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Adaptive fuzzy cognitive maps vs neutrosophic cognitive maps: decision support tool for knowledge based institutions

Goutam Banerjee*

Central Glass & Ceramic Research Institute, P O, Jadavpur University, Kolkata 700 032

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This paper explores feasibility of self-adaptive Fuzzy cognitive maps (FCM) in context of knowledge-based organizations. An illustration of encoding explains how combination of initial subjective knowledge with real life data can help a knowledge organization exploring its strategic decisions. Neutrosophic generalization of FCM offers more practical implications of problem domain.

Keywords: Decision support systems, Fuzzy cognitive maps (FCM), Neutrosophic cognitive maps (NCM)

Introduction

Knowledge management[1-2] (KM) and artificial intelligence (AI) are interconnected disciplines[3-7] to discern information for information management systems. Researchers have raised issues of knowledge that are living and active[8-11]. Decisions based on real life knowledge bases are subjective judgments in nature[12,13]. AI has well-developed cognitive tools that can process qualitative information of knowledge domains (universities, educational bodies, research laboratories, business enterprises and bureaucracy). Artificial Neural Network (ANN) is a simulation of human brain consisting of billions of neurons interconnected by network of synapses. Due to uncertainties involved in relationships, system cannot model human expert's behaviour as the number of rules increases. Decision support system (DSS) tools should be equipped to model dynamically evolving knowledge through feedback mechanisms.

This paper evolves a decision-making system using Fuzzy cognitive maps (FCM) for knowledge-based institutions. The paper showing FCM of a research institution encoded with symbolic input knowledge learns through selective interconnected alternatives and evolves its strategic decisions. Learning is finally generalized using Neutrosophic cognitive maps (NCM).

*Author for correspondence
E-mail: goutam@cgcri.res.in

Methodology

Fuzzy Cognitive Map (FCM)

Cognitive maps[14] are a collection of causal nodes linked by arcs or edges. Nodes drawn as circle (Fig. 1) represent concepts (C_1 i=1,…., N), which are variables of problem domain. FCM[15-19] is a fuzzy version of Axelrod's cognitive maps. FCM combines ideas of fuzzy logic and neural network (NN) in a hybrid mode, wherein an organization(s)[11] can be interconnected. In Axelrod's cognitive maps, interconnections are crisp values [+1, -1]. In fuzzy version, connection weights are obtained from either fuzzy membership functions[20] or fuzzified from crisp values. These weights (edge values) are posted along digraph arrows in the map. Causal influence between concepts can be negative, positive or none. Influences are expressed in fuzzy terms as weak, medium, strong, very strong etc. Concepts can assume any of three values: –1 (moderately on); 0 (off); or +1 (on). Inclusion of real values assigned to concepts has recently been made possible[18]. FCM applications in knowledge organizations belong to business[21-22], stock investment[23] and finanace[24] disciplines in supervised mode. Present study describes FCM in unsupervised mode, which has relatively limited applications.

FCM: Theoretical Framework

Major steps to build FCM are: i) identification of domain concepts; ii) identification of causal connections;

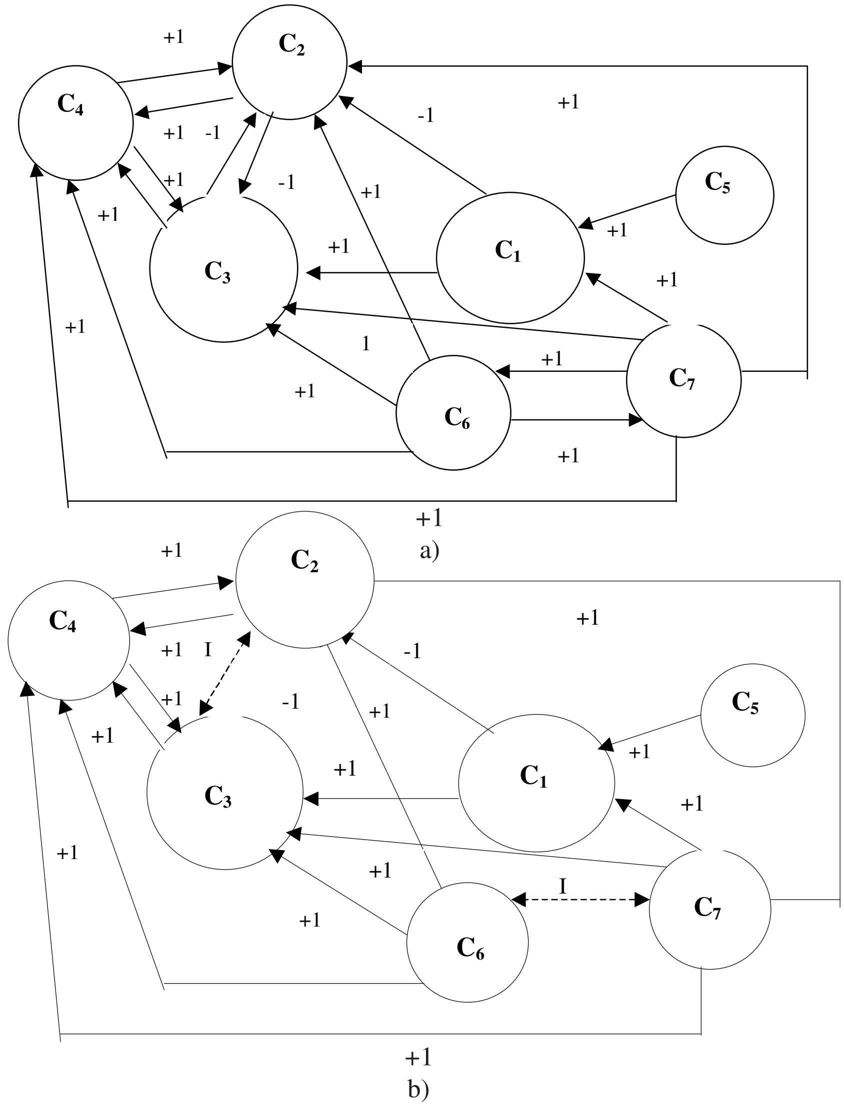

Fig. 1 — R&D domain: a) FCM; b) NCM (C_1, ECF; C_2, *SCI* journal publication; C_3, Indian journal publication; C_4, Patent filings; C_5, Royalty earned; C_6, Ph.D's awarded; C_7, *NET/GATE* entrants)

and iii) estimation of connection weights. To estimate connection weights, Differential Hebbian Learning[25,26,28,29] (DHL) and Genetic methods[27] are used.

(i) DHL Paradigm

Hebbian Learning involves a sequence of iterative runs, in which network output from previous run is mapped as their back onto the input for next run. For the system to evolve a new scenario, state vector (a set of concepts) is repeatedly passed through a matrix of connection weights, which are used to draw inferences. If E designate connection weights matrix and C(t) the state vector of concepts at time t, transformation of multiplication is written as C(t+1) = F[C(t), E], where F is non-linear input-output transformation function, C(t+1) is output value of concepts at time t+1. In next iteration, C (t+1) becomes input for output value of concepts at time t+2 and so on. In most practical applications, concepts are assumed to be bivalent as 0 or 1. In present study, an activation value of 0.5 (a midpoint of bivalent concepts) has been considered.

(ii) DHL— Mathematical Abstractions

Kosko[15,17,18] was first to transplant DHL into FCM to operate in self adaptive or unsupervisory mode. Connection weight eij's denote edge values between ith and jth concepts for i=1,…,N and j=1,…,N. Edge values are altered over time steps t, t+1, t+2 and so on. Discreet version of DHL accounts for the difference in concept

Table 1 — Time series data on R & D performance indicators based on CGCRI annual reports

Variables	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05
External cash flow, Rs crores	4.06	5.38	10.16	3.83	5.21	4.25
SCI journal publication, No.	41	36	46	43	55	58
Indian journal publication, No.	4	8	16	21	6	11
Patent filings, No.	24	30	37	26	16	22
Royalty earned, Rs lakhs	4.251	1.504	2.60	6.225	13.50	2.000
Ph D's awarded, No.	2	3	4	5	3	1
NET/GATE entrants, No.	0	2	11	5	10	7

values over two immediate time points as $\Delta C_i\ (t) = C_i\ (t) - C_i\ (t\text{-}1)$. Edge values are iteratively changed as follows: if $\Delta C_i\ (t) \neq 0$,

$$e_{ij}(t+1) = e_{ij}(t) + \mu_t[\Delta C_i(t)\Delta C_j(t) - e_{ij}(t)] \quad ...(1)$$

$$\text{If } \Delta Ci\ (t) = 0,\ e_{ij}(t+1) = e_{ij}(t) \quad ...(2)$$

Where, μ_t is learning rate and defined[30] as

$$\mu_t = 0.1\left[1 - \frac{t}{1.1N}\right]\text{K} \quad ...(3)$$

where N, number of concepts in the map.

DHL formalism reveals that connection weights diminish exponentially on moving back as t, t-1, t-2, etc. The value of N should be such that $\mu_t > 0$. This arrangement fuzzifies connection weights. Besides this, DHL cannot automate connection weight estimation. Genetic and other algorithms have been proposed to get over these disadvantages[27,28] of DHL. However, these schemes are computationally rigorous and for accuracy purposes more relevant to control systems. Their use in DSS mode reduces qualitative emphasis of FCM[31].

In present study, a simple way to combine human expert's initial assignment of crisp causal links with historical data of the problem domain has been provided to automate generation of initial causal connection weight matrix using adaptive FCM.

Development of Proposed FCM

Adaptive FCM[32] is used with a novelty that instead of direct assignment of bivalent data to concepts, time changes in past data of the concept designated policy variables in decision domain are incorporated as concept differentials ΔC_i (t) over time t. If there is a rise in the value of data, $\Delta C_i\ (t) = +1$, and if there is fall, $\Delta C_i\ (t) = -1$. In case of neither rise nor fall, $\Delta C_i\ (t) = 0$. In this way, a set of past quantitative data gets transformed into trivalent data of concept differentials over successive time intervals, which can be plugged into DHL's iterative scheme for connection weight estimations. However, values of causal connections at t=0 are crisp and depend on experts' judgment. Under DHL iterative scheme, edge value eij's at t=1 will require previous knowledge of e_{ij}'s at t=0, in Eqs (1) - (3) respectively. This set of values at t=0 is provided by a matrix of crisp values of causal relations based on tacit knowledge of domain expert about concepts and their causal relations. Table 1 presents time changes in concepts over a period of 5 years.

Knowledge Domain

FCM (Fig. 1a) is designated by concepts representing variables of R&D performance indicators data of CGCRI, Kolkata. Different concepts are: C_1, external cash flow (ECF); C_2, Science Citation Indexed (SCI) journal publications; C_3, Indian journal publications (IJP); C_4, patents filing; C_5, royalty earned; C_6, Ph D's awarded; and C_7, NET/GATE qualifiers joined. Values of +1 and –1 along arrows (Fig. 1a) are crisp edge values. Concepts C_i's i=1,..,N refer to research inputs and outputs, which are variables of problem domain. While C_2, - C_6 are soft output indicators, C_1 and C_7 are research inputs. Indian journals refer to journals under non-SCI category. ECF is fund generated from research sponsored by the state and corporate world and *NET/GATE* refer to India's highly rated National Eligibility Test (NET) in science and Graduate Aptitude Test in Engineering (GATE) streams to promote scholarships in science and technology.

FCM (Fig. 1a) explains by symbols (+1 and –1) that C_2 and C_3 promote C_4, which have similar effect on causal nodes as C_2 and C_3 are believed to contribute to C_4. The concept C_5 enhances C_1. With increase in number of C_7, domain experts believe that it is possible to keep up C_1 and also promote C_2 and C_4 because of more manpower involvement. Rise in research entrants would consequently lead to doctoral awards. Increase in C_6 would promote C_2 and C_4 and further attract fresh *NET/GATE* qualifiers into the domain as doctoral success of predecessors would embolden confidence of fresher to choose the Institute as workplace for research.

There is dark side also. High level of C_1 implies high volume of exploratory work. Sponsors will stipulate project duration and this would leave very little quality time for project staff to produce at short notice C_2 that have impact factors (IFs). Hence, increased C_1 will decrease C_2, which will promote C_3; as experts believe that C_2 and C_3 are inversely related. Thus, bright young research entrants who are generally attracted to research in basic science may get discouraged and choose other places to pursue research of their choice. Decrease in inflow of bright research workers would lead to decline in soft outputs. With all these perceptions of domain experts, FCM will examine if it is possible to maintain a high level of soft intellectual outputs simultaneously with a heavy inflow of revenue

Fuzzy Edge Value Computation

Crisp connection weight matrix imposed on problem domain is given by E, which reflects features of knowledge domain. Crisp values (-1 and +1) are initial values of connection weights assigned by experts of problem domain. Matrix is represented as E = $[e_{ij}]$

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

Changes in data patterns (Table 1) are represented as concept difference ΔC_i (t) matrix as

$$\Delta C_i\ (t)= \begin{bmatrix} +1 & -1 & +1 & +1 & -1 & +1 & +1 \\ +1 & +1 & +1 & +1 & +1 & +1 & +1 \\ -1 & -1 & +1 & -1 & +1 & +1 & -1 \\ +1 & +1 & -1 & -1 & +1 & -1 & +1 \\ -1 & +1 & +1 & +1 & -1 & -1 & -1 \end{bmatrix}$$

With initial values of connection weights and concept difference matrix, Eqs (1) to (2) of DHL are applied to fuzzify edge value $[e_{ij}]$ matrix over 5 years time period represented as

$$E_1 = \begin{bmatrix} 0.271 & -0.667 & 0.725 & 0.108 & 0.020 & 0.066 & 0.271 \\ 0.062 & 0.271 & -0.802 & 0.768 & 0.089 & -0.143 & 0.062 \\ -0.004 & -0.802 & +0.271 & 0.888 & -0.031 & 0.201 & 0.004 \\ 0.108 & 0.768 & 0.888 & 0.271 & -0.143 & 0.089 & 0.108 \\ 0.749 & 0.089 & -0.031 & -0.143 & 0.271 & 0.039 & 0.020 \\ 0.066 & 0.586 & 0.930 & 0.818 & 0.039 & 0.271 & 0.795 \\ 1.000 & 0.791 & 0.725 & 0.837 & 0.020 & 0.795 & 0.271 \end{bmatrix}$$

Causal connections in E_1 now become initial values for subsequent simulation. One can thus avoid use of fuzzy membership functions to define causal links between concepts.

Architecture of Proposed FCM

(i) New FCM Creation

FCM state vector at any time-year is a picture of events in the scenario being created. FCM (Fig 1a) reveals that C_1 is the first component of state vector C and state [1,0,0,0,0,0,0] implies that ECF has been generated. In E_1, all diagonal elements must be set to zero to avoid self feedback. A stimulus state vector C_1 [1,0,0,0,0,0,1] that represents ECF generation and *NET/GATE* qualifiers, and gives rise to future scenario or sequence of vectors is defined as

C1x E1 = [1, 0.124, 1.550, 1.045, 0.040, 0.861, 0.271] → C2= [1,0,1,1,0,1,1]

C2 x E1=[1.17, 0.658,3.268, 2.851, - 0.095, 1.151, 1.17] → C3=[1,1,1,1,0, 1, 1]

C3 x E1=[1.232, 0.676, 2.466, 3.419, 0.059,1.008, 1.232] → C4=[1,1,1,1, 0,1,1]

Stimulus state vector C_1 is repeatedly passed through matrix E_1. If elements in product matrix exceed activation value of 0.5, corresponding concepts in stimulus state vector are put on as 1; otherwise, elements remain off at zero level. In three passes, a limit vector as $C_3=C_4$ is reached. If C_1 and C_7 continue to increase, C_2, C_3, C_4 and C_6 will also continue to increase. The notion that increase in ECF will lead to decrease in soft R&D output is not true. Also, the belief that an inverse relation exists between *SCI* and Indian journal publications is not tenable Hence, organizational priority[33] on ECF generation can continue without any soft output being risked. If training called encoding of network is done, subsequent FCMs can reach the same limit.

(ii) Encoding (Simultaneous)

FCM is fed with knowledge of a sequence of policy events so that current scenario of FCM is able to generate a new scenario. Events (C_1, C_2, C_4, C_6 and C_7) can occur simultaneously and can be accentuated by new contracts of exploratory work and backlog effect of previous R&D work done would result in these parallel events. It is assumed that these events occur from values of concepts at previous time t-1, which are at zero level as follows:

C(t-1): 0 0 0 0 0 0 0; C(t): 1 1 0 1 0 1 1

Above encoding in DHL will generate a new edge value matrix represented as

E_2 =

0.334	−0.552	0..662	0.186	0.018	0.147	0.334
0.144	0.334	−0.732	0.788	0.081	−0.044	0.144
−0.004	−0.732	0.247	0.811	−0.028	0.184	−0.004
0.186	0.788	0.811	0.334	−0.131	0.168	0.186
0.684	0.081	−0.028	−0.131	0.247	0.036	0.018
0.147	0.622	0.849	0.834	0.036	0..334	0.813
1.000	0.809	0.662	0.851	0.018	0..813	0.334

In E_2 (e_{72} = 0.809**,** e_{74} = 0.851 and e_{67}= e_{76} =0.813), weights have increased compared to their earlier values in E_1. Increase in C_1 and C_7 enhances the belief that there will be increase in number of C_2, C_4 and C_6.

(iii) Encoding (Sequential 1)

In this case, events do not occur in parallel but follow a time sequence, in which one is dependent on the other. As before, events are assumed to start from knowledge that the values of concepts at initial time t-1 are at zero level. Stimulus state vector is as follows:

C(t-1): 0 0 0 0 0 0 0
C(t): 1 0 0 0 0 0 1
C(t+1): 1 0 0 1 0 0 1
C(t+2): 1 0 1 1 0 0 1
C(t+3): 1 1 1 1 0 0 1

At time t, concepts C_1 and C_7 are put on. Consequently, concept C_4 gets on at time t+1 followed by C_3 at t+2 and finally C_2 at t +3 are put on. Connection between C_2 and C_3 is negative as e_{32} = -0.732 in E_2. Above encoding in DHL will generate a new connection matrix E_3 as

E_3 =

0.324	−0.394	0..500	0.141	0.014	0.111	0.324
0.109	0.300	−0.553	0.595	0.061	−0.033	0.109
−0.003	−0.553	0.245	0.613	−0.021	0.139	−0.003
0.141	0.595	0.613	0.319	−0.099	0.127	0.141
0.517	0.061	−0.021	−0.099	0.187	0.027	0.014
0.111	0.470	0.642	0.630	0.027	0.252	0.614
0.828	0.611	0.500	0.643	0.014	0..614	0.324

In E_3 (e_{71} = 0.828, e_{74} = 0.643, e_{43} = 0.613 and e_{32} = -0.553), magnitude of weights has fallen compared to their earlier values in E_1. Magnitude of link value (e_{32} = -0.553) in E_3 has reduced from e_{32} = -0.732 in E_2 with time. This means that strength about the belief of inverse relation between C_2 and C_3 is weakened. Thus it cannot be explicitly concluded that with increase in number of papers in Indian journals, number of papers in *SCI* journals will decrease over time. DHL points that allotment of tacit knowledge, e_{23} = e_{32} = -1 in E is improper. Publications, no matter in Indian or *SCI* journals, are result of human intellect and therefore the reason to think of an inverse relation between two systems is not a proper judgment. Causal link e_{23} = e_{32} should have been taken positive in initial matrix E. Thus self-adaptive FCM is able to question the judgment of domain experts, which exemplifies its intelligent computational ability.

(iv) Encoding (Sequential 2)

Events in this case follow a sequence of interdependent concepts. It is again assumed that these events do occur from knowledge that initial values of concepts are at zero level.

C(t-1): 0 0 0 0 0 0 0
C(t): 1 0 0 0 0 0 1
C(t+1): 1 0 0 1 0 0 1
C(t+2): 1 0 1 1 0 0 1
C(t+3): 1 0 1 1 0 1 1
C(t+4): 1 0 1 1 0 1 1

Here, sequence of events is C_1 and C_7 at t followed by C_4 at t+1, C_3 at t+2, C_6 at t+3 followed by recruitment of fresh batch of C_7 at t+4 occur sequentially. Above encoding in DHL rule will generate a new matrix E_4 of causal connections as

E_4 =

$$\begin{bmatrix} 0.306 & -0.287 & 0..365 & 0.103 & 0.010 & 0.081 & 0.306 \\ 0.079 & 0.219 & -0.403 & 0.434 & 0.044 & -0.024 & 0..079 \\ -0.002 & -0.403 & 0.235 & 0.447 & -0.015 & 0.101 & -0.002 \\ 0.103 & 0.434 & 0.447 & 0.296 & -0..072 & 0.093 & 0.103 \\ 0.377 & 0.044 & -0.015 & -0.072 & 0.136 & 0.020 & 0.010 \\ 0.081 & 0.343 & 0.468 & 0.459 & 0.020 & 0.230 & 0.448 \\ 0.673 & 0.446 & 0.365 & 0.469 & 0.010 & 0..448 & 0.306 \end{bmatrix}$$

In E_4 (e_{71} = 0.673, e_{72} = 0.446, e_{74} = 0.469 and $e_{67} = e_{76}$ = 0.448), magnitude of weights has further fallen compared to their earlier values in E_3. Thus, with increase in fund and manpower, the belief that publication in Indian journals will increase followed by increase in Ph D is weakened. Hence, result produced by E_2 only leads to a reasonable position as concerned weights increase and strengthen belief that if level of ECF and *NET/GATE* entrants increase, number of publications in *SCI* journals would also increase along with number of Ph D awards.

As before, all diagonal elements in E_4 are set at zero to avoid feedback. A stimulus state vector C1=[1,0,0,0,0,0,1] represents C_1 and C_7 in symbolic terms of unity and as resultant stimulus state vector is repeatedly passed through E_4, the sequence of state vectors obtained is

C1x E4 = [0.673, 0.159, 0.730,0.572,0.020,0.529,0.612]
$\rightarrow$ C2= [1,0,1,1,0,1,1]

C2x E4 = [0.754, 0.53, 1.645, 1.465, 0.03, 0.650,0.855]
$\rightarrow$ C3= [1,0,1,1,0,1,1]

C3x E4 = [0.934, 0.533, 1.242, 1.912, 0.03,0.699,0.934]
$\rightarrow$ C4= [1,0,1,1,0,1,1]

State vectors C_4=C_2 implies that new scenario after 3 sets of encoding has repeated limit vector attained by FCM before encoding. This means that new scenario of FCM has learned to repeat the limit obtained by old scenario of FCM. This has helped in current decision-making. The decision is that given a fleet of bright research scholars and ECF on hand, it is possible to produce soft performance outputs in terms of publications in ´:*SCI* and Indian journals, Patent filings, Ph D awards and entry of fresh *NET/GATE* qualifiers. Tacit notion of inverse relationship between publications indexed in *SCI* and Indian journals cannot be proved explicit. On contrary, limit vector C**4** suggests that both these concepts can be concurrent. Mandate of *NET/GATE* qualifiers for the organization to be right place to pursue their research career is brought to focus. These points also reveal that it is not exploratory research but the right choice of exploratory problems, which makes the difference in quality of research performance.

Neutrosophic Cognitive Maps (NCM)

A Neutrosophic treatment of the problem is carried out to generalize results. The notion of neutrosophic logic created by Florentin Samarandache[34] is an extension of fuzzy logic, in which indeterminacy is included. Indeterminacy will be introduced into causal relationships between some of concepts of FCM. This is a generalization of FCM and the structure is called Neutrosophic Cognitive Maps (NCM)[35]. An NCM (Fig. 1b) is a neutrosophic directed graph with indeterminate casualties between concepts as edges. Let C_1, C_2, …., C_n denote n concepts, where it is assumed that each concept is a neutrosophic vector. So a concept C_i will be represented by x_k where x_k's are zero or one or I; x_k = 1 means that C_k is in on state, x_k =0 means, it is in off state, and x_k = I means, the concept state is an indeterminate at that time or in that situation.

Like FCM, directed edge e_{ij} from C_i to C_j denotes causality of concept called connections. Every edge in NCM is weighted with a number in the set {-1, 0, 1, I}. If C_i does not have any effect on C_i, e_{ij} = 0; if C_i causes increase (or decreases) as C_j increase (or decrease), e_{ij} = 1; if C_i causes increase (or decreases) as Cj, decrease (or increase), e_{ij} = -1, and if effect of C_i on C_j is indeterminate, e_{ij} = I. With C_1, C_2, …., C_n as concepts of NCM, that have feedback, let N(E) be associated neutrosophic adjacency matrix. Hidden pattern is to be found when C_1 is switched on. An input is given as vector A_1 = (1, 0, 0,…, 0), the data is passed through matrix

N(E), which is done by multiplying A_1 by matrix. Let A_1 x N (E) = (a_1, a_2,…, a_n) with threshold operation by replacing a_i by 1 if a_i > k and a_i by 0 if a_i <k (k – a suitable positive integer) and a_i by I if a_i is not an integer. It is then updated. Concept C_1 is included in updated vector by making first coordinate as 1 in resulting vector. Suppose A_1 x N (E) =A_2, then A_2 x N(E) is considered and same procedure is repeated. This is continued till a limit cycle or a fixed point is arrived.

Working of NCM

It is assumed that the connection between concepts C_2 and C_3 and that between C_6 and C_7 are indeterminate. NCM is utilized to examine effect of indeterminate nature of relationships on problem domain. The conclusion that doctoral successes of NET/GATE students will attract more bathes of NET/GATE fresher is not within management control. Such a conclusion may prove its falsity; hence this relation is also treated as indeterminate. Neutrosophic adjacency matrix is written as

$$N(E) = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & I & 1 & 0 & 0 & 0 \\ 0 & I & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & I \\ 1 & 1 & 1 & 1 & 0 & I & 0 \end{bmatrix}$$

Since FCM has proved that increased C_1 would lead to increase in C_2, connection weight between these concepts in matrix N(E) is treated as $e_{12} = e_{21} = +1$. Now, an instantaneous stimulus vector is defined as A_1 = [1,0,0,0,0,0,1], which indicates that increased C_1 would attract C_7. The effect of A_1 on neutrosophic system N(E) is given by

A_1x N(E) = [1, 2, 2, 1, 0,.I, 0] $\rightarrow A_2$
= [1, 1, 1, 1, 0, I, 1]
A_2 x N(E) = [1, 2I+3, 2I+3, I+3, 0, I, I^2] $\rightarrow A_3$
= [1, 1, 1, 1, 0, I, 1] = A_2

Here I^2 =I and neutrosophic system has converged to a fixed point in just three passes. Vector A_2 suggests that if C_1 and C_7 concepts are kept on the concepts C_2, C_3, C_4 will be on state while concept C_5 will be off state. However, advent of C_7 fresher does not give indication that they would lead to their doctoral success, as C_6 concept in A_3 is indeterminate. Hence, influx of bright researchers does not ensure that number of Ph D awardees will increase. Again an instantaneous vector is defined as A_1 = [1,0,0,0,0, 1,0]. Effect of increased C_1 and C_6 would be examined especially on fresh C_7. Effect of A_1 on neutrosophic system N(E) is given by

A_1x N(E) = [0, 2, 2, 1, 0,.0, I] $\rightarrow A_2$
= [1, 1, 1, 1, 0, 1, I]
A_2 x N(E) = [I, 2I+3, 2I+3, I+3, 0, I^2 , I] $\rightarrow A_3$
= [1, 1, 1, 1, 0, 1, I] = A_1

Neutrosophic system has converged to fixed point in just two passes and vector A_1 suggests that result is same as before. However, doctoral success of NET/GATE qualifiers does not give indication that fresh batch of NET/GATE qualifiers would be motivated by success of their predecessors. Concept C_7 in A_3 remain indeterminate. Hence, NCM has proved that increased Ph.D output does not ensure inflow of bright youngsters to the organization. Again an instantaneous vector is defined as A_1 = [1,1,0,0,0,0,0]. Effect of concepts C_1 and C_2 is examined on neutrosophic system. Effect of A_1 on neutrosophic system N(E) is given by

A_1x N(E) = [0, 1, I+1, 1, 0,.0, 0] $\rightarrow A_2$
= [1, 1, 1, 1, 0, 0, 0]
A_2 x N(E) = [I, I+2, I+2, 2, 0, 0 , 0] $\rightarrow A_3$
= [1, 1, 1, 1, 0, 0, 0] =A_1

State vector A_1 indicates that strategy of increased C_1 coupled with C_2 will put the concepts C_3, C_4 on state while C_5 will put off. However, this strategy will not produce Ph D output and attract NET/GATE qualifiers. If an input vector is defined as A_1 = [1,0,0,0,0,0,0], effect of concept C_1 on neutrosophic system will produce same result. Effect of A_1 on neutrosophic system N(E) is given by

A_1x N(E) = [0, 1, 1, 0, 0,.0, 0] $\rightarrow A_2$
= [1, 1, 1, 0, 0, 0, 0]
A_2 x N(E) = [0, I+1, I+1, 2, 0, 0 , 0] $\rightarrow A_3$
= [1, 1, 1, 1, 0, 0, 0]
A_3 x N(E) = [0, I+2, I+2, 2, 0,0,0] $\rightarrow A_4$
= [1, 1, 1, 1, 0, 0, 0] = A_3

While FCM suggested that it is not exploratory or applied research rather the choice of problems, which would lead to high number of Ph D's that would further motivate NET/GATE qualifiers to join Institute as right place for research, NCM has proved that it is not the choice of problem but the choice of profession that could make the difference. A fresh batch of bright researchers may join research but may not complete their research as proven by indeterminate components of resulting state vectors. They may opt for other professions ushered in by globalization. It is true that young people are motivated by glamour of managerial positions in corporate jobs because of large pay packets. The results offered by NCM appear more practical and pervasive. Injection of indeterminacy into few relationships between concepts of problem domain is able to create difference in the results and their implications.

Conclusions

Self-adaptive FCM can be used as a decision support tool for conducting qualitative studies of knowledge based organizations in situations where knowledge domain is tacit or unstructured. The paper serves to reproduce fixed point limit of an R&D institution after neuro-fuzzy formulation of organization has been simultaneously and sequentially encoded with knowledge in a decision support mode. Soft intellectual output can be sustained even with high level of revenue generation. Organization can reproduce its desired state under changed context, as connection weights between concepts of FCM are trained and adapted to knowledge inputs of empirical data and experts' belief. However, FCM cannot handle real life indeterminacy. NCM can serve such purpose. NCM reveals that it is possible to sustain soft intellectual outputs with high ECF generation. However, question on choice of research organizations by NET/GATE qualifiers remains indeterminate. Even if these research entrants join organization, ultimately rise in number of successful Ph D's would still remain indeterminate. Thus, it is not the choice of research problem but the choice of research profession that is a critical factor. Results by NCM are therefore more practical. Such a result could be achieved because two pairs of causal relations in NCM were contemplated indeterminate.

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References

1 Wiig K, Knowledge Management Foundations: Thinking about Thinking – How People and Organizations Create, Represent and Use Knowledge (Schema Press, Texas) 1993, 471.

2 Courtney J F, Decision making and knowledge management in inquiring organizations: toward a new decision-making paradigm for DSS, *Decision Support Syst*, **31** (2001) 17-38.

3 Haeley P, Exploring synergies between knowledge management and case based reasoning, in *American Association for Artificial Intelligence Workshop* (American Association for Artificial Intelligence, California) 18-19 July 1999.

4 Noh J B, Lee K C, Kim J K, Lee J K & Kim S H, A case based reasoning approach to cognitive map-driven tacit knowledge management, *J Expert System Applications*, **19** (2000) 249-259.

5 Smith R G & Farquhar A, The road ahead for knowledge management: An AI perspective, *Winter*, **21** (2000) 17-40.

6 Liebowitz J, *Building Organizational Intelligence: A Knowledge Management Primer* (CRC Press, ca Raton, Florida) 2000, 160.

7 Metaxiotis K, Ergazakis K, Samouilidis E & Psarras J, Decision support through knowledge management: the role of the artificial intelligence, *Inform Manage & Compu Security*, **11** (2003) 216-221.

8 Walsh J P & Ungson G R, Organizational memory, *Acad Manage Rev*, **16** (1991) 57-91

9 Bannon L J & Kuutti K, Shifting perspectives on organizational memory: from storage to active remembering, in *Proc. 29th Hawaii Int Conf Syst Sci* (Institute of Electrical and Electronics Engineers, Wailea, HI, USA) 1996, 156-167.

10 Guerrero L A & Pino Jose A, Understanding organizational memory, *Interact Compu*, **8** (1996) 299-310.

11 Huber G P, A theory of the effects of advanced information technologies on organizational design, intelligence and decision making, *Acad Manage J*, **15** (1990) 47-71.

12 Nonaka I, A dynamic theory of organizational knowledge creation, *Org Sci*, **5** (1994) 14-37

13 Bhatt G D & Zaveri J, The enabling role of decision support systems in organization learning, *Decision Support Syst*, **32** (1997) 297-309.

14 Axelrod R, *Structure of Decision: The Cognitive Maps of Political Elites* (Princton University Press, New Jersey) 1976, 404.

15 Kosko B, Differential Hebbian learning, in *Proc AIP Conf 151(*American Institute of Physics, New York) 1986, 265-270.

16 Kosko B, Fuzzy cognitive maps, *Int J Man-Machine Stud*, **24** (1986) 65-75.

17 Kosko B, Hidden patterns in combined and adaptive knowledge networks, *Int J Approx Reason*, **2** (1988) 377-393.

18 Kosko B, *Neural Networks and Fuzzy Systems* (Prentice Hall, New Jersey) 1992, 480-p.

19 Kosko B, *Fuzzy Engineering* (Prentice Hall, New Jersey) 1997, 549p.

20 Klir G J & Folger T A, *Fuzzy Sets, Uncertainty And Information* (Prentice Hall, New Delhi) 1991, 65-106.

21 Kang I, Lee S & Choi J, Using fuzzy cognitive map for the relationship management in airline service, *Expert Syst Applications*, **24** (2004) 545-555.

22 Xirogiannis G & Glykas M, Fuzzy cognitive maps in business analysis and performance-driven change, *IEEE Trans Eng Manage*, **51** (2004) 334-351.

23 Lee K C & Kim H S, A fuzzy cognitive map based bidirectional inference mechanism: an application to stock investment

analysis, *J Intelligent Syst Accounting*, *Finance & Manage*, **6** (1997) 41-57.

24 Xirogiannis G, Glykas M & Staikouras C, Fuzzy cognitive maps as a back end to knowledge-based systems in geographically dispersed financial organizations, *Knowledge Process Manage*, **11** (2004) 137-154.

25 Papageorgiou E, Stylios C D & Groumpos P P, Fuzzy cognitive map learning based on nonlinear Hebbian rule, in 16th *Australian Conf on Artificial Intelligence*(Perth, Australia) 3-5 December 2003.

26 Papageorgiou E, Stylios C D & Groumpos P P, Active Hebbian learning algorithm to train fuzzy cognitive maps, *Int J Approx Reason*, **37** (2004) 219-249.

27 Stach W, Kurgan L, Pedrycz W & Reformat M, Genetic learning of fuzzy cognitive maps, *Fuzzy Sets Syst*, **153** (2005) 371-401.

28 Papageorgiou E L, Stylios C & Groumpos P P, Unsupervised learning techniques for fine-tuning fuzzy cognitive map causal links, *Int J Human-Compu Stud*, **64** (2006) 727-743.

29 Hebb D O, *The Organization of Behavior*, **12th edn** (Wiley, New York) 1949, 378.

30 Dickerson J & Kosko B, Virtual worlds as fuzzy cognitive maps, *Presence*, **3** (1994) 173-189.

31 Khan M S & Quaddus M, Group decision support using fuzzy cognitive maps for casual reasoning, *Group Decision Negotiation*, **13** (2004) 463-480.

32 Khan M S, Chong A & Gredeon T, A methodology for developing adaptive fuzzy cognitive maps for decision support, *J Adv Compu Intelligence & Intelligent Informatics*, **4** (2000) 403-407.

33 Banerjee G, Roadmapping in R&D: A neuro-fuzzy thinking, in *Proc Int Conf Innovation and Technology Management* (Indian Association for Productivity, Quality and Reliability & Central Glass & Ceramic Research Institute, Kolkata) 2006, 281-291.

34 Samarandche F, Definitions derived from neutrosophics, in *Proc First Int Conf Neutrosophy, Neutrosophic Logic, Neutrosophic Set, Neutrosophic Probability and Statistics* (University of New Mexico, Gallup) 1-3 December 2001.

35 Vasanthakandaswamy, W B & Samarandche F, *Fuzzy Cognitive Maps and Neutrosophic Cognitive Maps* (Xiquan, Phoenix) 2003, 123-190.