PCM with Linguistic Contradiction Degree Representations in Decision making on Academic Stress causing Factors

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Abstract

Plithogenic Cognitive Map (PCM) is the generalized form of Cognitive maps that has recently ebbed into the field of decision-making. The first developed PCM model comprises of factors, connection matrix with numeric contradiction degree between the factors. In this research work a PCM model with linguistic contradiction degree representations between the core and sub factors is developed to make the decision-making more comprehensive. The model formulated in this research work is illustrated with the factors causing academic stress to the students of digital educational system. Personal, Social, Economic and Institutional are considered as the core factors and the contradiction degree in linguistic sense is considered with respect to each of these core factors and ten sub factors. The obtained results on comparing with conventional models are highly promising and this model will certainly set new benchmarks of a comprehensive decision-making model.

Keywords: PCM; linguistic variable; contradiction degree; academic stress

1. Introduction

Plithogenic sets developed by Smarandache perform prominent role in the process of decision making. The plithogenic representations moderate the complicated phases involved in making optimal decisions. The demonstration of a plithogenic set (P) as a pentuple of the form (P, a, V,d,c) facilitates easy depiction of data. The origin and development of plithogeny is more closely associated with the handling of attributes (a) and set of attribute values (V) together with the degree of appurtenance (d) and contradiction (c). The plithogenic set is more comprehensive as it accommodates various kinds of representations namely crisp, fuzzy, intuitionistic and neutrosophic. Researchers have applied these plithogenic sets to simplify the process of making decision involving several criteria and alternatives. Abdel et al [1] in manufacturing industries, banking sectors, disaster management, supplier selection, Grida et al [20] in IOT based supply chain, Ulutas et al [37] in logistic risks, Ahmad et al [3] in novel MCDM model for COVID diagnosis, and also in materials selection, food processing methods.

Researchers have also combined the theory of plithogeny with other decision making methods to evolve a more generalized plithogenic decision making models. For instance the decision making models based on Plithogenic graphs, Plithogenic Hypersoft sets, Plithogenic hypergraph, Plithogenic soft sets are developed by extending plithogenic representations to the existing domains of decision making. The integrated plithogenic models are also widely applied in several decision making scenarios. Ahmad et al [2] in AI based decision making Covid 19, Ozcil et al [31] in MAIRCA

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method, Rana et al [35] in frequency matrix multi attribute decision making technique, Gayen et al [15] introduced plithogenic hypersoft subgroup, Gomez et al [17] applied plithogenic sets in the field of education and so on.

Another significant decision making model developed on integrating plithogenic sets with cognitive maps is Plithogenic Cognitive Maps (PCM). Nivetha and Smarandache laid the foundation for the conceptualization of PCM. This integrated decision making model is applied by the researchers in making optimal decisions. Martin et al [27] developed new plithogenic cognitive maps, Priya et al [34] developed induced plithogenic cognitive maps, instigating spiritual intelligence in youth.

Generally, a plithogenic cognitive map is defined as a directed graph with nodes and edges to mirror the factors of the problems and their relationship with one another. The plithogenic connection matrix comprises of the degree of appurtenance representing the degree of influence of one factor over another. The most influential factor is determined by finding the limit point of the dynamical system by considering the degree of contraction between the factors. But on deep investigation over the aspects of assigning contradiction degree between the factors several questions arises. In the above developed PCM by Nivetha and Smarandache, the influence and the association between the factors is determined by placing the factors in ON position. If a factor is placed in ON position, then it is assumed to be the dominant factor and the other factors that are in OFF position are assigned the contradiction degree in sequential manner with respect to the dominant factor. For instance, if there are three factors say F1, F2 and F3. If the factor F1 is placed in ON position, then the factor F1 is considered to be dominant and henceforth the contradiction degree of F2 and F3 with respect to F1 are 1/3 and 2/3 respectively. The construction of PCM model based on such a way of assigning of contradiction degree with respect to dominant factors have few shortcomings as follows

- The way of assigning contradiction degree lacks realism.
- The factors considered for making decisions are more alike as they belong to the same category and also, they lack differentiation.
- The numerical degree of contradiction may not be promising at all instances of decision making.

To handle the above stated limitations, PCM model with linguistic contradiction degree is developed in this research work, also in addition to the factors of the decision making problem, the core factors to which these factors are associated are also considered and the contradiction degree of the factors are assigned with respect to the factors but with respect to the core factors to make the representations more meaningful and pragmatic.

The research work is organized into the following sections, section 2 presents the state of art of research of the applications of different representations of Cognitive Map models namely crisp, fuzzy, intuitionistic and neutrosophic with respect to the academic problems of the learners. The Section 3 describes the steps involved in PCM model with linguistic contradiction degree. Section 4 applies the proposed model to the decision making problem on academic stress. Section 5 discusses the results and concludes the work.

2. Literature Review

This section presents the conceptualizations of crisp, fuzzy, intuitionistic, neutrosophic and plithogenic cognitive maps and their application with special reference to the field of education. Cognitive Maps are the primary decision-making tool used in making decisions related to many social entities. Cognitive Maps was initially originated by Robert Alexrod [7] .Fuzzy Cognitive Maps (FCM) developed by Kosko [23] are widely used in the many fields like medicine, Education, agriculture, politics, social awareness, technology, psychology, and many other fields too. These type of cognitive maps are further extended to intuitionistic fuzzy cognitive maps (IFCM). The notion of intuitionistic sets introduced by Atanssov [6] comprises of membership and non-membership values. IFCM are applied in the field of medicine, agriculture, architecture, decision making entities, technology and so on. These IFCMs are also extended to Neutrosophic cognitive Maps (NCM) by Vasantha and Smarandache. The neutrosophic sets introduced by Smarandache comprises truth, intermediate and falsity membership values. NCMs are applied in the fields of medicine, day to day life entities, education, psychology, economics and many other fields too.

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Researchers have applied these decision making approaches in the field of education especially to investigate the academic problems associated with learning, learners and teachers. The decision making based on Cognitive Maps are applied. Gorelova et al [19] in studying the interrelationship between the factors associated with effective education, Banathy [8] in framing the educational system for future generations.

The decision making based on the fuzzy cognitive maps in the field of education are applied. Cole J R et al [11] developed FCM in education, Baron et al [9] in assessment of learning in the environment, Luo X et al [24] in game based learning, Merlin [30] developed augmented fuzzy cognitive maps in education and applied FCM in AJEL type learning in students, Mansouri et al [25] to predict student performance, Anusha et al [4] in analysing the reasons for stress in college students, Devadoss A V et al [12] in environmental education for next generation learners, Prakash P et al [33] in causes for aversion to mathematics by engineering students, Glykas et al [16] in the theories, methodologies and tools, Dias et al [14] in higher education blended learning environment, Asghari et al [5] presented Iran's future higher education scenarios, Pena Ayala et al [32] made an approach of FCM in student centered education, Gordaliza et al [18] used FCM to support complex learning environment, Chiang et al [10] used FCM in supporting underrepresented students and so on.

NCMs are also applied in the field of education. Devadoss et al [13] in studying the quality of primary education, Kalaichelvi et al [21] in studying the problems faced by girl students in the education, Thiruppathi et al [36] made a study in suicide problems using NCM and also gave a solution for the above said problem, Mary et al [29] made a comparative study using NCM on the factors of quality training on student and teachers and so on.

3. Methodology

This section describes the step involved in determining the fixed point of the Plithogenic dynamical system.

Step I: The decision making problem is first well defined and the core factors, sub factors (Fi) encircled with the problem along with the association between the sub factors are initially decided based on the expert's opinion. Inaddition to the sub factors, the core factors are also considered to which each of the factors say Fi are subjected to.

Step 2: The sub factors of the problem are taken as the nodes say P1, P2 ,… Pn. The relationship between the sub factors are represented using the crisp degree of appurtenance which assumes crisp values say {-1,0,1}, fuzzy degree of appurtenance that assumes values from [-1,1], intuitionistic degree of appurtenance that assigns values from $\rho([0,1])^2$and neutrosophic degree of appurtenance that takes values from $\rho([0,1])^3$.

Step 3: The connection matrix representing the associational impact between the factors is termed as Plithogenic crisp, Plithogenic fuzzy, Plithogenic intuitionistic and Plithogenic neutrosophic based on the nature of the degree of appurtenance.

Step 4: An instantaneous vector is of the form Z (t) = (a1,a2,…,an) is initially considered, in which the ai's assume either of the value 0 or 1 to indicate the ON or OFF position of the factors. An instantaneous vector of the form (10000..00) represents the ON position of the first factor and it is passed on to the connection matrix. The resultant vector is obtained using plithogenic operators together with the linguistic contradiction degree of the factors Fi with respect to the core factors. The resultant vector thus obtained is updated using threshold function by assigning the value 1 if the ai's values are greater than 1, 0 if the values of ai's are lesser than 1.

Plithogenic operators are defined as follows:

$$f \wedge_P g = (1-c)[f \wedge_F g] + c[f \vee_F g]$$

where c represents the contradiction degree and

$\wedge_F$ represents the t_{norm} given by $f \wedge_F g = fg$

$\vee_F$ represents the t_{conorm} given by $f \vee_F g = f + g - fg$

The linguistic variable are quantified using fuzzy numbers of conveniences.

Step 5: The Step 4 is repeated until two consecutive resultant vectors are equal

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i.e $|Z(t+1) - Z(t)| \leq \epsilon$

Let us consider a decision making problem on weight management involving three core factors say CF1,CF2 and CF3 and five sub-factors say SF1,SF2,SF3,SF4 and SF5.

In this case the strategies or the measures of weight management are taken into consideration. The main objective is to determine the most significant and most influential strategy.

The core factors that are considered in this context are

CF1 Biological

CF2 Behavioural

CF3 Psychological

The strategies that are considered as the sub factors are as follows

SF1 Refraining from stressful factors

SF2 Avoidance of Junk Food items

SF3 Intake of supplementary nutrients to maintain hormone levels

SF4 Developing a positive tendency of maintaining ideal weight

SF5 Leading a healthy lifestyle by affiliating closely with nature

The association between the sub-factors are presented as a connection matrix of the form

	SF1	SF2	SF3	SF4	SF5
SF1	0	0.2	0.3	0.5	0.7
SF2	0.5	0	0.8	0.7	0.5
SF3	0.3	0.7	0	0.8	0.8
SF4	0.7	0.7	0.5	0	0.7
SF5	0.8	0.7	0.7	0.5	0

The contradiction degree of the sub factors with respect to the core factors are presented in the following table

	SF1	SF2	SF3	SF4	SF5
CF1	0.5	0.2	0.2	0.7	0.5
CF2	0.5	0.7	0.8	0.5	0.5
CF3	0.2	0.5	0.7	0.3	0.5

ON Position of Vectors	Core Factors	SF1	SF2	SF3	SF4	SF5
(1 0 0 0 0)	CF1	1	0.67	0.67	0.85	0.85
	CF2	1	0.88	0.92	0.86	0.86
	CF3	1	0.78	0.86	0.77	0.85

4. Application to Decision making on Academic Stress of the Learners

The emerging problem of the students is the competition among themselves which leads to stress in them. The competitive world leads the children today to a stressful life. The factor causing academic stress among the students are studied by

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educationalist. Majority of the factors are subjected to Personal, Social, Institutional and Economical. Moreover, these factors were analyzed using statistical tools and not using the concept of cognitive maps of any kind. Based on the above said factors, the following are considered as the nodes of Plithogenic Cognitive maps. These nodes are the sub-factors of the decision-making problem subjected to the four core factors of Personal, Economic, Social and Institutional

The following stress causing sub-factors are taken into consideration in constructing a PCM model

1. Peer Competition (P1)
2. Mismanagement of time (P2)
3. Confined evaluation system (P3)
4. Phobia of examinations (P4)
5. Parental pressure (P5)
6. Anxiety of future (P6)
7. Lack of encouragement (P7)
8. Poor family background (P8)
9. Weak bond between student and teacher (P9)
10. Infeasible Learning environment (P10)

Case (i) PCM with Linguistic contradiction degree with respect to Core Factors

To draw conclusions on the interrelationship between the factors, the contradiction degree between the attributes is given by linguistic variables and they are further quantified by triangular numbers as given in Table 4.2

Table 1: Quantifications of Linguistic Variables

Linguistic Representation of Contradiction Degree	**Triangular Quantifications**	**Crisp value**
Very High	(0.7,0.8,0.9)	0.8
High	(0.6,0.7,0.8)	0.7
Moderate	(0.4,0.5,0.6)	0.5
Low	(0.4,0.3,0.2)	0.3
Very Low	(0.3,0.2,0.1)	0.2

Also the contradiction degree of the sub-factors is assumed with respect to each of the core factors as follows.

The contradiction degree of the attributes with respect to the personal aspect of a student is given as in Table 4.3

Table 2: Contradiction degree of the sub-factors with respect to the core factor Personal

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
M	M	VH	L	H	VL	H	VH	VH	VH
0.5	0.5	0.8	0.3	0.7	0.2	0.7	0.8	0.8	0.8

Let us take P1 to be in ON position and the other attributes in OFF position.

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

$X *_P P(E)$ = (0.5 0.75 0.96 0.86 0.85 0.6 0.76 0.84 0.84 0.84)

→ (1 0.75 0.96 0.86 0.85 0.6 0.76 0.84 0.84 0.84) = X1

$X1 *_P P(E)$ = (0.88 0.83 0.96 0.86 0.9248 0.8128 0.9156 0.941 0.9152 0.9088)

→ (1 0.83 0.96 0.86 0.93 0.81 0.92 0.94 0.92 0.91) = X2

$X2 *_P P(E)$ = (0.88 0.91 0.96 0.86 0.9496 0.8608 0.9428 0.9618 0.9344 0.9408)

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→ (1 0.91 0.96 0.86 0.95 0.86 0.94 0.96 0.93 0.94) = X3

X3*$_P$ P(E) = (0.88 0.92 0.96 0.8706 0.9564 0.8756 0.9462 0.967 0.9408 0.9472)

→ (1 0.92 0.96 0.87 0.96 0.88 0.95 0.97 0.94 0.95) = X4

X4*$_P$ P(E) = (0.88 0.925 0.96 0.8772 0.9598 0.883 0.9496 0.9696 0.944 0.9504)

→ (1 0.93 0.96 0.88 0.96 0.88 0.95 0.97 0.94 0.95) = X5

X5*$_P$ P(E) = (0.88 0.925 0.96 0.8838 0.9598 0.883 0.9496 0.9696 0.944 0.9504)

→ (1 0.93 0.96 0.88 0.96 0.88 0.95 0.97 0.94 0.95) = X6

X5 = X6

Thus the fixed points of the system is obtained. The result obtained shall be interpreted as follows: the interrelationship between the factor P1 and other factors with respect to personal core factor is reflected in the fixed point. The degree of association of the factor P1 with factors P8, P3, P5 are very high and that of with the factors P4 and P6 is high. The same shall be repeated by keeping other factors in ON position.

By repeating the same procedure for other core factors the results obtained are tabulated in Table 4.4.

Table 3: Interrelationship score values between the sub-factors with respect to the core factors

ON Position of Vectors	Core Factors	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
(1000000000)	P	1	0.93	0.96	0.88	0.96	0.88	0.95	0.97	0.94	0.95
	E	1	0.94	0.96	0.96	0.84	0.88	0.92	0.81	0.93	0.81
	S	1	0.93	0.9	0.95	0.81	0.79	0.82	0.83	0.83	0.72
	I	1	0.92	0.84	0.91	0.97	0.89	0.86	0.97	0.78	0.84
(0100000000)	P	0.88	1	0.94	0.93	0.96	0.88	0.95	0.97	0.94	0.95
	E	0.94	1	0.95	0.98	0.85	0.88	0.92	0.83	0.93	0.82
	S	0.9	1	0.89	0.97	0.82	0.84	0.86	0.84	0.84	0.73
	I	0.89	1	0.81	0.95	0.97	0.9	0.86	0.97	0.81	0.84
(0010000000)	P	0.9	0.93	1	0.88	0.96	0.88	0.95	0.97	0.94	0.95
	E	0.96	0.94	1	0.96	0.86	0.87	0.92	0.82	0.93	0.81
	S	0.94	0.93	1	0.95	0.84	0.84	0.82	0.83	0.83	0.72
	I	0.9	0.92	1	0.91	0.97	0.9	0.86	0.97	0.78	0.84
(0001000000)	P	0.88	0.93	0.96	1	0.96	0.89	0.96	0.97	0.96	0.95
	E	0.95	0.94	0.96	1	0.86	0.88	0.92	0.84	0.94	0.82
	S	0.9	0.94	0.9	1	0.84	0.8	0.84	0.86	0.86	0.75
	I	0.89	0.92	0.84	1	0.97	0.89	0.86	0.97	0.84	0.84
(0000100000)	P	0.9	0.93	0.93	0.88	1	0.88	0.95	0.98	0.94	0.95
	E	0.96	0.94	0.95	0.96	1	0.88	0.92	0.92	0.93	0.86
	S	0.94	0.94	0.88	0.95	1	0.84	0.86	0.93	0.83	0.79
	I	0.9	0.92	0.78	0.91	1	0.9	0.86	0.98	0.78	0.85
(0000010000)	P	0.9	0.94	0.93	0.89	0.96	1	0.97	0.97	0.95	0.95
	E	0.96	0.95	0.95	0.97	0.84	1	0.95	0.84	0.93	0.82
	S	0.94	0.96	0.88	0.96	0.82	1	0.93	0.86	0.84	0.75
	I	0.9	0.95	0.79	0.93	0.97	1	0.93	0.97	0.79	0.84

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(0000001000)	P	0.88	0.95	0.93	0.9	0.96	0.92	1	0.97	0.96	0.95
	E	0.94	0.97	0.95	0.97	0.84	0.93	1	0.82	0.94	0.81
	S	0.91	0.98	0.88	0.96	0.81	0.92	1	0.84	0.86	0.73
	I	0.88	0.97	0.8	0.94	0.97	0.95	1	0.97	0.84	0.84
(0000000100)	P	0.89	0.93	0.93	0.88	0.97	0.88	0.95	1	0.94	0.96
	E	0.94	0.94	0.95	0.96	0.93	0.88	0.92	1	0.93	0.9
	S	0.91	0.93	0.88	0.95	0.92	0.84	0.82	1	0.83	0.84
	I	0.89	0.92	0.78	0.91	0.98	0.9	0.86	1	0.78	0.86
(0000000010)	P	0.88	0.94	0.93	0.89	0.96	0.9	0.97	0.97	1	0.95
	E	0.94	0.95	0.95	0.97	0.84	0.9	0.95	0.82	1	0.81
	S	0.89	0.96	0.88	0.96	0.81	0.87	0.93	0.84	1	0.73
	I	0.89	0.95	0.79	0.93	0.97	0.92	0.93	0.97	1	0.84
(0000000001)	P	0.88	0.93	0.92	0.88	0.96	0.88	0.95	0.97	0.94	1
	E	0.94	0.94	0.95	0.96	0.84	0.88	0.92	0.81	0.93	1
	S	0.89	0.94	0.88	0.95	0.81	0.82	0.86	0.83	0.83	1
	I	0.89	0.92	0.78	0.91	0.97	0.89	0.86	0.97	0.78	1

Case (ii) : PCM with Linguistic contradiction degree with respect to Factors

The obtained results in Table 4.4 are compared with the results obtained using the approach of PCM developed in [60]

Let us determine the approach of PCM to our problem which considers the linguistic contradiction degree between only the sub-factors without the intervention of the core factors. Let us take P1 to be in ON position and the other factors to be in OFF state. The contradiction degree of the node P1 with respect to the other nodes are as represented in Table 4.5.

Table 4: Contradiction degree of the node P1 with respect to the other nodes

P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
0	M	L	L	M	M	H	H	H	M
0	0.5	0.3	0.3	0.5	0.5	0.7	0.7	0.7	0.5

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

$X*_P$ P(E) = (0 0.75 0.86 0.86 0.75 0.75 0.76 0.76 0.76 0.6)

→ (1 0.75 0.86 0.86 0.75 0.75 0.76 0.76 0.76 0.6) = X1

$X1*_P$ P(E) = (0.688 0.83 0.86 0.86 0.83 0.83 0.8884 0.8868 0.8868 0.78)

→ (1 0.83 0.86 0.86 0.83 0.83 0.89 0.89 0.89 0.78) = X2

$X2*_P$ P(E) = (0.688 0.895 0.86 0.86 0.895 0.895 0.9326 0.9122 0.8982 0.845)

→ (1 0.9 0.86 0.86 0.9 0.9 0.93 0.91 0.9 0.85) = X3

$X3*_P$ P(E) = (0.72 0.915 0.86 0.864 0.905 0.915 0.936 0.936 0.9134 0.855)

→ (1 0.92 0.86 0.86 0.91 0.92 0.94 0.94 091 0.86) = X4

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X4*P P(E) = (0.736 0.92 0.86 0.8772 0.92 0.92 0.9428 0.9394 0.9172 0.87)

→ (1 0.92 0.86 0.88 0.92 0.92 0.92 0.94 0.94 0.92 0.87) = X5

X5*P P(E) = (0.736 0.92 0.86 0.8772 0.92 0.92 0.9428 0.9428 0.9172 0.87)

→ (1 0.92 0.86 0.88 0.920.92 0.94 0.94 0.92 0.87) = X6

X5 = X6

In the above obtained fixed point the factor P1 has closer association with the factors P7 and P8, but it is not possible to make interpretations on the nature of association. The results obtained by considering each of the factors are presented in Table 4.6

Table 5: Fixed Point of the ON position of the factors of PCM

ON position of vectors	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
(1000000000)	1	0.92	0.86	0.88	0.92	0.92	0.94	0.94	0.92	0.87
(0100000000)	0.92	1	0.88	0.95	0.95	0.92	0.94	0.95	0.92	0.92
(0010000000)	0.9	0.93	1	0.88	0.95	0.86	0.88	0.95	0.79	0.83
(0001000000)	0.82	0.89	0.86	1	0.9	0.93	0.88	0.9	0.9	0.9
(0000100000)	0.86	0.88	0.89	0.86	1	0.86	0.86	0.95	0.89	0.92
(0000010000)	0.86	0.92	0.89	0.88	0.95	1	0.93	0.95	0.87	0.92
(0000001000)	0.87	0.93	0.89	0.88	0.92	0.93	1	0.94	0.86	0.82
(0000000100)	0.91	0.9	0.91	0.86	0.93	0.86	0.9	1	0.9	0.9
(0000000010)	0.88	0.88	0.87	0.94	0.95	0.88	0.93	0.95	1	0.88
(0000000001)	0.9	0.94	0.8	0.89	0.9	0.9	0.9	0.9	0.8	1

5 Discussion

The average values of the interrelational impacts in the first case is presented in Table 5.1 and the differences between the values obtained in Table 4.6 between each of the interrelational impacts are presented in Table 5.2

Table 6: Average values of the Interrelationship score values between the sub-factors with respect to the core factors

ON position of vectors	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
(1000000000)	1	0.93	0.92	0.93	0.9	0.86	0.89	0.9	0.87	0.83
(0100000000)	0.9	1	0.9	0.96	0.9	0.88	0.9	0.9	0.88	0.84
(0010000000)	0.93	0.93	1	0.93	0.9	0.87	0.89	0.9	0.87	0.83
(0001000000)	0.91	0.93	0.92	1	0.91	0.87	0.9	0.91	0.9	0.84
(0000100000)	0.93	0.93	0.89	0.93	1	0.88	0.9	0.95	0.87	0.86
(0000010000)	0.93	0.95	0.89	0.94	0.9	1	0.95	0.91	0.88	0.84
(0000001000)	0.9	0.97	0.89	0.94	0.9	0.93	1	0.9	0.9	0.83
(0000000100)	0.91	0.93	0.89	0.93	0.95	0.88	0.89	1	0.87	0.89

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(0000000010)	0.9	0.95	0.89	0.94	0.9	0.9	0.95	0.9	1	0.83
(0000000001)	0.9	0.93	0.88	0.93	0.9	0.9	0.9	0.9	0.87	1

Table 7: Differences between the values with respect to case (i) & case (ii)

ON position of vectors	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
(1000000000)	0	0.01	0.06	0.05	-0.02	-0.06	-0.05	-0.04	-0.05	-0.04
(0100000000)	-0.02	0	0.02	0.01	-0.05	-0.04	-0.04	-0.05	-0.04	-0.08
(0010000000)	0.03	0	0	0.05	-0.05	0.01	0.01	-0.05	0.08	0
(0001000000)	0.09	0.04	0.06	0	0.01	-0.06	0.02	0.01	0	-0.06
(0000100000)	0.07	0.05	0	0.07	0	0.02	0.04	0	-0.02	-0.06
(0000010000)	0.07	0.03	0	0.06	-0.05	0	0.02	-0.04	0.01	-0.08
(0000001000)	0.03	0.04	0	0.06	-0.02	0	0	-0.04	0.04	0.01
(0000000100)	0	0.03	-0.02	0.07	0.02	0.02	-0.01	0	-0.03	-0.01
(0000000010)	0.02	0.07	0.02	0	-0.05	0.02	0.02	-0.05	0	-0.05
(0000000001)	0	-0.01	0.08	0.04	0	0	0	0	0.07	0

On observing the differences, it is very evident that the results obtained in both the cases are promising, but in the latter case the nature of the interrelation cannot be determined whereas in the first case the nature of the interrelation is very explicit and henceforth the decision making is made more comprehensive.

Conclusion

This paper proposes a modified version of plithogenic cognitive maps with linguistic contradiction degree. The newly developed PCM model is more advantageous in comparison to the earlier formulated PCM. The extended PCM model is highly compatible in making interpretations on the associations between the factors in relation with the core factors of the decision making problem. The comparative analysis substantiates the efficacy of the constructed model. As an extension of this research work, the PCM based on contradictions using linguistic variable shall be associated with other decision making methods.

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References

[1] Abdel-Basset, M., Ding, W., Mohamed, R., & Metawa, N. (2020). An integrated plithogenic MCDM approach for financial performance evaluation of manufacturing industries. *Risk Management*, *22*, 192-218.

[2] Ahmad, M. R., & Afzal, U. (2022). Mathematical modeling and AI based decision making for COVID-19 suspects backed by novel distance and similarity measures on plithogenic hypersoft sets. *Artificial Intelligence in Medicine*, *132*, 102390.

[3] Ahmad, M. R., Saeed, M., Afzal, U., & Yang, M. S. (2020). A novel MCDM method based on plithogenic hypersoft sets under fuzzy neutrosophic environment. *Symmetry*, *12*(11), 1855.

[4] Anusha, G., & Ramana, P. V. (2015). Analysis of Reasons for Stress on College Students using Combined Disjoint Block Fuzzy Cognitive Maps (CDBFCM). *International Journal For Research In Emerging Science And Technology*, *2*, 16-21.

DOI: https://doi.org/10.54216/IJNS.210312
Received: February 17, 2023 Revised: May 28, 2023 Accepted: June 22, 2023

[5] Asghari, S., & Akbarpour Shirazi, M. (2023). Presenting Iran's future higher education scenarios using fuzzy cognitive maps. *Research and Planning in Higher Education*, *24*(1), 1-26.
[6] Atanassov, K. (2016). Intuitionistic fuzzy sets. *International journal bioautomation*, *20*, 1.
[7] Axelrod, R. (Ed.). (2015). *Structure of decision: The cognitive maps of political elites*. Princeton university press.
[8] Banathy, B. H. (1991). Cognitive mapping of educational systems for future generations. *World Futures: Journal of General Evolution*, *31*(1), 5-17.
[9] Barón, H. B., Crespo, R. G., Pascual Espada, J., & Martínez, O. S. (2015). Assessment of learning in environments interactive through fuzzy cognitive maps. *Soft Computing*, *19*, 1037-1050.
[10] Chiang, D. F., Guerrero, S. A., & Sexton, E. C. (2023). Supporting Underrepresented Students in Health Sciences: Using a Fuzzy Cognitive Mapping Approach.
[11] Cole, J. R., & Persichitte, K. A. (2000). Fuzzy cognitive mapping: Applications in education. *International journal of intelligent systems*, *15*(1), 1-25.
[12] Devadoss, A. V., Anand, M. C. J., & Bellarmin, A. J. (2013). A Study of Quality in Primary Education Combined Disjoint Block Neutrosophic Cognitive Maps (CDBNCM). In *Indo-Bhutan International Conference On Gross National Happiness* (Vol. 2, pp. 256-261).
[13] Devadoss, A. V., Anand, M. C. J., Felix, A., & Alexandar, S. (2015). A analysis of environmental education for the next generation using combined disjoint block fuzzy cognitive maps (CDBFCMS). In *Indo-Bhutan international conference on gross national happiness* (pp. 262-268).
[14] Dias, S. B., Hadjileontiadou, S. J., Hadjileontiadis, L. J., & Diniz, J. A. (2015). Fuzzy cognitive mapping of LMS users' quality of interaction within higher education blended-learning environment. *Expert systems with Applications*, *42*(21), 7399-7423.
[15] Gayen, S., Smarandache, F., Jha, S., Singh, M. K., Broumi, S., & Kumar, R. (2020). *Introduction to plithogenic hypersoft subgroup*. Infinite Study.
[16] Glykas, M. (Ed.). (2010). *Fuzzy cognitive maps: Advances in theory, methodologies, tools and applications* (Vol. 247). Springer Science & Business Media.
[17] Gómez, G. Á., Moya, J. V., Ricardo, J. E., & Sánchez, C. B. V. (2020). *Evaluating Strategies of Continuing Education for Academics Supported in the Pedagogical Model and Based on Plithogenic Sets* (Vol. 37). Infinite Study.
[18] Gordaliza, J. A., & Flórez, R. E. V. (2013). Using fuzzy cognitive maps to support complex environmental issues learning. In *Proceedings of New Perspectives in Science Education Conference,*.
[19] Gorelova, G. V., LYABACH, N. N., & KUIZHEVA, S. K. (2017). Application of Cognitive Modeling in the Study of the Interrelations between the Educational system and Society. *Revista ESPACIOS*, *38*(56).
[20] Grida, M., Mohamed, R., & Zaied, A. N. H. (2021). *A novel plithogenic MCDM framework for evaluating the performance of IoT based supply chain*. Infinite Study.
[21] Kalaichelvi, A., & Gomathy, L. (2011). Application of neutrosophic cognitive maps in the analysis of the problems faced by girl students who got married during the period of study. *Int. J. of Mathematical Sciences and Applications*, *1*(3).
[22] Kandasamy, W. V., & Smarandache, F. (2003). *Fuzzy cognitive maps and neutrosophic cognitive maps*. Infinite Study.
[23] Kosko, B. (1986). Fuzzy cognitive maps. *International journal of man-machine studies*, *24*(1), 65-75.
[24] Luo, X., Wei, X., & Zhang, J. (2009, October). Game-based learning model using fuzzy cognitive map. In *Proceedings of the first ACM international workshop on Multimedia technologies for distance learning* (pp. 67-76).
[25] Mansouri, T., ZareRavasan, A., & Ashrafi, A. (2021). A learning fuzzy cognitive map (LFCM) approach to predict student performance. *Journal of Information Technology Education: Research*, *20*, 221-243.
[26] Martin, N. (2022). Plithogenic SWARA-TOPSIS Decision Making on Food Processing Methods with Different Normalization Techniques. *Advances in Decision Making*, 69.
[27] Martin, N., & Smarandache, F. (2020). Plithogenic cognitive maps in decision making. *Infinite Study*.
[28] Martin, N., Priya, R., & Smarandache, F. (2021). *New Plithogenic sub cognitive maps approach with mediating effects of factors in COVID-19 diagnostic model*. Infinite Study.
[29] Mary, M. F. J., & Merlin, M. M. M. *A Comparative Study Using Neutrosophic Cognitive Map and Triangular Fuzzy Cognitive Map for Analyzing The Factors for Quality Training of Elementary Education Student Teachers In Tamilnadu*. Infinite Study.

DOI: https://doi.org/10.54216/IJNS.210312
Received: February 17, 2023 Revised: May 28, 2023 Accepted: June 22, 2023

[30] Merlin, M. (2015). Application of augmented fuzzy cognitive map in education. *International Journal in IT & Engineering*, *3*(3), 39-54.
[31] Özçil, A., Tuş, A., Öztaş, G. Z., Adalı, E. A., & Öztaş, T. (2021). The novel integrated model of plithogenic sets and MAIRCA method for MCDM problems. In *Intelligent and Fuzzy Techniques: Smart and Innovative Solutions: Proceedings of the INFUS 2020 Conference, Istanbul, Turkey, July 21-23, 2020* (pp. 733-741). Springer International Publishing.
[32] Peña-Ayala, A., & Sossa-Azuela, J. H. (2013). Decision making by rule-based fuzzy cognitive maps: an approach to implement student-centered education. In *Fuzzy cognitive maps for applied sciences and engineering: From fundamentals to extensions and learning algorithms* (pp. 107-120). Berlin, Heidelberg: Springer Berlin Heidelberg.
[33] Prakash, P., Jerlin, E., & Fernandes, B. (2014). A study on the causes for aversion to mathematics by engineering students using fuzzy cognitive maps (FCMs). *International Journal of Innovative Research in Science*, *Engineering and Technology*, *3*(3), 10143-10150.
[34] Priya, R., Martin, N., & Kishore, T. E. (2022, May). Plithogenic cognitive analysis on instigating spiritual intelligence in smart age youth for humanity redemption. In *AIP Conference Proceedings* (Vol. 2393, No. 1, p. 020181). AIP Publishing LLC.
[35] Rana, S., Qayyum, M., Saeed, M., Smarandache, F., & Khan, B. A. (2019). *Plithogenic fuzzy whole hypersoft set, construction of operators and their application in frequency matrix multi attribute decision making technique*. Infinite Study.
[36] Thiruppathi, P., Saivaraju, N., & Ravichandran, K. S. (2010). A study on suicide problem using combined overlap block neutrosophic cognitive maps. *International Journal of Algorithms, Computing and Mathematics*, *3*(4), 22-28.
[37] Ulutaş, A., Meidute-Kavaliauskiene, I., Topal, A., & Demir, E. (2021). Assessment of collaboration-based and non-collaboration-based logistics risks with plithogenic SWARA method. *Logistics*, *5*(4), 82.

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