E.I.; Roo, J.D.; Cools,H.; Jaulent,M.C. Clinical Decision Support System based on Fuzzy Cognitive Maps. *Journal of Computer Science & Systems Biology*, **2015**, 8(1), pp 112-120.

[14] Evangelia,B.; Chrysostomos,D.; George,M.; Voula,C,G. Time Dependent Fuzzy Cognitive Maps for Medical Diagnosis.*Artificial Intelligence: Methods and Applications*, **2014**, 8445, pp 544-554.

[15] Greeda,J.; Mageswari,A,; Nithya.R.A. Study on Fuzzy Logic and its Applications in Medicine. *International Journal of Pure and Applied Mathematics*, **2018**, 119(16), pp 1515-1525.

[16] Gaurav.; Megha Kumar.; Kanika,B.; Swati,A. Hybrid Model for Medical Diagnosis using Neutrosophic Cognitive Maps with Genetic Algorithms. *IEEE International Conference on Fuzzy Systems*(FUZZ-IEEE), **2015**, pp 1-7.

[17] Hamidi,M.; Smarandache.F. Neutro-BCK-Algebra. *International journal of Neutrosophic Science,* **2020,** 8(2), pp 110-117.

[18] Innocent,P.R.; John,R.I.; Garibald,G.M. Fuzzy Methods for Medical Diagnosis. *Applied Artificial Intelligence,* **2005**, 19, pp 69-98.

[19] Khodadadi,M., ; Shayanfar,H. ; Maghooli,K. ; Hooshang Mazinan,A. Prediction of Stroke Probability Occurrence Based on Fuzzy Cognitive Maps. AUTOMATIKA, **2019**, 4, pp 385-392.

[20] Kosko, B. Fuzzy Cognitive Maps. *International Journal of Man Machine studies*, **1986**, 24, pp 65–75.

[21] Merlyn Margaret,H.; Lilly Merline,W.A. Study on the Symptoms of Migraine using Induced Fuzzy Cognitive Maps. AIP Conference Proceedings, **2019**, 2112, pp 1-5.

[22] Masooma,R.H.; Muhammad,R.; Smarandache.F. m-Polar Neutrosophic Topology with Applications to Multi-criteria Decision-Making in Medical Diagnosis and Clustering Analysis. *International Journal of Fuzzy Systems*, **2020**, 22(1), pp 273-292.

[23] Muhammad,A.; Osama H. A.; Rehan,K. New Diagnosis Test under the Neutrosophic Statistics: An Application to Diabetic Patients. *BioMed Research International*, **2020**, 7, pp 1-7**.**

[24] Mumtaz ,A. ; Nguyen,V.M. ; Le, H.S. A Neutrosophic Recommender System for Medical Diagnosis Based on Algebraic Neutrosophic Measures. *Applied Soft Computing*, **2018**, 71,pp 1054-1071.

[25] Nabeeh,N.A.; Abdel-Basset,M.; Soliman,G. A model for evaluating credit rating and its impact on sustainability performance, *Journal of Cleaner Production*, **2021**, 280, pp 1-16.

[26] Nabeeh,N.A.; Smarandache,F.; Abdel-Basset,M.; El-Ghareeb,H.A.; Abelfetouh,A. An Integrated Approach and its Application to Personal Selection: A New Trend in Brain Processing and Analysis. *IEEE Access*. **2019,** 7, pp 29734-29744.

[27] Nabeeh,N.A.; Abdel-Basset,M.; El-Ghareeb,H.A.; Abelfetouh,A. Neutrosophic Multi-Criteria Decision Making Approach for IoT-Based Entreprises. *IEEE Access*, **2019**,7, pp 59559-59574.

[28] Neil, A.; Hilah,S. Fuzzy cognitive mapping: An Old Tool with New Uses in Nursing Research. Journal of Advanced Nursing, **2019**, 75(12), pp 1-8.

[29] Nivetha,M.;Aleeswari,A. ;Lilly Merline,W.Risk Factors of Lifestyle Diseases – Analysis by Decagonal Linguistic Neutrosophic Fuzzy Cognitive Map, *Materials Today: Proceedings*, **2020**, 24(3), pp 1939-1943.

[30] Palash,D.;Soumendra, G.Fuzzy Decision Making in Medical Diagnosis Using an Advanced Distance Measure on Intuitionistic Fuzzy Sets. *The Open Cybernetics & Systemics Journal,* **2018,** 12, pp 136-149.

[31] Papageorgiou,E.I.;Jayashree,S.; Akila,K.; Nikolaos,P.A. Risk Management Model for Familial Breast Cancer: A New Application using Fuzzy Cognitive Map method**.** *Computer methods and programs in biomedicine***, 2015,** 122(2), pp 1-13**.**

[32] Ruben,R.C.;Olivas,J.A. ;Romero,F.P.;Francisco,A.G.;Jesus,S.G.An Application of Fuzzy Prototypes to theDiagnosis and Treatment of Fuzzy Diseases. *International Journal of Intelligent Systems,* **2016**, pp 1-17.

[33] Shaista,H.; Muhammad,A. Medical Decision Support Systems Based on Fuzzy Cognitive Maps. *International Journal of Biomathematics*, **2019**, 12, pp 1-34.

[34] Shawkat,A.; Ayman,A.H. n-Valued Refined Neutrosophic Soft Sets and their Applications in Decision Making Problems and Medical Diagnosis. *Journal of Artificial Intelligence and Soft Computing Research***, 2018**, 8(1), pp 79-86.

[35] Smarandache, F.; Vasantha kandasamy W.B, "Fuzzy Cognitive Maps and Neutrosophic Cognitive Maps", Xiquan, Phoenix (2003).

[36] Sunny,T.; JatinderSingh,B. Medical Applications on Fuzzy Logic Inference System: A Review. International *Journal of Advanced Networking and Applications*, **2019**, 10(4), pp 3944-3950**.**

[37] Sundaresan,T.; Sheeja,G. ;Govindarajan,A. Different Treatment Stages in Medical Diagnosis using Fuzzy Membership Matrix. *IOP Conference. Series: Journal of Physics*, **2018**, 1000, pp 1-7**.**

[38] Tatiana,K.; Maka,K.; Karaman,P. Fuzzy Logic in Diagnostics of Rare Diseases. *Fuzziness and Medicine,* STUDFUZZ, **2013**, 302, pp. 379–399.

[39] Voula ,C.G.; Chrysostomos,D.S. Fuzzy Cognitive Maps for Medical Decision Support – A Paradigm from Obstetrics. *32nd Annual International Conference of the IEEE EMBS Buenos Aires*, Argentina, **2010**, pp 1174-1177.

[40] Zadeh ,L.A. Fuzzy Sets. *Information and Control*, **2011**, 8, pp139-146.

Received: Jan. 13, 2021. Accepted: April 11, 2021.