A Comparative Study of Fuzzy Cognitive Maps and Neutrosophic Cognitive Maps on Covid Variants

Regan Murugesan[1], Yamini Parthiban[2], R. Narmada Devi[3],

Kala Raja Mohan[4], Sathish Kumar Kumaravel[5],

[1,2,3,4,5]Department of Mathematics,

Vel Tech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology, Chennai, India.

E-mail: [1]mreganprof@gmail.com, [2]yaminiparthiban.msc@gmail.com, [3]narmadadevi23@gmail.com,

[4]kalamohan24@yahoo.co.in, [5]k.sathi89@gmail.com,

*Correspondence: Authour (narmadadevi23@gmail.com)

Abstract: The pandemic situation created by COVID'19 is ridiculous. It has made even the blood relations hide themselves from the infected person. The whole world was stunned by this situation. This is because of the uncertainty in the way in which this disease is spread. As an advancement of this disease, a few other variants like delta, omicron etc. also got spread. It is essential to find a solution to this situation . The variants Omicron and Delta are taken into consideration here. Though both the vibrant colours look alike, the symptoms and prevention methods changes for each of these vibrants. This work aims to make a study of the parameters responsible for these variants. As a result of this study, the parameters involved in the spread of these diseases are identified, and the prevention parameters are concluded. The major benefit of this comparatively study is to identify the parameters that are inconclusive, applying the concepts of fuzzy cognitive maps and neutrosophic cognitive maps is applied to bring out the result.

1 Introduction

A new viral infection, COVID-19 (Coronavirus Disease 2019), emerged in early 2020 and attracted widespread attention. The virus spread around the world at a very high speed, and many studies have been carried out. Examining different epidemic patterns of COVID-19 based on official data.

Nowadays, the development of the Corona virus forms a lot of variants, such as beta, gamma, delta, and omicron, etc.,. In the Corona variants, especially the Delta variant causes, the more deaths among the population which have different symptoms when compared with the initial form of Corona. Recently, the Corona variant, Omicron spreads all over the world and has a different symptoms, prevention methods etc.,. In the medical field, the experts have a different opinions on the diseases with respect to prevention, symptoms, causes etc., even though the vaccinated people are getting affected, which leads to fear among the population.

The applications of FCM and NCM in the medical field are with respect to the knowledge base, and data base of patient, diagnosis which is to recognise symptoms and signs, the other method of diagnosing gallstones

is through ultrasound and radiation, knowledge acquisition and to find the the possibility of problems with indeterminate cases in which fuzzy logic plays an important role. In that it played a great role in the invention of the Doctor Moon.

Al-Subhi et al. have suggested a decision-making model in project management. In this process, FCM and NCM technique in bringing out the decision on effective implementation of projects, Bertolini, M. has used a FCM algorithm in finding the important factors that affects human reliability. A food-processing An industrial plants have been considered for this decision-making algorithm. Jantzen, J. et al. dedicated their work in the process industry. Fuzzy controllers have been applied in identifying the predictive control in the cement industry. Kalaichelvi. A. and Gomathy, L. have studied the problems faced by girl students who got married during the period of study using NCM. The study is based on the responses received from the graduate students of Coimbatore city.

-Khatua, D. et al. have presented fuzzy dynamical system-based granular differentiability in identifying an optimal control model for COVID-19. The fuzzy SEIAHRD model described by them proposes a disease control procedure for the disease specified. Martin, N. et al. have developed a methodology that helps to risk factors of Lifestyle Diseases. Decagonal Linguistic Neutrosophic Fuzzy cognitive map is applied in the analysis. Mary. M.F.J. et al. aim to identify the factors affecting the quality of the training of elementary education teachers in Tamil Nadu. Various factors like techno-pedagogic skills, the students' academic skills, teaching competencies, etc. are analyzed applying FCM and NCM. Montazemi, A.R. et al. utilised cognitive maps in the design and development of intelligent information systems. Causal mapping is used to investigate the cognition of decision-makers. Papageorgiou. E.I. et al introduced the concept reduction approach in decision making and management. FCM is applied in modelling solid waste management systems.

Pramanik, S et al made an analysis of the problems faced by the construction workers with the help of NCM. The analysis has been performed with the list of issues given by the workers of West Bengal. Raich.V.V., et al performed their study by pointing out the qualities of an effective teacher. Fuzzy relational maps the concept of the Teacher Quality Index has been put in a place to bring the results. Ramalingam, S. et al. made an mathematical analysis of COVID-19 based on the symptoms of the disease. FCM and NCM concepts are applied in finding out the conclusion. Schuh. C introduced fuzzy set theory in medical sciences on three concrete medical fuzzy applications. Stylios, C.D. et al. discussed knowledge sharing, modelling methodology, knowledge-based reasoning with the help of FCM. Their study has provided effective results in identifying the knowledge-based methodologies. Vasantha, et al. in performed a search in in order to overcome the hindrance posed by complicated nature of psychological or social data. The search is based on imaginative play in children, applying the concepts of NCM. Visalakshi, V. et al. performed a survey on women to identify their entrepreneurial mindset. Combined Effective Time Dependent Data Matrix, and Average Time Dependent Data Matrix concepts applied in extracting the suggestions on pointing out the factors that affect entrepreneurship. William, M.A. et al. analysed the risk factors on women getting affected by breast cancer, making use of the NCM and FCM.

Kumaravel,S.K. et al. and Murugesan, R. et al. discussed the effectiveness of online classes considering the opinion of faculty and students during the COVID pandemic. The fuzzy models, like combined effective time-dependent matrix (CETD), average time-dependent data matrix (ATD), and refined time-dependent data matrix (RTD) are applied in their work using the fuzzy matrix theory. Devi, R.N. and Muthumari, G. have expressed a view on the properties of distance measure in P-F graph and applied Neutrosophic overset in real life scenarios for a decision making problem. They also introduced neutrosophic over topologized dominance graphs in their work. Recently, they have discussed various types of energy in Nover Top Graphs.

In this paper, a comparative study is made on different parameters related to omicron and delta such as travelling history, Prevention measures for the disease, Blood pressure, Cancer patient, Loss of taste and smell,

Brain fog, etc. The parameters are analysed by taking any one as ON state by the concept of FCM. Simultaneously, those parameters are analysed through the NCM, as like FCM, by considering the same state as ON state. The aim of this paper is to analyze the COVID through comparison between FCM and NCM among the COVID variant parameters.

2   Parameters of omicron & delta virus

In order to analyse the parameters of The Omicron and Delta viruses, data were collected from the medical experts. Based on their opinions the following factors were identified and collected .

- C_1-Travelling history

- C_2-Prevention measures for the disease

- C_3-Maintain social distance, Wearing mask and Continuous hand wash

- C_4-Fever, cough and difficulty breathing

- C_5-Brain fog

- C_6- the possibility of delta variant

- C_7-Blood pressure, Cancer patient, diabetes, older age who violate precautions

- C_8-High risk of getting omicron and delta variant

- C_9- the possibility of omicron

- C_{10}-Loss of taste and smell

- C_{11}-No symptoms

- C_{12}-Spread more easily

3   Fuzzy cognitive map

The experts opinions were collected and based on their opinion, they formed a graph by mapping between the parameters. In which, based on the fuzzy cognitive map concept, weight age was assigned by the casual relation between the nodes. i.e., the edge weight was assigned as 1 (positive causality between the nodes), if the relationship between the nodes had a majority of respondents, but at the same time the majority of respondents was uncertain then it is denoted by 0. The corresponding fuzzy cognitive maps for the parameters are given below in figure 1
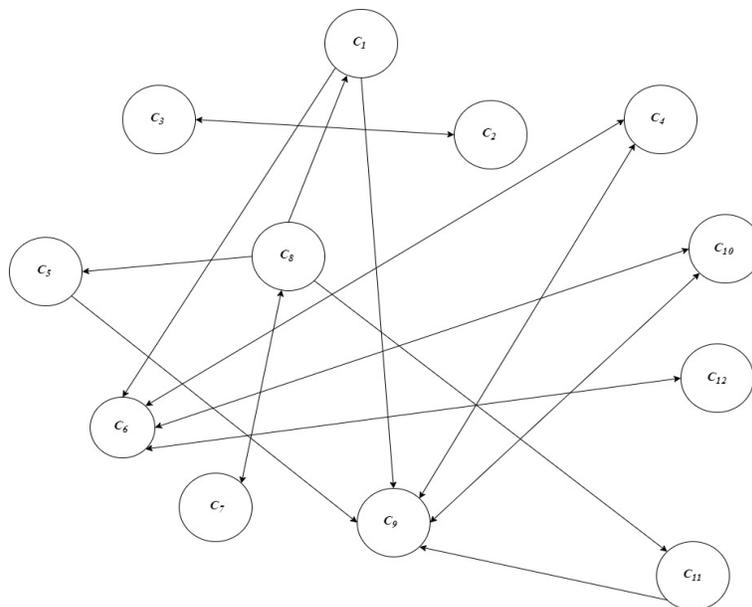
Figure 1: Fuzzy Cognitive Maps on COVID VARIANTS

3.1   Matrix Representation of FCM

The matrix representation of the fuzzy cognitive map is designed based on the connectives between the nodes, which are the possibilities among the parameters. The entries of the matrix are noted as either 0 or 1. The number 0 denoted an unconnected node, and 1 represented the connection between the nodes. The adjacent matrix of figure 1 is given below.

$$
\mathbf{E} = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \\ C_{10} \\ C_{11} \\ C_{12} \end{array}
\begin{array}{c}
\begin{array}{cccccccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 & C_9 & C_{10} & C_{11} & C_{12} \end{array} \\
\left(\begin{array}{cccccccccccc}
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0
\end{array} \right)
\end{array}
$$

3.2   Iteration Process of FCM

Case-1: the possibility of delta variant - ON state

Let us consider the C_6 parameter as ON state. i.e., the possibility of delta variant for the iteration process.

A Comparative Study of Fuzzy Cognitive Maps and Neutrosophic Cognitive Maps on Covid Variants

The initial matrix required for the process is taken as below, which has the entries as 0 for the OFF state and 1 for ON state.

$$A_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$A_1 * E = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \end{bmatrix}$$
$$= A_2$$
$$A_2 * E = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 3 & 0 & 0 & 2 & 1 & 0 & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}$$
$$= A_3$$
$$A_3 * E = \begin{bmatrix} 0 & 0 & 0 & 2 & 0 & 3 & 0 & 0 & 2 & 2 & 0 & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}$$
$$= A_4$$
$$\therefore A_3 = A_4$$

The last two iterations' values are obtained as the same, so that the iteration process may stop and it shows that when the C_6 parameter is taken as ON state then the parameters C_4, C_9, C_{10}, and C_{12} are obtained as ON state. It concludes that the parameters fever, cough, difficulty breathing, loss of taste, and smell are the risk factor for the parameter C_6, i.e., the the possibility of a delta variant as well as for omicron variant. In general, delta variant's spread more easily and faster. Its symptoms are loss of smell and taste, and which might cause omicron.

Case-2:High risk of getting omicron and delta variant- ON state

Let us take the C_8 parameter as ON state. i.e., high risk of getting Omicron and Delta for the iteration process. The initial matrix required for the process is taken as below, which have the entries as 0 for the OFF state and 1 for ON state.

$$A_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$A_1 * E = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \end{bmatrix}$$
$$= A_2$$
$$A_2 * E = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \end{bmatrix}$$
$$= A_3$$
$$A_3 * E = \begin{bmatrix} 1 & 0 & 0 & 2 & 1 & 1 & 1 & 1 & 1 & 2 & 1 & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$
$$= A_4$$

$$A_4 * E = \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 4 & 0 & 0 & 3 & 2 & 1 & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$
$$= A_5$$
$$\therefore A_4 = A_5$$

The last two iteration values are obtained as the same, so that the iteration process may stop, and it shows that when the C_8 parameter is taken as ON state then the parameters C_2 and C_3 are obtained as ON states. It concludes that the parameters Loss of taste and smell, No symptoms, spreads more easily are the factors related to the parameter C_8. Also, the persons who are violating C_2 and C_3 parameters, then it causes a the possibility of omicron and delta. Those parameters are treated as important factors to prevent from the COVID Variants. .

Case-3: Prevention measures for the disease -ON state

For the iteration process, the parameter C_2 is considered in the ON state. i.e., prevention measures of the diseases. The initial matrix required for the process is taken as below, which has the entries as 0 for the OFF state and 1 for ON state.

$$A_1 = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$A_1 * E = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\rightarrow \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$= A_2$$
$$A_2 * E = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\rightarrow \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$= A_3$$
$$\therefore A_2 = A_3$$

The iteration process may be stopped when the current and previous iteration seems as same. The above iteration process shows that when the C_2 parameter is taken as ON state then expect the parameters C_3 are obtained as OFF state. It concludes that the parameter travelling history is more related to the parameter C_2, so that avoiding travelling from one place to another via public transport or independently is one of the main prevention measures from the effects of COVID variants.

Case-4: the possibility of having Omicron Virus- ON state

For the iteration process, the parameter C_9 i.e., the possibility of having Omicron Virus is considered as ON state and the rest of the parameters are taken as OFF state which is denotes as initial matrix A_1. The initial matrix required for the process is taken as below, which has the entries of 0 for the OFF state and 1 for the ON state.

$$A_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix}$$

$$A_1 * E = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix}$$
$$= A_2$$
$$A_2 * E = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 2 & 0 & 0 & 2 & 1 & 0 & 0 \end{bmatrix}$$

$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix}$$
$$= A_3$$
$$A_3 * E = \begin{bmatrix} 0 & 0 & 0 & 2 & 0 & 2 & 0 & 0 & 2 & 2 & 0 & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}$$
$$= A_4$$
$$A_4 * E = \begin{bmatrix} 0 & 0 & 0 & 2 & 0 & 3 & 0 & 0 & 2 & 2 & 0 & 1 \end{bmatrix}$$

$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}$$
$$= A_5$$
$$\therefore A_4 = A_5$$

The above iteration process shows that when the C_9 parameter is taken as ON state then the parameters C_4, C_6, C_{10}, and C_{12} are obtained as ON states. It concludes that the possibility of the Omicron virus having major symptoms such as loss of taste and smell, Cough, fever, difficulty breathing, etc., leads to the spread pf Omicron virus more easily. So that based on the clarity of factors, one can prevent themselves from diseases.

Case-5: Spread more easily -ON state
Let us take the C_{12} parameter, i.e., spread more easily as ON state. For the iteration process and rest of the parameters are taken as OFF state which denotes initial matrix A_1.The initial matrix required for the process is taken as below, which has the entries as 0 for the OFF state and 1 for ON state.

$$A_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_1 * E = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$
$$= A_2$$
$$A_2 * E = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \end{bmatrix}$$

$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \end{bmatrix}$$
$$= A_3$$

$$A_3 * E = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 3 & 0 & 0 & 2 & 1 & 0 & 1 \end{bmatrix}$$

$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}$$
$$= A_4$$
$$A_4 * E = \begin{bmatrix} 0 & 0 & 0 & 2 & 0 & 3 & 0 & 0 & 2 & 2 & 0 & 1 \end{bmatrix}$$

$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}$$
$$= A_5$$
$$\therefore \ A_4 = A_5$$

The above iteration process shows that when the C_{12} parameter is taken as ON state then the parameters C_4, C_6, C_9, and C_{10} are obtained as ON state. It concludes that the parameter C_4,is the main factor of possibility of omicron delta also those factors spread the CORONA variants more easily from one person to another and it causes loss of smell and taste.

4   Neutrosophic cognitive map

The experts opinions were collected, and based on their opinions, a graph was formed by mapping between the parameters. In which, based on the Neutrosophic cognitive map concept, weight age was assigned by the casual relation between the nodes. i.e., the edge weight was assigned as 1 (positive causality between the nodes), if the relationship between the nodes had majority of respondents, at the same time the respondents which are uncertain or indeterminate then it is denoted by I. The number zero is assigned, when there is no relationship between the parameters based on experts opinion. In the neutrosophic graph, for the indeterminate case the edges between the nodes is drawn by the dotted lines. The corresponding neutrosophic cognitive maps for the parameters is given below in figure 2
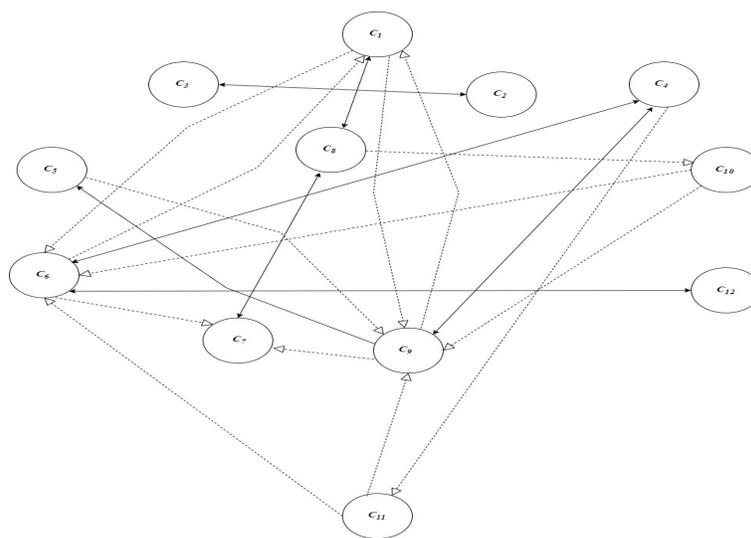

Figure 2: Neutrosophic Cognitive Maps on COVID VARIANTS

A Comparative Study of Fuzzy Cognitive Maps and Neutrosophic Cognitive Maps on Covid Variants

4.1 Matrix representation of NCM

The matrix representation of the neutrosophic cognitive map is designed based on the connectives between the nodes, which are possibilities among the parameters. In addition to the FCM concept, here one more case is occur, when there is an inconclusive possibility of relationship between the parameters which is denoted as indeterminate I case. The entries of the matrix are noted as 0 or 1 or I. The number 0 denotes for unconnected, 1 represents the connection between the nodes and I noted for the indeterminate case between the nodes which is connected by the dotted lines. The adjacent matrix of figure 2 is given below.

$$
\mathbf{E} = \begin{array}{c} \\ \mathbf{C_1} \\ \mathbf{C_2} \\ \mathbf{C_3} \\ \mathbf{C_4} \\ \mathbf{C_5} \\ \mathbf{C_6} \\ \mathbf{C_7} \\ \mathbf{C_8} \\ \mathbf{C_9} \\ \mathbf{C_{10}} \\ \mathbf{C_{11}} \\ \mathbf{C_{12}} \end{array}
\begin{array}{c}
\begin{array}{cccccccccccc} \mathbf{C_1} & \mathbf{C_2} & \mathbf{C_3} & \mathbf{C_4} & \mathbf{C_5} & \mathbf{C_6} & \mathbf{C_7} & \mathbf{C_8} & \mathbf{C_9} & \mathbf{C_{10}} & \mathbf{C_{11}} & \mathbf{C_{12}} \end{array} \\
\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & I & 0 & 1 & I & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & I & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & I & 0 & 0 & 0 \\
I & 0 & 0 & 1 & 0 & 0 & I & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & I & 0 & 0 \\
I & 0 & 0 & 1 & 1 & 0 & I & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & I & 0 & 0 & I & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & I & 0 & 0 & I & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
\end{array}
$$

4.2 Iteration Process of NCM

Case-1: the possibility of delta variant -ON state
Let us consider the C_6 parameter as being in the ON state. i.e., the possibility of a delta variant for the iteration process. The initial matrix required for the process is taken as below, which has the entries as 0 for the OFF state and 1 for ON state. While comparing with the FCM iteration process, here in the each step of iteration I may observe based on choosing of parameter as ON or OFF state.

$$
\begin{aligned}
B_1 &= \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \\
B_1 * E &= \begin{bmatrix} I & 0 & 0 & 1 & 0 & 0 & I & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \\
&\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 0 & 1 & I & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \\
&= B_2 \\
B_2 * E &= \begin{bmatrix} I & 0 & 0 & 1 & 0 & I^2+1 & I & 2I & I^2+1 & 0 & I & 1 \end{bmatrix} \\
&\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 0 & 1 & I & I & 1 & 0 & I & 1 \end{bmatrix} \\
&= B_3 \\
B_3 * E &= \begin{bmatrix} 3I & 0 & 0 & 2 & 1 & 2I^2+1 & 3I & 2I & 2I^2+1 & I^2 & I & 1 \end{bmatrix} \\
&\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 1 & 1 & I & I & 1 & I & I & 1 \end{bmatrix}
\end{aligned}
$$

A Comparative Study of Fuzzy Cognitive Maps and Neutrosophic Cognitive Maps on Covid Variants

$$= B_4$$
$$B_4 * E = \begin{bmatrix} 3I & 0 & 0 & 2 & 1 & 3I^2 + 1 & 3I & 2I & 3I^2 = I + 1 & I^2 & I & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 1 & 1 & I & I & 1 & I & I & 1 \end{bmatrix}$$
$$= B_5$$
$$\therefore \ B_4 = B_5$$

The last two iterations values are obtained as the same, so that the iteration process may be stopped and it shows that when the C_6 parameter is taken as ON state then the parameters C_4, C_5, C_6, C_9, and C_{12} are obtained as ON state and the states C_1, C_7, C_8, C_{10}, and C_{11} are obtained as I. It concludes that the parameters spread easily, the patient with the symptoms of fever,cough, breathing problem, but it may be cause of omicron if the person have the symptom of brain fog except prevention.

Case-2: High risk of getting omicron and delta - ON state

Let us take the C_8 parameter as ON state. i.e., high risk of getting Omicron and Delta for the iteration process. The initial matrix required for the process is taken as below, which has the entries as 0 for the OFF state and 1 for ON state.

$$B_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$B_1 * E = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & I & 0 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & I & 0 & 0 \end{bmatrix}$$
$$= B_2$$
$$B_2 * E = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & I + I^2 & 1 & 2 & I + I^2 & I & 0 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & I & 1 & 1 & I & I & 0 & 0 \end{bmatrix}$$
$$= B_3$$
$$B_3 * E = \begin{bmatrix} 1+I & 0 & 0 & I & I & 2I + I^2 & 1+I & 3 & 2I + I^2 & I & 0 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 1 & 0 & 0 & I & I & I & 1 & 1 & I & I & 0 & 0 \end{bmatrix}$$
$$= B_4$$
$$B_4 * E = \begin{bmatrix} 1+I & 0 & 0 & I & I & 3I + I^2 & 1+I & 3 & 3I + 2I^2 & I & I^2 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 1 & 0 & 0 & I & I & I & 1 & 1 & I & I & I & 0 \end{bmatrix}$$
$$= B_5$$
$$B_5 * E = \begin{bmatrix} 1+I & 0 & 0 & I & I & 4I + I^2 & 1+I & 3 & 3I + 2I^2 & I & I^2 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 1 & 0 & 0 & I & I & I & 1 & 1 & I & I & I & 0 \end{bmatrix}$$
$$= B_6$$
$$\therefore B_5 = B_6$$

The iteration process may be stopped when the current and previous iterations seem as the same. The above iteration process shows that when the C_7 parameter is taken as ON state then expect the parameters C_2, C_3, and C_{12} to be obtained as ON state, and the rest of parameters shows as I or ON state. It concludes that the parameter C_7 i.e., persons with blood pressure, cancer, diabetes, and the person who travelled from one country to another country have a high risk factor for the diseases. Also, a few of the parameters are indeterminate

cases.

Case-3: Prevention measures of the diseases - ON state

For the iteration process, the parameter C_2 i.e., prevention measures for the diseases is considered as ON state. The initial matrix required for the process is taken as below, which has the entries as 0 for the OFF state and 1 for ON state. While comparing with the FCM iteration process, here in each step of iteration I may occur based on the choice of parameter as ON or OFF state.

$$B_1 = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$B_1 * E = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$= B_2$$
$$B_2 * E = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$= B_3$$
$$\therefore B_2 = B_3$$

The iteration process may be stopped when the current and previous iterations seem as the same. The above iteration process shows that when the C_2 parameter is taken as ON state, then expect the parameters C_3 to be obtained as OFF state. It concludes that maintaining social distance and usuage of hand sanitizer and wearing mask are the prevention measures for the COVID variants.

Case-4: the possibility of Omicron - ON state.

For the iteration process, the parameter C_9 i.e., the possibility of Omicron is considered as ON state. The initial matrix required for the process is shown below.

$$B_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix}$$
$$B_1 * E = \begin{bmatrix} I & 0 & 0 & 1 & 1 & 0 & I & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 1 & 0 & I & 0 & 1 & 0 & 0 & 0 \end{bmatrix}$$
$$= B_2$$
$$B_2 * E = \begin{bmatrix} I & 0 & 0 & 1 & 1 & I^2+1 & I & 2I & I^2+I+1 & 0 & I & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 1 & 1 & I & I & 1 & 0 & I & 0 \end{bmatrix}$$
$$= B_3$$
$$B_3 * E = \begin{bmatrix} 3I & 0 & 0 & 2 & 1 & 2I^2+1 & 3I & 2I & I^2+2I+1 & I^2 & I & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 1 & 1 & I & I & 1 & I & I & 1 \end{bmatrix}$$
$$= B_4$$
$$B_4 * E = \begin{bmatrix} 3I & 0 & 0 & 2 & 1 & 3I^2+2 & 3I & 2I & I^2+3I+1 & I^2 & I & 1 \end{bmatrix}$$

$$\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 1 & 1 & I & I & 1 & I & I & 1 \end{bmatrix}$$
$$= B_5$$
$$\therefore B_4 = B_5$$

The iteration process may be stopped when the current and previous iterations seem as the same. The above iteration process shows that the person affected by omicron has brain fog and common symptoms like fever, cough, and breathing problems. It also spread easily from one infected person to another. It may cause delta variant because the symptoms are more similar. The parameter C_1, i.e., travelling history, seems to be as indeterminate case.

Case-5: Spread more easily - ON state

For the iteration process, the parameter C_{12} i.e., spread more easily, is considered as ON state. The initial matrix required for the process is shown below.

$$B_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$
$$B_1 * E = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$
$$= B_2$$
$$B_2 * E = \begin{bmatrix} I & 0 & 0 & 1 & 0 & 1 & I & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 0 & 1 & I & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$
$$= B_3$$
$$B_3 * E = \begin{bmatrix} I & 0 & 0 & 1 & 0 & I^2+2 & I & 2I & I^2+1 & 0 & I & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 0 & 1 & I & I & 1 & 0 & I & 1 \end{bmatrix}$$
$$= B_4$$
$$B_4 * E = \begin{bmatrix} 3I & 0 & 0 & 2 & 1 & I^2+3 & 2I & 2I & 2I^2+1 & I^2 & I & 1 \end{bmatrix}$$
$$\rightarrow \begin{bmatrix} I & 0 & 0 & 1 & 1 & 1 & I & I & 1 & I & I & 1 \end{bmatrix}$$
$$= B_5$$
$$\therefore B_5 = B_6$$

The above iteration process shows that when the C_{12} parameter is taken as ON state then expect that the parameters C_2 and C_3 are obtained as ON or I state. It means that Omicron and Delta variants are spread more easily and faster, when the persons affected by fever, brain fog, cough, and difficulty breathing.

5 Comparison and discussion

Table 1: Comparison Results of FCM and NCM on COVID Variants

On State	FCM Iteration	NCM Iteration	Comparison Remarks
C_6	$A_3 = A_4$; [0 0 0 1 0 1 0 0 1 1 0 1]	$B_4 = B_5$; [I 0 0 1 1 1 I I 1 I I 1]	Changes in Parameters
C_8	$A_4 = A_5$; [1 0 0 1 1 1 1 1 1 1 1 1]	$B_5 = B_6$; [1 0 0 I I I 1 1 I I I 0]	Changes in Parameters
C_2	$A_2 = A_3$; [0 1 1 0 0 0 0 0 0 0 0 0]	$B_2 = B_3$; [0 1 1 0 0 0 0 0 0 0 0 0]	No Changes
C_9	$A_4 = A_5$; [0 0 0 1 0 1 0 0 1 1 0 1]	$B_4 = B_5$; [I 0 0 1 1 1 I I 1 I I 1]	Changes in Parameters
C_{12}	$A_4 = A_5$; [0 0 0 1 0 1 0 0 1 1 0 1]	$B_5 = B_6$; [I 0 0 1 1 1 I I 1 I I 1]	Changes in Parameters

The parameters related to the COVID variants such as Omicron and Delta are considered as C_1, C_2, C_3, $\cdots$, C_{12}. The FCM and NCM among the parameters are designed based on the experts opinions. The adjacent matrix of fuzzy cognitive maps and neutrosophic cognitive maps is evaluated and it is used for the iteration process. The comparison is made between the FCM and NCM, by considering any one state as ON state commonly.From which we have obtained the following results.

First we are taking 6th parameter as on state (i.e.,) Using the possibility of delta variant (C_6) as on state,In our comparison of FCM and NCM we are getting that it spreads more easily and the symptoms are fever, cough, difficulty breathing, but it may be the the possibility of getting omicron with brain fog.In next case, we are analyzing the high risk factors of diseases, the result shows that persons with blood pressure, cancer patient, diabetes, older age who are violating C_3.Prevention measures include maintaining social distance,wearing mask, often wash our hand. The possibility of omicron FCM shows that one of the important symptoms of omicron is brain fog in off state but while we are analysing by the NCM method, brain fog in on state.while we are taking C_{12} in state of on, In FCM it shows some less parameter in on state but in NCM there are some indeterminate state like depending on our travelling history and also this diseases spreads more easily for the persons in the 7th parameter.

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