A MODIFIED LINGUISTIC FUZZY COGNITIVE MAPS

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Abstract: In the Fuzzy theory to obtain a meaningful decision and for better understanding, defuzzification is the main process. It is used to produce output in terms of crisp values. Therefore, the Converting of Fuzzy data into Crisp Scales (CFCS) method proposed by Opricovic and Tzeng is used to construct a modified FCM. Thanthai Periyar was an atheist, social reformer, rationalist and an original thinker who had a great impact over the history of Tamilnadu. In this paper we analyses how the Periyar's philosophies on self-Respect have influenced the society using modified linguistic Fuzzy Cognitive Maps (FCMs).

Keywords: Fuzzy Cognitive maps - Modified linguistic Fuzzy Cognitive Maps - Thanthai Periyar E.V Ramasamy - self-Respect

Introduction: Thanthai Periyar E.V Ramasamy (1897-1973) was a unique social reformer and humanist of twentieth century. His Philosophy was all men and women should live with dignity and have equal opportunity. He formed the self – respect movement in 1925 .It carried out on a vigorous and ceaseless propagation against ridiculous and harmful superstitions, traditions customs and habits (Rathinagiri 2003). The current study examines Periyar's view on self- respect and how it influenced the society using Fuzzy Cognitive maps and Triangular FCM. Axelrod. R proposed Cognitive Maps to study political decision making problem (Axelrod1976).

Kosko introduced Fuzzy Cognitive maps (FCM) by enhancing the power of cognitive maps with fuzzy values for the concept of the cognitive map and fuzzy degree of interrelationships between concepts (Kosko 1986, 1997). FCM can successfully represent knowledge and human experience, it introduces the concept to represent the essential elements and the cause and effect relationships among the concepts to model the behaviour of any system. Devadoss et.al, used linguistic triangular fuzzy number in FCM to bring stronger relationship among the factors (Devadoss 2013). Under the Fuzzy environment to obtain a meaningful decision and for better understanding, defuzzification is the main process used to produce output in terms of crisp values. Therefore, the Converting of Fuzzy data into Crisp Scales (CFCS) method proposed by Opricovic and Tzeng (Opricovic 2003) is used to construct a modified FCM. In this current study, it is anlyzed how the Periyar's philosophies on self-Respect have influenced the society using the above mentioned methods.

Fuzzy Cognitive Maps (FCMs): Fuzzy Cognitive Maps (FCMs) are more applicable when the data in the first Place is an unsupervised one. The FCMs work on the opinion of experts. FCMs model the world as a collection of classes and causal relations between classes.

Definition 2.1: A FCMs is a directed graph with concepts like policies, events etc, as nodes and causalities as edges. It represents causal relationship between concepts.

Definition 2.2: When the nodes of the FCM are fuzzy sets then they are called as fuzzy nodes.

Definition 2.3: FCMs with edge weights or causalities from the set {-1, 0, 1} are called simple FCMs

Definition 2.4: Let C_i and C_j denote the two nodes of the FCM. The directed edge from C_i to C_j denote the causality of C_i on C_j called connections. Every edge in the NCM is weighted with a number in the set {-1, 0, 1}. Let e_{ij} be the weight of the directed edge C_iC_j, $e_{ij} \in$ {.1, 0, 1}. e_{ij} = 0 if C_i does not have any effect on C_j, e_{ij} = 1 if increase (or decrease) in C_i causes increase (or decreases) in C_j. e_{ij} =1 if increase (or decrease) in C_i causes decrease (or increase) in C_j

Definition 2.5: Let $C_1, C_2, \ldots, C_n$ be nodes of a FCM. Let the adjacency matrix E be defined as $E=(e_{ij})$ where e_{ij} is the weight of the directed edge C_iC_j, where $e_{ij} \in$ {0, 1}.

Definition 2.6: Let $C_1, C_2, \ldots, C_n$ be the nodes of the FCM. Let $A = \{a_1, a_2 \ldots a_n\}$, where $a_i \in \{0, 1\}$. A is called the instantaneous state vector and it denotes the on-off state position of the node at an instant

a_i = 0 if a_i is off (no effect)

a_i = 1 if a_i is on (has effect) for $i=1,2..n$

Definition 2.7: Let $C_1, C_2, \ldots, C_n$ be the nodes of the FCM. Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3} \ldots \overrightarrow{C_iC_j}$ be the edges of the FCM. Then the edges form a directed cycle. An FCM is said to be cyclic if it possesses a directed cyclic. An FCM is said to be acyclic if it does not possess any directed cycle.

Definition 2.8: An FCM with cycles is said to have a feedback. When there is a feedback in the FCM i.e. when the causal relations flow through a cycle in a revolutionary manner the FCM is called a dynamical system.

Definition 2.9: Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}...\overrightarrow{C_{n-1}C_n}$ be cycle, when C_i is switched on and if the causality flow through the edges of a cycle and if it again causes C_i, we say that the dynamical system goes round and round. This is true for any node C_i, for $i=1,2...n$ the equilibrium state for this dynamical system is called the hidden pattern.

Definition 2.10: If the equilibrium state of a dynamical system is a unique state vector, then it is called a fixed point. Consider the FCM with $C_1, C_2,...,C_9$ as nodes. For example let us start the dynamical system by switching on C_1 Let us assume that the NCM settles down with C_1 and C_n on, i.e. the state vector remain as (1, 0 ,., 1) this state vector (1,0,., 0, 1) is called the fixed point.

Definition 2.11: If the FCM settles with a state vector repeating in the form $A_1 \to A_2 \to ... A_i \to A_1$ then this equilibrium is called a limit cycle of the FCM.

Method of Determining Hidden Pattern in FCM: Let $\{C_1, C_2,...,C_n\}$ be the nodes of an FCM, with feedback. Let E be the associated adjacency matrix. Let us find the hidden pattern when C_1 is switched on when an input is given as the vector $A_1 = (1, 0, 0,., 0)$, the data should pass through the matrix E, this is done by multiplying A1 by the matrix E. Let $A_1E=\{a_1, a_2...,a_3\}$ with the threshold operation that is by replacing ai by 1 if $a_i > k$ and a_i by 0 if $a_i < k <$ ($k-a$ suitable positive integer). We update the resulting concept, the concept C_1 is included in the updated vector by making the first coordinate as 1 in the resulting vector. Suppose $A_2E \to A_2$ then consider A_2E and repeat the same procedure. This procedure is repeated till we get a limit cycle or a fixed point.

Fuzzy set theory: Fuzzy theory deals with vagueness of human thoughts and language in the process of making decisions. Decision makers opine, evaluate and resolve situations using their knowledge and experiences from the past. Their assessments are often delivered in a muddled way with linguistic slips. In order to integrate various experiences, opinions and impetus of an individual decision maker, it is better to convert the linguistic estimation into fuzzy numbers. Thus the problems one encounters in arriving at (mass) decision-making in real world have generated a need for fuzzy logic.

Definition 3.1. A fuzzy set $\tilde{A}$ is a subset of a universe of discourse *X*, which is characterized by a membership function $\mu_{\tilde{A}}(x)$ representing a mapping $\mu_{\tilde{A}}: X \to [0,1]$. The function value of $\mu_{\tilde{A}}(x)$ is called the membership value, which represents the degree of truth that *x* is an element of fuzzy set $\tilde{A}$.

Definition 3.2. A fuzzy set $\tilde{A}$ defined on the set of real numbers R is said to be a fuzzy number and its membership function $\tilde{A}: R \to [0,1]$ has the following characteristics, [18]

1. $\tilde{A}$ is convex.
$\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min(\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)),$
$\forall x \in [x_1, x_2], \lambda \in [0,1].$
2. $\tilde{A}$ is normal if $\max \mu_{\tilde{A}}(x) = 1$.
3. $\tilde{A}$ is piecewise continuous.

Definition 3.3. The α-cut of the fuzzy set $\tilde{A}$ of the universe of discourse X is defined as $\tilde{A}_\alpha = \{x \in X / \mu_{\tilde{A}}(x) \geq \alpha\}$, where $\alpha \in [0,1]$.

Definition 3.4. A triangular fuzzy number $\tilde{N}$ can be defined as a triplet (*l, m, u*), and the Membership function $\mu_{\tilde{N}}(x)$ is defined as: [18]

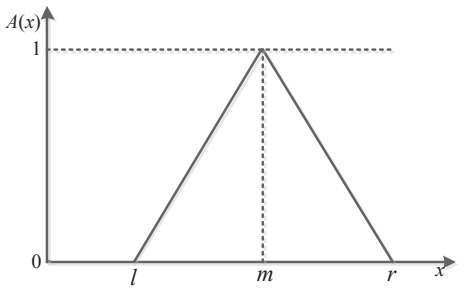

Fig.3: A triangular Fuzzy number $\tilde{A}$

$$\mu_{\tilde{N}}(x) = \begin{cases} \dfrac{x-l}{m-l} & l \leq x \leq m \\ \dfrac{r-x}{r-m} & m \leq x \leq r \\ 0 & \text{otherwise} \end{cases}$$

Where *l*, *m* and *r* are real numbers and $l \leq m \leq r$.

Theorem 3.1. Let $\tilde{N}_1 = (l_1, m_1, r_1)$ and $\tilde{N}_2 = (l_2, m_2, r_2)$ be two triangle fuzzy numbers. The addition, subtraction, multiplication operations of $\tilde{N}_1$ and $\tilde{N}_2$, denoted by $\tilde{N}_1 \oplus \tilde{N}_2, \tilde{N}_1 \Theta \tilde{N}_2$ and $\tilde{N}_1 \otimes \tilde{N}_2$ respectively, yield another triangular fuzzy number.

$\tilde{N}_1 \oplus \tilde{N}_2 = (l_1 + l_2, m_1 + m_2, r_1 + r_2)$

$\tilde{N}_1 \Theta \tilde{N}_2 = (l_1 - r_2, m_1 - m_2, r_1 - l_2)$

$k \otimes \tilde{N}_1 = (kl_1, km_1, kr_1),\ k > 0$ a crisp number

$\tilde{N}_1 \otimes \tilde{N}_2 = (l_1 \times l_2, m_1 \times m_2, r_1 \times r_2)$

Definition 3.5. A Linguistic variable / term is variable whose value is not crisp number but word or sentence linguistic in a natural language. (Zadeh, 1975) [30]

Experts may provide their judgment in the linguistic term when they have no clear idea about it. This uncertain linguistic term is used as an input in decision analysis. Linguistic values are represented as fuzzy number. Triangular fuzzy numbers are commonly used. In the fuzzy expert system, finally fuzzy value is converted into crisp value. The converting of Fuzzy data into Crisp Scales (CFCS) method was proposed by Opricovic and Tzeng (Opricovic 2003)

The CFCS defuzzification method: The CFCS method involves a five step algorithms follows.

Let $A_{ij} = (l_{ij}^k, m_{ij}^k, r_{ij}^k)$ mean the degree of criteria *i* affects criteria *j* and experts k (k=1, 2, 3...p).

Step1: Normalization

$$xr_{ij}^k = (r_{ij}^k - \min l_{ij}^k) \Big/ \Delta_{\min}^{\max}$$

$$xm_{ij}^k = (m_{ij}^k - \min l_{ij}^k) \Big/ \Delta_{\min}^{\max}$$

$$xl_{ij}^k = (l_{ij}^k - \min l_{ij}^k) \Big/ \Delta_{\min}^{\max}$$

Where $\Delta_{\min}^{\max} = \max r_{ij}^k - \min l_{ij}^k$

Step2: Compute right side and left side normalized values:

$$xrs_{ij}^k = xr_{ij}^k \Big/ (1 + xr_{ij}^k - xm_{ij}^k)$$

$$xls_{ij}^k = xm_{ij}^k \Big/ (1 + xm_{ij}^k - xl_{ij}^k)$$

Step3: Compute total normalizes crisp values:

$$x_{ij}^k = [xls_{ij}^k (1 - xls_{ij}^k) + xrs_{ij}^k \times xrs_{ij}^k] \Big/ [1 - xls_{ij}^k + xrs_{ij}^k]$$

Step4: Compute crisp values:

$$z_{ij}^k = \min l_{ij}^k + x_{ij}^k \times \Delta_{\min}^{\max}$$

Step5: Integrate the crisp values:

$$z_{ij} = 1/p\,(z_{ij}^1 + z_{ij}^2 + \ldots + z_{ij}^p)$$

Modified Fuzzy Cognitive Maps: The procedure of the proposed modified Fuzzy Cognitive Maps is described as follows.

Step 1: Set up the linguistic initial direct- relation matrix *X*.

Let $C=\{C_1, C_2, \ldots, C_n\}$ be a finite set of attributes and $E=\{E_1, E_2, \ldots, E_m\}$ be the finite set of experts. Then, Experts provides their opinion on the correlation among the attributes in terms of their vocal language from the linguistic set *L*={*Very Low, Low Influence, Medium, High Influence, Very High Influence*}.

Step 2: Transform Linguistic Variable in to Triangular fuzzy numbers Matrices *T*.

With the help of triangular fuzzy membership function, the Linguistic Variables are transformed into triangular fuzzy Number.

Step 3: Set up the crisp value direct-relation matrix *E*

Using CFCS Algorithm, a crisp value direct-relation matrix is developed for each attributes.

Step: 4 Consider the dynamical system as matrix $E_{(m\,x\,n)}$ and $A_{(1\,x\,n)}$ as the input vector

Step: 5 Pass on the vector $A_i\ (i = 1, 2, \ldots, n)$ into a system *E* and let its resultant be $A_i E = (x_1', x_2', \ldots, x_n')$

Step: 6 Threshold and update this *AE* using the sigmoidal function S as

$S(x_j') = 0$ if $x_j \le 0$ $1 \le j \le n$

$S(x_j') = 1$ if $x_j > 0$ $1 \le j \le n$

i.e. if $x_1', x_2' \ldots, x_n' \hookrightarrow x_1, x_2, \ldots, x_n$

We use the symbol $\hookrightarrow$ for thresholding. Moreover, keep the state x_j is ON, If it was in ON position in $A_i\ (i = 1, 2, \ldots, n)$ A_i. Then, the values x_i, are either 0 or 1

Step: 7 Assign $A_i \leftarrow x_1, x_2, \ldots, x_n$

Go to step 5,

Stop: when the resultant vector converges $A_i = A_j$.

Adaptation of the Problem: The following attributes related to Periyar and self-respect was given by an expert who is a Periyarist.

C_1-Racial Consciousness
C_2-Rationalism
C_3-Humanism
C_4-Scientific thinking
C_5-Castesim / religion
C_6-Women's right

We formed a directed graph based on expert opinion.

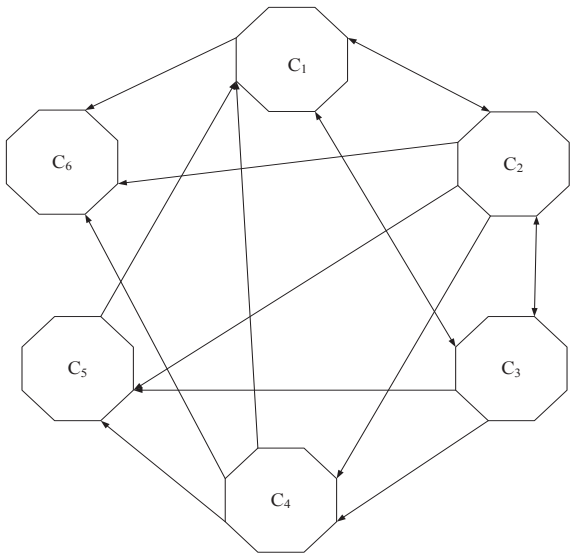

Fig-1: The directed graph for FCM

The related connection matrix M is as follows

	C1	C2	C3	C4	C5	C6
C1	0	1	1	1	1	1
C2	1	0	1	1	1	1

C3	1	1	0	1	1	1
C4	1	1	0	0	1	1
C5	1	0	0	0	0	0
C6	0	0	1	0	0	0

Let us consider that the node rationalism is kept in ON state and other nodes are in OFF state. i.e. the input vector is C1 ={0 1 0 0 0 0}

C1M= (0 1 0 0 0 0)M = (1 0 1 1 1 1) ↪ (1 1 1 1 1 1) = X1

X1M=(1 1 1 1 1 1)M= (4 3 4 4 4 4)

↪ (1 1 1 1 1 1) = X2=X1 (The resultant vectors are convergent. Therefore, it is the limit point for the input vector.)

No	Input Vector	Limit Points
1	(1 0 0 0 0 0)	(1 1 1 1 1 1)
2	(0 1 0 0 0 0)	(1 1 1 1 1 1)
3	(0 0 1 0 0 0)	(1 1 1 1 1 1)
4	(0 0 0 1 0 0)	(1 1 1 1 1 1)
5	(0 0 0 0 1 0)	(1 1 1 1 1 1)
6	(0 0 0 0 0 1)	(1 1 1 1 1 1)

Table: 1 Output for FCM

Next, the problem is analyzed through modified linguistic Fuzzy Cognitive Maps.

Step 1: Set up the linguistic initial direct- relation matrix *X*.

The linguistic direct relation matrix X is derive with the aid of expert, who is a Periyarist.

	C1	C2	C3	C4	C5	C6
C1	0	VH	H	H	M	M
C2	VH	0	M	H	L	M
C3	M	M	0	L	VH	H
C4	H	H	M	0	M	M
C5	VL	VL	L	VL	0	L
C6	M	M	H	H	L	0

Table: The linguistic initial direct- relation matrix *X*

Step 2: Transform Linguistic Variable in to Triangular fuzzy numbers Matrices T.

	C1	C2	C3	C4	C5	C6
C1	0	(0.75, 1, 1)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)
C2	(0.75, 1, 1)	0	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0, 0.25, 0.5)	(0.25, 0.5, 0.75)
C3	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	0	(0, 0.25, 0.5)	(0.75, 1, 1)	(0.5, 0.75, 1)
C4	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	0	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)
C5	(0, 0, 0.25)	(0, 0, 0.25)	(0, 0.25, 0.5)	(0, 0, 0.25)	0	(0, 0.25, 0.5)
C6	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0, 0.25, 0.5)	0

Table: Triangular fuzzy Matrices *T*.

Step 3: Set up the crisp value direct-relation matrix *E*

Using CFCS Algorithm (Chapter 3.3), a crisp value direct-relation matrix *E* is derived. Here E is treated as a dynamical system.

	C1	C2	C3	C4	C5	C6
C1	0	0.97	0.73	0.73	0.5	0.5
C2	0.97	0	0.5	0.73	0.33	0.5
C3	0.5	0.5	0	0.33	0.97	0.73
C4	0.73	0.73	0.5	0	0.5	0.5
C5	0.27	0.27	0.33	0.27	0	0.33
C6	0.5	0.5	0.73	0.73	0.33	0

Dynamical System

Now Let us consider that the node rationalism is kept in ON state and other nodes are in OFF state. i.e. the input vector is C1 ={0 1 0 0 0 0}

C1E = (0 0.97 0.73 0.73 0.5 0.5) $\hookrightarrow_{0.97}$(1 1 0 0 0 0)= X1

X1E = (0.97 0.97 1.23 1.46 0.83 1) $\hookrightarrow_{0.97}$(1 1 1 1 0 1)= X2

X2E = (2.7 2.7 2.46 2.52 2.63 2.23) $\hookrightarrow_{0.97}$(1 1 1 1 1 1)= X3

X3E = (2.97 2.97 2.79 2.79 2.63 2.56) $\hookrightarrow_{0.97}$(1 1 1 1 1 1)= X4=X3

It is observed that C_1-Racial Consciousness, C_2-Rationalism get the highest value. Hence, Racial Consciousness, Rationalism have impacted more on the the society.

The limit point for different input vector,

No	Input Vector	Limit Points
1	(1 0 0 0 0 0)	(1 1 1 1 1 1)
2	(0 1 0 0 0 0)	(1 1 1 1 1 1)
3	(0 0 1 0 0 0)	(1 1 1 1 1 1)
4	(0 0 0 1 0 0)	(1 1 1 1 1 1)
5	(0 0 0 0 1 0)	(1 1 1 1 1 1)
6	(0 0 0 0 0 1)	(1 1 1 1 1 1)

By the above three method, it is found that rationalism plays very important role to shape the society.

Conclusion: The attributes of Periyar's self-respect movement is governed by propagating racial consciousness, rationalism, humanism, scientific thinking, castesim / religion and women's right.

Using Fuzzy Cognitive maps (FCM), it is observed that rationalism induces all other attributes. Modified Linguistic Fuzzy Cognitive Maps (MLFCM) when applied brings to fore that racial consciousness, and rationalism induce all other attributes. Hence it can be concluded that rationalism plays a key role in inducing all other attributes and has a greater impact in the society.

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