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New Plithogenic Sub Cognitive Maps Approach with Mediating Effects of Factors in COVID-19 Diagnostic Model

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ABSTRACT

The escalation of COVID-19 curves is high and the researchers worldwide are working on diagnostic models, in the way this article proposes COVID-19 diagnostic model using Plithogenic cognitive maps. This paper introduces the new concept of Plithogenic sub cognitive maps including the mediating effects of the factors. The thirteen study factors are categorized as grouping factors, parametric factors, risks factors and output factor. The effect of one factor over another is measured directly based on neutrosophic triangular representation of expert's opinion and indirectly by computing the mediating factor's effects. This new approach is more realistic in nature as it takes the mediating effects into consideration together with contradiction degree of the factors. The possibility of children, adult and old age with risk factors and parametric factors being infected by corona virus is determined by this diagnostic model.

1. Introduction

Robert Axelrod [1] developed cognitive maps, a graphical representation of decision maker's perception towards the problem. The factors of the problem are taken as the nodes and the influence of one factor over the other is represented by directed edges. The edge weights assume either of the values -1, 0, 1. The positive influence of one factor is indicated by 1, no influence by 0 and negative influence by -1. The edge weights in Cognitive maps are crisp in nature and it does not include the partial influence of the factors. Suppose if factor A has some influence on factor B, the edge weight is assumed to be 0 as it lacks the completeness. This limitation of cognitive maps is handled by extending cognitive maps to Fuzzy Cognitive Maps (FCM)

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by Kosko [2]. In FCM the edge weights take values between the range of values from [-1, 1]. Fuzzy cognitive maps consider both partial and complete influence of the factors. The applications of Fuzzy cognitive maps are extensively investigated by many researchers. Vasantha Kandasamy [3] introduced the method of Combined Disjoint Block Fuzzy Cognitive Maps to study the influence of the factors. In this method the factors are grouped into disjoint blocks and the influence of the factors is determined based on expert's opinion. Combined overlap block fuzzy cognitive maps were also introduced by Vasantha Kandasamy [3] in which the overlapping factors are subjected to investigation. These combined overlap and block FCM are extensively used to design optimal solutions to the decision – making problems on finding the effect of smart phone on children [4], role of happiness in family [5], analysis of environmental education for the next generation [6], reasons of failure of engineering students [7].

The concept of fuzzy introduced by Zadeh [8] was extended to neutrosophic sets by Smarandache [9]. Neutrosophic sets consists of truth, indeterminacy and falsity membership functions and it is significant in handling the notion of indeterminacy in decision – making environment. Neutrosophic representation of expert's opinion in problem solving scenario resolves the mishaps of indeterminacy [10]. Neutrosophic sets are widely used in making feasible decisions. Sudha et al. [11] assessed MCDM problems by the method of TODIM using neutrosophic aggregate weights. Singh et al. [12, 13] has used pentagonal neutrosophic numbers to investigate social media linked MCGDM skill. Paul et al. [14] developed a generalized neutrosophic solid transportation model to handle deficit supply. Das and Tripathy [15] developed multi-polar neutrosophic causal modelling for examining the state of institutional culture. Kandasamy and Smarandache introduced Neutrosophic Cognitive Maps (NCM) [16]. In NCM the edge weights are represented as neutrosophic sets. Neutrosophic cognitive maps are used in finding the risk factors of breast cancer [17], situational analysis [18], medical diagnosis [19], selection approach of leaf diagnosis [20]. The different methods of Fuzzy cognitive maps are also discussed in neutrosophic environment. Farahani et al. [21] compared combined block and overlap block NCM and applied the methods to find the hidden patterns and indeterminacies in a case study of Attention-Deficit/Hyperactivity Disorder (ADHD).

Smarandache introduced the concept of plithogeny [22]. Plithogenic sets are the extension of crisp set, fuzzy set, intutionistic and neutrosophic sets and it can be termed as higher order sets. The significance of Plithogenic sets is the incorporation of degree of appurtenance and contradiction degree with respect to the attributes of the decision-making components. Plithogenic sets are widely used in making optimal decisions. Abdel-Basset developed Plithogenic decision making model to solve supply chain problem; constructed Plithogenic MCDM approach for evaluating the financial performance of the manufacturing industries [23]. Concentric Plithogenic hypergraphs, Plithogenic n– super hypergraphs developed by Martin and Smarandache [24, 25] finds novel applications in decion-making. Plithogenic hypersoft sets introduced by Rana et al. [26] was extended to Plithogenic fuzzy whole hypersoft set by Smarandache [27] and to combined Plithogenic hypersoft sets by Martin and Smarandache [28]. Plithogenic cognitive maps was introduced by Martin and Smarandache [29]. PCM involves contradiction degree in addition to the influence of the factors. Based on this approach of PCM the contradiction degree of the experts was also discussed.

The extension of cognitive models to FCM, NCM and PCM measures only the direct influence of one factor over another, but not the mediating effects of the factors. The factors are grouped as combined or overlapping blocks to study the effects, but the factors are not classified into various groups of factors to study the individual impacts or the combined effects of one factor of a group over the factors of other groups. The connection matrix representing the association between the factors taken for study is fully considered for determining the influence of the factors in ON position over the factors in OFF position. In this paper the PCM introduced by Nivetha and Florentin is examined profoundly and the concept of Plithogenic sub cognitive maps are introduced to determine the mediating effects of the factors. Also the factors 13 factors taken for study are classified as grouping factors, parametric factors, risks factors and output factor. The proposed approach is modeled to diagnose Covid-19. Several Covid-19 predictive models are framed by researchers. Ibrahim Yasser et al. [30] has used neutrosophic classifier in developing a framework COVID -19 confrontation. Khalifia [31] used the concept of neutrosophic and deep learning approach to diagnose COVID-19 chext X ray. These models are the forecasting models of COVID -19 are based on neutrosophic sets. A PCM Covid 19 diagnosis model with contradiction degree of expert's opinion is proposed by Broumi. Covid -19 predictive models based on Plithogenic sets are limited and this motivated the authors to explore more in this area of decision-making.

In all these COVID-19 neutrosophic and Plithogenic prediction models the study factors are not categorized and the mediating effects are not studied. But in this paper the mediating effects are considered to determine the cumulative effect of one factor over another together with the respective contradiction degree of the factors with respect to the dominating factor. The proposed approach of PSCM with linguistic representation of impacts based on expert's opinion will pave way for determining the true impacts of the factors. The paper is organized as follows: Section 2 presents the methodology of PSCM of determining mediating effects. Section 3 comprises of the application of the proposed approach to COVID 19 diagnosis model. Section 4 discusses the results and the last section concludes the work.

2. Methodology

2.1. Plithogenic Sub Cognitive Maps with Mediating Effects of the Factors

Plithogenic sub cognitive maps are the subgraphs of Plithogenic cognitive maps that comprises of one of the grouping factors, all the parametric factors, one of the risk factors and the output factor. In general, the factors are categorized based on the nature of the problem, but generally the factors are essentially classified as grouping factors, measuring factors, risk factors and output factors. Measuring factors are the factors that take certain parameters into consideration and sometime they are the describing factors of the grouping factors. The grouping factors are the factors based on which the Plithogenic sub cognitive maps are constructed. The vertex representing the grouping factors in the Plithogenic cognitive maps is the prime vertex in the PSCM. Let C1, C2, C3, C4, C5, C6, C7 be the factors taken for study to explore the decision-making problem. C1 and C2 are taken as the grouping factors, C3, C4 are taken as the parametric factors, C5, C6 are taken as the risk factors and C7 is the output factor. The intra association between the factors of each kind are not considered, if considered the Plithogenic sub cognitive maps are known as Plithogenic super sub cognitive maps.

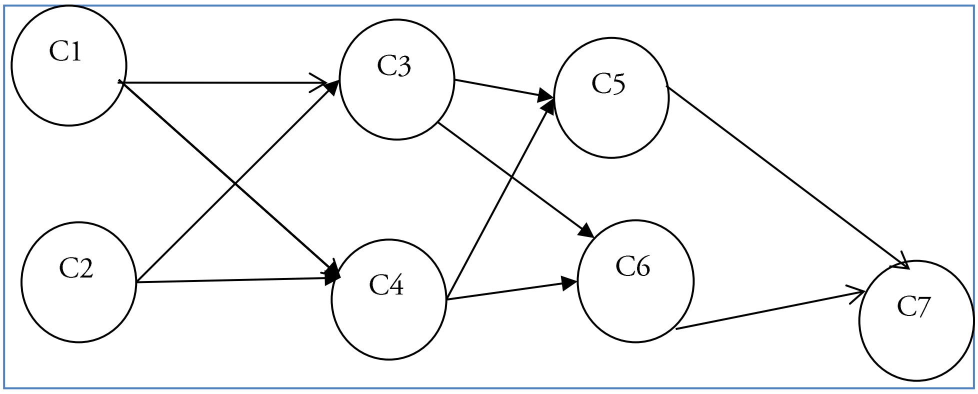


Fig 1. The Plithogenic cognitive maps.

The Plithogenic cognitive maps represented in the ***Fig. 1*** presents all the possible inter relationships between the factors, to study the inter association between the grouping factors and the output factor through the mediating effects of the parametric factors and or on the risk factors, the Plithogenic sub cognitive maps are derived from Plithogenic cognitive maps.

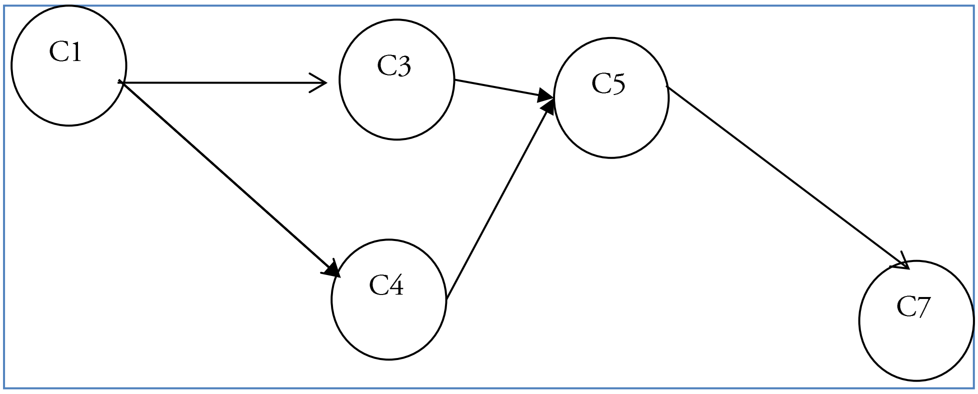


Fig 2. Prime vertex with inter-association.

In ***Fig. 2*** the grouping factor C1 is taken as the prime vertex and the inter-association between the parametric factors and C5, one of the risk factors is represented to find the ultimate association between the grouping factor C1 and the output factor C7. The other Plithogenic sub cognitive maps to examine the inter associations between other set of factors can also constructed as in ***Fig. 3***.

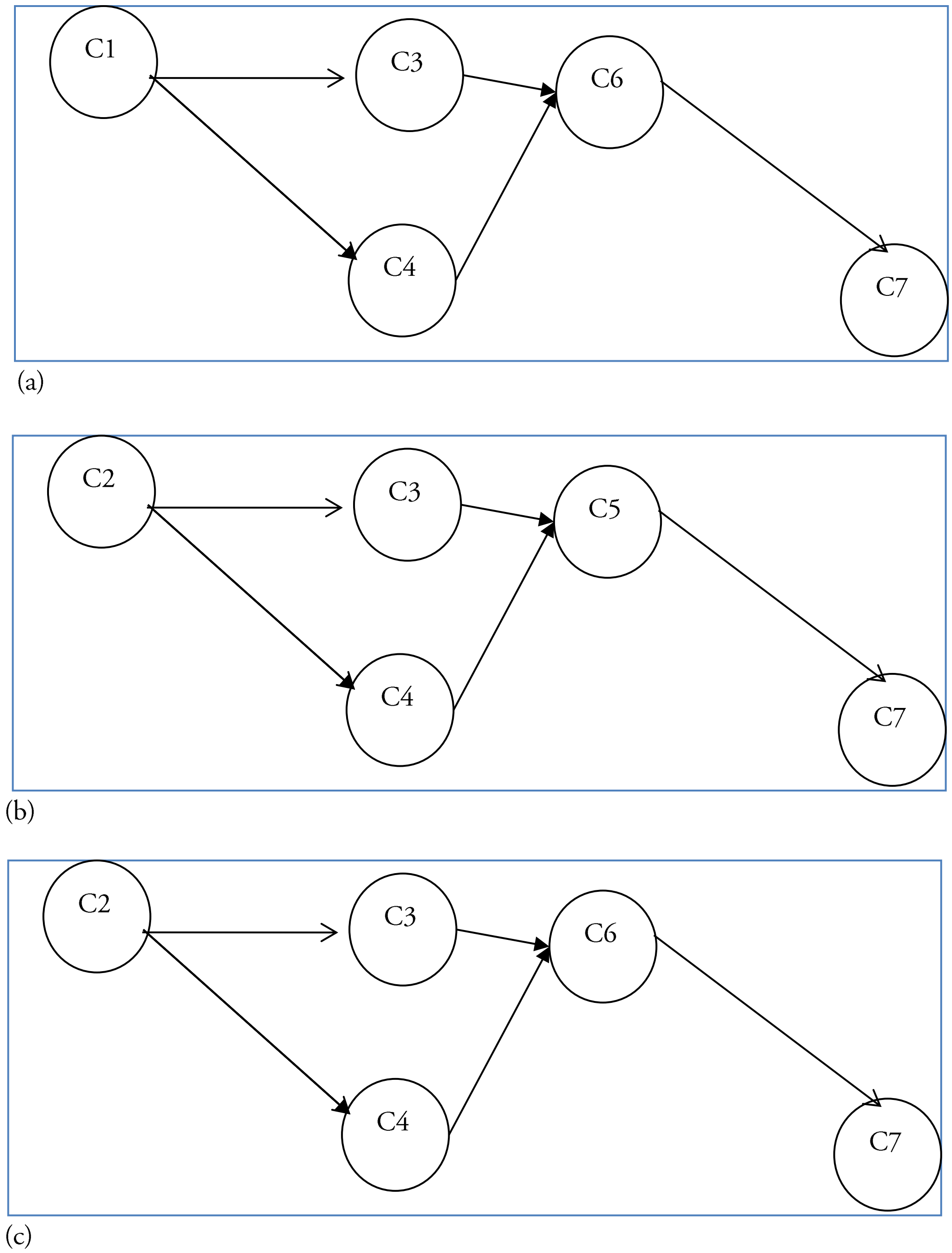


Fig 3. Plithogenic sub cognitive maps.

In each of the Plithogenic sub cognitive maps, the effects of the mediating factors representing the association between the grouping factor and the output factor are considered.

The steps involved in determining the mediating effects of the factors are presented as follows:

Step 1. The factors of the decision-making problem are categorized as grouping factors, parametric factors, risk factors and output factor.

Step 2. The Plithogenic cognitive maps representing the association between all the factors is represented graphically and the association or the connection matrix is constructed. The connection matrix M comprises of the direct effects and the indirect unknown effects between the factors in terms of linguistic variables. The association between the parametric and the risk factors are known. The levels of association between the grouping factors and the parametric factors are unknown as of certain time, until the real data is collected. The association between the grouping factor and the output factor is determined by finding the cumulative effect i.e. known and the unknown levels of impact are taken to find it. These linguistic representations are quantified using triangular neutrosophic numbers in this method, but it can be quantified by using other kinds of linguistic representations.

Step 3. The Plithogenic sub cognitive maps are constructed to determine the individual association of the grouping factor and that of the output factor. The association matrix M1 presenting the relationships between the vertices of the PSCM is derived from M. The matrix M1 also comprises of the levels of associations and the impacts.

Step 4. The factors presented under each categorization are graded as dominant when it is kept in ON position as in Plithogenic cognitive maps. The contradiction degree of the factors that are considered in PSCM are also taken into account in determining the impact of the factors.

Step 5. The factors in the PSCM are kept in ON position to determine the impact of the ON factors over the output factor and the procedure of finding the fixed point of Plithogenic cognitive maps is adopted.

3. COVID 19 Diagnostic Model

This section comprises of the formulation of COVID 19 diagnostic model. The thirteen factors taken in developing diagnostic model are categorized as grouping factors, parametric factors, risks factors and output factor. The factors C1, C2, C3 are the grouping factors based on the age group vulnerable to Covid-19, C4, C5, C6 are the parametric factors, C7, C8, C9, C10, C11, C12 are the risk factors and C13 is the output factor. The factors are

- C1 Children,
- C2 Adult,
- C3old age,
- C4 Blood Sugar level,
- C5 Blood pressure Level,
- C6 State of immune system,
- C7 Risk of Heart diseases,
- C8 Risk of Cancer,
- C9 Risk of Chronic kidney disease,
- C10 Asthma Effect,
- C11 Risk of Liver disease,
- C12 Risk of Sickle cell disease,
- C13 Possibility of being Infected by Corona Virus,

This model aims in determining the association between grouping factors and the output factor with the intervention of the mediating effects of the parametric and the risk factors. The comprehensive outlook of the association between the factors are presented graphically in Fig. 4.and the respective connection matrix M.

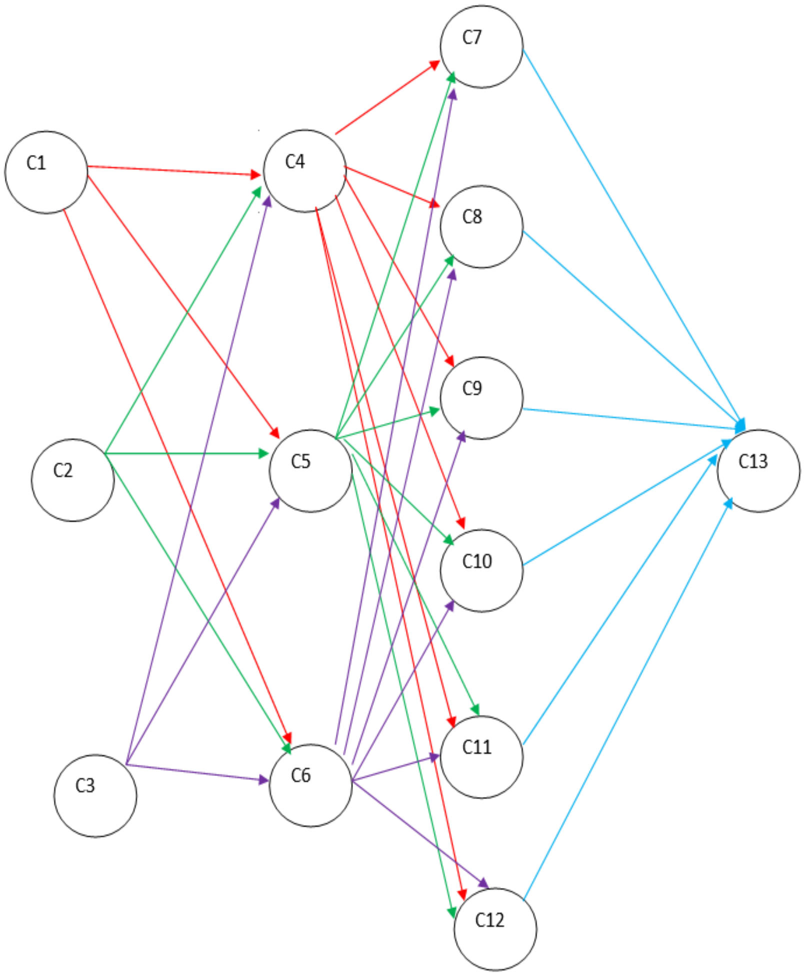


Fig. 4. Association between the factors.

The general connection matrix with possible direct effects D (D = H or M or L) and unknown indirect cumulative effects Y & Z. The matrix also comprises of the direct effects of the parametric factors over the risk factors. The effects between the grouping factors and parametric factors are represented as D and it indicates the low or medium or high impacts between the factors. The association between the parametric factors and the risk factors are represented using linguistic variables. The cumulative effects of the grouping factors on the risk factors through the mediating effects of the parametric factors are represented as Y and on the output factor is represented as Z. The connection matrix in the Plithogenic cognitive maps presents the direct associations, but in the constructed connection matrix both the direct and the indirect associations are included to make optimal decisions and this is the distinguishing aspect of this model from the earlier models.

Based on the above description of the model with the direct and indirect effects between the factors of various kinds, the individual examination of one of the grouping factors in relation to the parametric factors and one of the risk factors subjected to the output factor is modelled as follows using the notion of Plithogenic sub cognitive maps. Let us now determine the association between the grouping factor C2 and the output factor C13 with the consideration of the mediating effects. Th e association refers to the relational impacts between adults and the possibility of being infected by corona. To determine the associational impacts, firstly the relational impacts of the adult [chosen for study] with the parametric factors are initially assigned as linguistic variables on investigation. The levels of the relational impacts are either high or medium or low or sometimes in combination.

Let us consider the factor C2 to be dominant amidst the grouping factors, C4 to be dominant amidst parametric factors and C7 to be the dominant among the risk factors. Th e associational impact between the adult [possessing the factors C4, C5 and C6 at various levels and the risk factor C7] and the possibility of being infected by Corona Virus is determined as follows. The contradiction degree of the factors is presented

Table1. Contradiction Degree of the Factors.

C1	C2	C3
1/3	0	2/3

C4	C5	C6
0	1/3	2/3

C7	C8	C9	C10	C11	C12
0	1/6	2/6	3/6	4/6	5/6

Here D = H/M/L, let us first analyse the case where the relational impacts are high (D=H) and the connection matrix obtained is

$$
\begin{array}{c} \\ C1 \\ C4 \\ C5 \\ C6 \\ C7 \\ C13 \end{array}
\begin{pmatrix}
C1 & C4 & C5 & C6 & C7 & C13 \\
0 & H & H & H & 2H & 3H \\
0 & 0 & 0 & 0 & H & 2H \\
0 & 0 & 0 & 0 & H & 2H \\
0 & 0 & 0 & 0 & H & 2H \\
0 & 0 & 0 & 0 & 0 & H \\
0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

$$
\begin{array}{c} \\ C1 \\ C4 \\ C5 \\ C6 \\ C7 \\ C13 \end{array}
\begin{pmatrix}
C1 & C4 & C5 & C6 & C7 & C13 \\
0 & D & D & D & Y & Z1 \\
0 & 0 & 0 & 0 & H & Z2 \\
0 & 0 & 0 & 0 & H & Z3 \\
0 & 0 & 0 & 0 & H & Z4 \\
0 & 0 & 0 & 0 & 0 & H \\
0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

Fig. 5 represents the respective Plithogenic sub cognitive map and the corresponding connection matrix with known and unknown effects is M1.

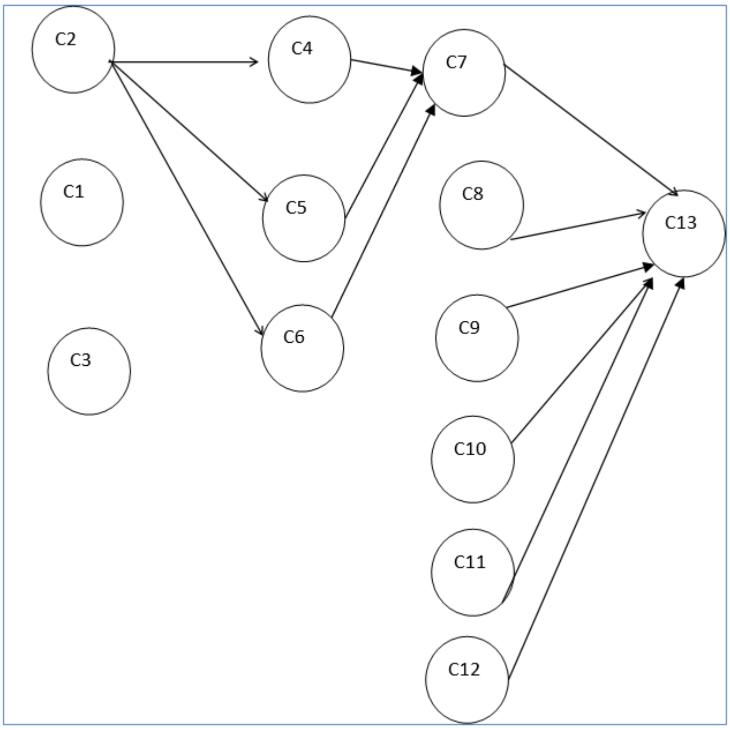


Fig. 5. Respective Plithogenic sub cognitive map.

The impact Y between C1 and C7 is determined as follows, the relational impact between C1 and C4 is H, the relational impact between C4 and C7 is H, as represented in the general connection matrix and so the cumulative impact between C1 and C7 is 2H, thus the indirect effects Y and Z are determined by taking the cumulative effects between the factors.

Table 2. Quantification of linguistic variable.

Linguistic Variable	Triangular Neutrosophic Representation	Crisp Value
High	(O.1,0.25,0.35)(0.6,0.2,0.3)	0.18
Moderate	(0.35,0.55,0.65)(0.8,0.1,0.2)	.48
Low	(0.65,0.85,0.95)(0.9,0.10.1)	.83

The modified Plithogenic fuzzy connection matrix P(E) is

	C1	C4	C5	C6	C7	C13
C1	0	0.83	0.83	0.83	1.66	2.49
C4	0	0	0	0	.83	1.66
C5	0	0	0	0	.83	1.66
C6	0	0	0	0	.83	1.66
C7	0	0	0	0	0	.83
C13	0	0	0	0	0	0

Let us consider the instantaneous state vector as X= (1 1 0 0 1 0)

$X *_P P(E) = F$ *where* $F = (a\ b\ c\ d\ e\ f)$;

$a = Max\ [1_{\wedge p}\, 0,\ 1_{\wedge p}\, 0,\ 0_{\wedge p}\, 0,\ ,0_{\wedge p}\, 0,\ 1_{\wedge p}\, 0,\ 0_{\wedge p}\, 0,\ ];$

$b = max\ [1_{\wedge p}\, 0.83,\ 1_{\wedge p}\, 0,\ 0_{\wedge p}\, 0,\ ,0_{\wedge p}\, 0,\ 1_{\wedge p}\, 0,\ 0_{\wedge p}\, 0,\ ];$

$c = max\ [1_{\wedge p}\, 0.83,\ 1_{\wedge p}\, 0,\ 0_{\wedge p}\, 0,\ ,0_{\wedge p}\, 0,\ 1_{\wedge p}\, 0,\ 0_{\wedge p}\, 0,\ ];$

$d = max\ [1_{\wedge p}\, 0.83,\ 1_{\wedge p}\, 0,\ 0_{\wedge p}\, 0,\ ,0_{\wedge p}\, 0,\ 1_{\wedge p}\, 0,\ 0_{\wedge p}\, 0,\ ];$

$e = max\ [1_{\wedge p}\, 1.66,\ 1_{\wedge p}\, 0.83,\ 0_{\wedge p}\, 0.83,\ ,0_{\wedge p}\, 0.83,\ 1_{\wedge p}\, 0,\ 0_{\wedge p}\, 0,\ ];$

$f = max\ [1_{\wedge p}\, 2.49,\ 1_{\wedge p}\, 1.66,\ 0_{\wedge p}\, 1.66,\ ,0_{\wedge p}\, 1.66,\ 1_{\wedge p}\, .83,\ 0_{\wedge p}\, 0,\ ];$

$X *_P P(E) = (0\ .83\ .8\ .94\ 1.66\ 2.49) \rightarrow (1\ 1\ .8\ .94\ 1\ 1) = X1;$

$X1 *_P P(E) = ((0\ 0.83\ \ .89\ \ .94\ \ 1.66\ \ 2.49) \rightarrow (1\ \ 1\ \ .89\ \ .94\ \ 1\ \ 1) = X2;$

$X2 *_P P(E) = (0\ 0.83\ \ .89\ \ .94\ \ 1.66\ \ 2.49) \rightarrow (1\ \ 1\ \ .89\ \ .94\ \ 1\ \ 1) = X3;$

$X2 = X3.$

The fixed point is:

$$(1\ \ 1\ \ .89\ \ .94\ \ 1\ \ 1), \tag{1}$$

thus obtained represents the influence of the factors in ON position over the other factors.

Let us consider D, the relational impacts to be moderate (i.e.) D= M. The respective connection matrix is as follows:

	C1	C4	C5	C6	C7	C13
C1	0	0.48	0.48	0.48	0.96	1.44
C4	0	0	0	0	0.48	0.96
C5	0	0	0	0	0.48	0.96
C6	0	0	0	0	0.48	0.96
C7	0	0	0	0	0	0.48
C13	0	0	0	0	0	0

Let us now consider the instantaneous state vector as X= (1 1 0 0 1 0)

$X *_P P(E)=(0\ \ 0\ .48\ \ .65\ \ .83\ \ 0.96\ 1.44) \rightarrow (\ 1\ \ 1\ .65\ .83\ 1\ 1\ ) = X1;$

$X1 *_P P(E)=((0\ 0.48\ \ .65\ \ .83\ \ .96\ \ 1.44) \rightarrow (1\ \ 1\ \ .65\ \ .83\ \ 1\ \ 1) = X2;$

X1 = X2.

The fixed point is:

$$(1\ \ 1\ \ .65\ \ .83\ \ 1\ \ 1), \tag{2}$$

Let us consider D, the relational impacts to be moderate (i.e.) D= L. The respective connection matrix is as follows

	C1	C4	C5	C6	C7	C13
C1	0	0.18	0.18	0.18	0.36	0.54
C4	0	0	0	0	0.18	0.36
C5	0	0	0	0	0.18	0.36
C6	0	0	0	0	0.18	0.36
C7	0	0	0	0	0	0.18
C13	0	0	0	0	0	0

$X1 *_P$ $X *_P$ Let us consider the instantaneous state vector as *X=(1 1 0 0 1 0)*

$P(E)=(0\ \ 0\ .18\ \ .45\ \ .73\ \ 0.36\ \ .54) \rightarrow (\ 1\ \ 1\ .45\ .73\ 1\ .54\ ) = X1;$

$P(E)=((0\ \ .18\ \ .45\ \ .73\ \ .36\ \ .44) \rightarrow (1\ \ 1\ \ .45\ \ .73\ \ 1\ \ 0.54) = X2;$

X1 = X2.

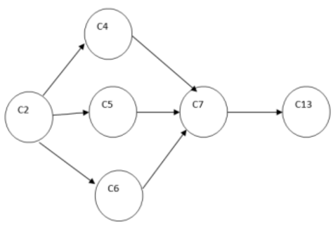
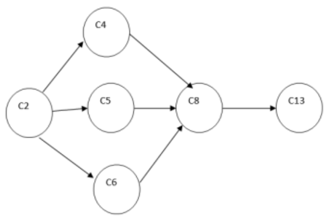
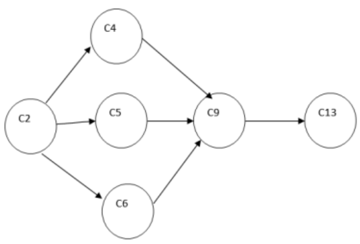
The fixed point is

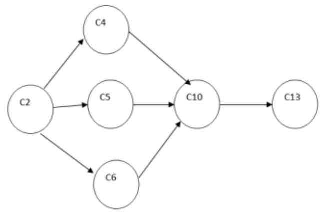
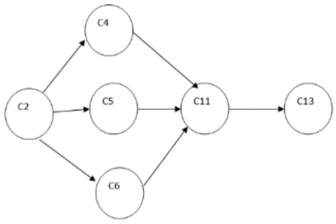
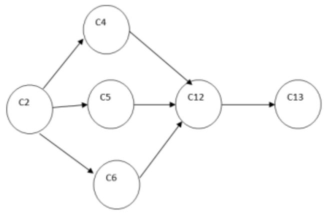
(1 1 .45 .73 1 0.54), (3)

Eqs. (1)- (3) represents the association of the adult (grouping factor) with the possibility of corona virus (output factor) together with the intervention of the various levels of the mediating effects of the parametric and the risk factor of heart disease.

The same procedure is repeated to analyse the association of the adult (grouping factor) with the possibility of corona virus (output factor) together with the intervention of the various levels of the mediating effects of the parametric and other risk factors. The fixed points thus obtained by considering the grouping factor C2, the output factor C13 , the diverse levels of parametric factors C4, C5, C6 with varying risk factors are tabulated as follows.

Table 3. Diverse levels of parametric factors.

Levels/Risk Factors	High	Moderate	Low
 C7	(1 1 .89 .94 1 1)	(1 1 .65 .83 1 1)	(1 1 .45 .73 1 0.54)
 C8	(1 1 .83 .94 1 1)	(1 1 .65 .83 1 1)	(1 1 .45 .73 1 0.54)
 C9	(1 1 .89 .94 1 1)	(1 1 .65 .83 1 1)	(1 1 .45 .73 1 0.54)

 C10	(1 1 .89 .94 1 1)	(1 1 .65 .83 1 1)	(1 1 .45 .73 1 0.54)
 C11	(1 1 .83 .94 1 1)	(1 1 .65 .83 1 1)	(1 1 .45 .73 1 0.54)
 C12	(1 1 .89 .94 1 1)	(1 1 .65 .83 1 1)	(1 1 .45 .73 1 0.54)

It is quite evident that the mediating effects of the risk factors in determining the association of the grouping factor with the output factor by considering various levels of parametric factors yields the same fixed point and thus the association between the grouping factor and the output factor exists and it is invariable with respect to the risk factors, also all the risk factors strongly indicates the association. The same procedure can be applied to determine the association between other grouping factors and the output factor together with the mediating effects of the factors by varying the contradiction degree with respect to the dominant factors

4. Discussion

The proposed diagnostic model provides the platform to take decisions on the possibility of corona virus to the persons of various age group with the various levels of common parametric values and the risk factors. In the first case of taking the relational impacts to be high, the blood sugar level was considered to be dominant as diabetic patients are highly vulnerable to COVID-19 and the other parametric factors are also considered. In addition to it the risk of heart diseases is taken to be dominant. The first case investigates the possibility of corona virus to the adult with high blood sugar level, and with the risk of heart diseases. The same fashion of investigation is done with various levels of the relational impacts and also with the consideration of other risk factors.

5. Conclusion

The paper introduces the concept of Plithogenic sub cognitive maps to design COVID-19 diagnostic model with the mediating effects of the factors. This model can be extended to Plithogenic super sub cognitive maps with the consideration of the intra relationship between the factors. This model assists in making exclusive examination of the possibility of corona virus infection to various age group of people with several mediating factors. This decision-making model will surely disclose novel vistas of constructing many more diagnostic models of this kind. The model can be extended by classifying the factors based on the needs of decision-making problem.

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