International Journal of Fuzzy Mathematics and Systems.
ISSN 2248-9940 Volume 4, Number 1 (2014), pp. 73-80

http://www.ripublication.com

The Application of Delphi Adapted (Weighted) Bidirectional Associative Memories (DABAM) in the Analysis of Women Empowerment through Capabilities

A. Victor Devadoss[1], K. Sudha[2] and D. Ajay[3]

[1]Head & Associate Professor, Department of Mathematics,
Loyola College, Chennai-34.
Email: hanivictor@ymail. com
[2, 3]Ph. D Research Scholar,
Department of Mathematics, Loyola College, Chennai-34.
Email: ashu. 8788@gmail. com, dajaypravin@gmail. com

Abstract

A new fuzzy technique Delphi Adapted BAM is proposed in this paper and is used to analyze the empowerment of women by adopting Amartya Sen's capability approach. DABAM is proposed to function as a multiple expert system, in that it can be used to combine any number of expert's views into one relational matrix. To create a balance between views of experts, who might have different experiences in the problem under analysis, each expert is given a weight as in Delphi method. The first section of this paper gives an introduction to what is done in the paper and the second section explains the dynamics of BAM. Section three explains the technique DABAM and in the fourth section DABAM is adapted to investigate the empowerment of women through their capabilities. Section five derives the conclusion.

Keywords: Bidirectional associative memory, Fuzzy Delphi method, Delphi adapted BAM, women empowerment, capability approach.

1. Introduction

The Delphi method (Dalkey & Helmer, 1963) is a proven tool for collective decision making (Linstone & Turoff, 2002) for a situation in which decision needs to be made by a group of experts who might have divergent views on the topic. This method can also be called a prediction method based ob expert judgment. The Delphi method is characterized by the properties like anonymity, feedback, statistical and convergence. It tries to achieve a consensus among the experts. In order to account for the amount of fuzziness in group decision making Murray, Pipino & Gigch (1985) proposed Fuzzy Delphi method. Since then the method has found many applications.

Bi-directional associative memories (BAM) was introduced by Kosko (1988) to produce two-way associative search for stored associations and as a model BAM has been applied to analyze problems by passing information through M (forward recall) and M^t (backward recall) in which the factors that attribute to the problem can be classified into antecedent and consequent sets. In this paper, the novelty of Fuzzy Delphi Method in bringing a consensus is combined with Bidirectional associative memories so that the new technique thus obtained can function as a multiple expert system.

2. Bidirectional Associative Memories (BAM)

2. 1. Neuron Fields

A group of neurons forms a field. Neural networks contain many fields of neurons. F_x denotes a neuron field which contains n neurons and F_y denotes a neuron field which contains p neurons.

2. 2. Neuronal Dynamical Systems

The neuronal dynamical system is described by a system of first order differential equations that govern the time evaluation of the neuronal activations or membrane potentials. $\dot{X}_i = g_i\ (X, Y, ...)$, $\dot{Y}_j = h_j\ (X, Y, ...)$ where x_i and y_j denote respectively the activation time function of the i^{th} neuron in F_x and the j^{th} neuron in F_y. The over dot denotes time differentiation, g_i and h_j are functions of X, Y etc. and $X(t) = (x_1(t), \ldots\ldots, x_n(t))$, $Y(t) = (y_1(t), \ldots\ldots, y_n(t))$

Define the state of the neuronal dynamical system at time t. Additive bivalent Models describe asynchronous and stochastic behavior. At each moment each neuron can randomly decide whether to change state, or whether to omit a new signal given its current activation.

The BAM is a non- adaptive, additive, bivalent neural network.

2.3. Bivalent Additive BAM

In neural literature, the discrete version of the earlier equations is often referred to as the Bidirectional Associative Memories or BAMs. A discrete additive BAM with threshold signal functions, arbitrary thresholds and inputs, an arbitrary but a constant synaptic connection matrix M and discrete time steps K are defined by the equations

$$x_i^{k+1} = \sum_j^p S_j(y_j^k)m_{ij} + I_i$$

$$y_j^{k+1} = \sum_i^n S_i(y_i^k)m_{ij} + I_j$$

where $m_{ij} \in M$. $S_i$andS_j are the signal functions. They represent binary or bipolar threshold functions.

2.4. Synaptic connection Matrices

Let us suppose that the field F_x with n neurons is synaptically connected to the field F_y with p neurons. Let m_{ij} be a synapse where the axon from the i^{th} neuron in F terminates, m_{ij} can be positive, negative or zero. The synaptic matrix M is a n X p matrix of real numbers whose entries are the synaptic efficacies m_{ij}. The matrix M describes the forward projections from the neuronal field F_x to the neuronal field F_y. Similarly, M^T, a p X n synaptic matrix and describes the backward projections F_y to F_x.

2. 5. Unidirectional Networks

These kinds of networks occur when a neuron synoptically interconnects to itself. The matrix N is n X n square matrix.

2. 6. Bidirectional Networks

A network is said to be a bidirectional network if $M = N^T$ and $N = M^T$.

2. 7. Bidirectional Associative Memories

When the activation dynamics of the neuronal fields F_x and F_y lead to the overall stable behavior, the bi-directional networks are called as Bi-directional Associative Memories or BAM. A unidirectional network also defines a BAM if M is symmetric, that is, $M = M^t$. In the next section, we proceed on to give more details about this BAM.

2. 8. Additive Activation Models

An additive activation model is defined by a system of n + p coupled first-order differential equations that interconnects the fields F_x and F_y through the constant synaptic matrices M and N described earlier.

$$\dot{x}_i = -A_i x_i + \sum_{j}^{p} S_j(y_j^k) m_{ji} + I_i$$

$$\dot{y}_j = -A_j y_j + \sum_{i}^{n} S_i(y_i^k) m_{ij} + I_j$$

$S_i(x_i)$ and $S_j(y_j)$ denote respectively the signal function of the i^{th} neuron in the field F_x and the signal function of the j^{th} neuron in the field F_y. Discrete additive activation models correspond to neurons with threshold signal functions. The neurons can assume only two values **ON** and **OFF**. On represents the signal value + 1 and OFF represents 0 or -1 (-1 when the representation is bipolar). At each moment each neuron define a random variable that can assume the value ON (+1) or OFF (0 or -1). The network is often assumed to be deterministic and state changes are synchronous ie an entire field of neurons is updated at a time. In case of simple asynchrony only one neuron makes a state change decision at a time. When the subsets represent the entire fields Fx and F_y synchronous state change results.

In a real life problem the entries of the constant synaptic matrix M depends upon the investigator's feelings. The synaptic matrix is given a weightage according to their feelings.

3. Methodology

Delphi Adapted (weighted) BAM

Form synaptic connection matrices $N_1 = \left(b_{ij}^{(1)}\right), N_2 = \left(b_{ij}^{(2)}\right), ...N_k = \left(b_{ij}^{(k)}\right)$, where $i = 1, 2, ..., n$ and $j = 1, 2, ..., p$, which represent opinions of k experts about causal relationship between the neuron field F_x with n neurons and the neuron field F_y with p neurons.

a. Assign each expert a weight α_n ranging from 1 to 5 according to his/her expertise in the problem under analysis.

b. Multiply the weight with the corresponding synaptic connection matrix $M_n = \alpha_n N_n = \alpha_n (b_{ij}^{(n)}) = (\alpha_n b_{ij}^{(n)}) = (a_{ij}^{(n)})$ where α_n is a constant, $n = 1, 2, ..., k$.

c. Form fuzzy triangular number $\left(P_{ij}, M_{ij}, O_{ij}\right)$. Here $P_{ij} = \min_{1 \le n \le k}\{a_{ij}^{(n)}\}$, $M_{ij} = \frac{1}{k}\sum_{n=1}^{k} a_{ij}^{(n)}$, and $O_{ij} = \max_{1 \le n \le k}\{a_{ij}^{(n)}\}$ where $i = 1, 2, \dots, n$ and $j = 1, 2, \dots, p$ and $a_{ij}^{(n)} \in M_n \ \forall n = 1, 2, \dots, k$

d. Obtain the combined synaptic connection matrix $M = \left(a_{ij}\right)$ where $a_{ij} = \frac{P_{ij} + M_{ij} + O_{ij}}{3}$ for all $i = 1, 2, \dots, n$ and $j = 1, 2, \dots, p$.

e. Choose different input vectors keeping different nodes in ON state to obtain the dynamical system.

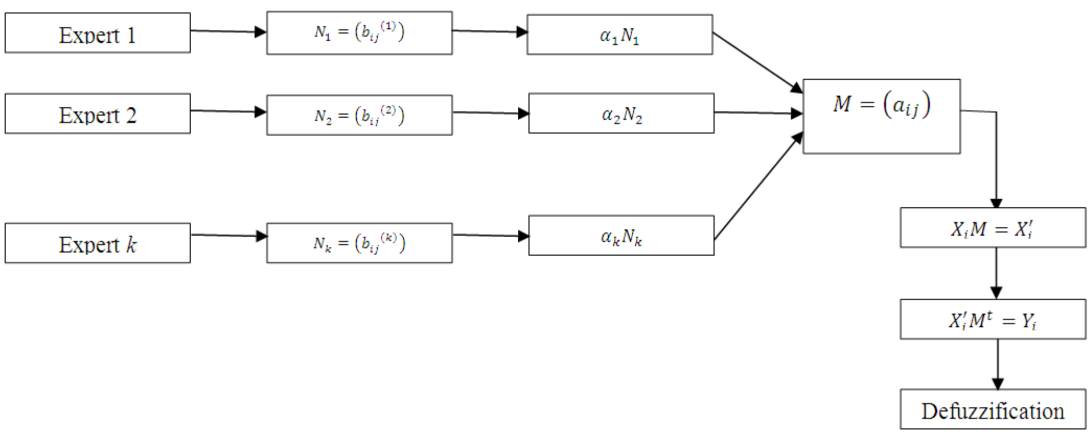

Fig. 1 DABAM as a multiple expert system

4. Application of DABAM to the problem

As traditional methods of analyzing the empowerment of women have not adequately enlightened the researchers, an attempt here is made to adopt Sen's capability approach. Capability of a person reflects a person's freedom to choose between different ways of living (Sen, 2003). Already many studies have been carried out using this approach. Alkire and Black (1997) chose Life, Knowledge and appreciation of beauty, Work and play, Friendship, Self-integration, Coherent self-determination, Transcendence, and Other species as capabilities for their study. Nussbaum (2003) selected the following capabilities Life, Bodily health, Bodily integrity, Senses, imagination, and thought, Emotions, Practical reason, Affiliation, Other species, Play, Control over one's environment. To analyze the gender inequality in Western socitiesRobeyns (2003) had another list of fifteen attributes. The following list of capabilities is chosen by the authors of this paper after analyzing the life of twenty successful Indian women and is identified to contribute to women empowerment.

The list of capabilities are selected as the nodes of the domain space

C_1 – Mental well-being and Resilience
C_2 – Bodily integrity
C_3 –Creative Imagination
C_4 – Emotion stability
C_5 – Social sensitivity
C_6 – Recreational activity
C_7 – Bodily control
C_8 – Growth of self-regulation
C_9 – Self-reorganization

The following attributes related with empowerment of women are taken as nodes of the range space:

P_1 – Freedom of movement
P_2 – Economic Independence
P_3 – Education
P_4 – Decision making power
P_5 – Vocational preference
P_6 – Property rights
P_7 – Respect
P_8 – Creating opportunities
P_9 – Dignified treatment
P_{10} –Equality
P_{11} –Self-esteem
P_{12} –Right to privacy
P_{13} –Change in social system and culture
P_{14} –Freedom to express own thought

The Delphi process of obtaining the relational matrix is given in the following table

	P_1	P_2	P_3	P_4	P_5	P_6	P_7
C_1	(1.2,1.67,2)	(0,0.1,0.3)	(1.5,1.97,2.8)	(2.4,3.47,4)	(0.6,0.87,1.2)	(-4,-3.27,-1.8)	(0,0.1,0.3)
C_2	(0,0.1,0.3)	(-2.8,-2.3,-1.8)	(2.4,2.93,3.2)	(1.2,1.47,1.6)	(1.2,1.73,2)	(-4,-3.67,-3)	(1.8,1.93,2)
C_3	(1.2,1.87,2.4)	(-4,-3.3,-2.7)	(2.4,3.47,4)	(1.5,1.97,2.4)	(0,0.1,0.3)	(-4,-3.67,-3)	(1.5,2.5,3.2)
C_4	(0.3,0.63,0.8)	(0,0.5,1.3)	(1.5,2.5,3.2)	(1.8,2.6,3.2)	(1.5,2.1,2.4)	(0,0.23,0.4)	(1.6,1.8,2)
C_5	(1.5,2.23,2.8)	(3,3.4,4)	(0.9,1.5,2)	(1.5,1.97,2.4)	(1.6,1.8,2)	(3,3.67,4)	(1.8,2.33,2.8)
C_6	(0,0.1,0.3)	(0.6,1,1.2)	(1.5,1.83,2)	(0,0,0)	(-4,-3.3,-2.7)	(-4,-3.4,-3)	(1.5,1.83,2)
C_7	(0.9,1.9,2.4)	(1.2,1.33,1.6)	(1.5,2.23,3.2)	(1,2.4,3.2)	(0,0,0)	(0,0,0)	(3,3.67,4)
C_8	(3,3.4,0.6)	(0.6,1.4,2)	(0.8,1.06,1.2)	(3,3.4,4)	(2,2.03,2.1)	(0,0,0)	(3,3.67,4)
C_9	(3,3.67,4)	(0.8,0.97,1.2)	(1.2,1.53,1.8)	(3,3.4,4)	(1.5,1.833,2)	(0,0,0)	(3,3.67,4)

	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
C_1	(0.6,0.73,0.8)	(1.5,1.833,2)	(1.5,1.967,2.4)	(3,3.4,4)	(-2.1,-1.367,0)	(-4,-2.067,0.8)	(0,0,0)
C_2	(0,0.13,0.4)	(0.8,0.633,2)	(0,0.133,0.4)	(2.7,3.3,4)	(0,0.27,0.8)	(-4,-3.267,-2.8)	(-2,-1.467,0)
C_3	(1.5,1.7,2)	(0.8,1.467,2)	(0,0.133,0.4)	(1.8,2.067,2.4)	(-4,-1.4,3)	(1.2,2.267,3.2)	(3,3.67,4)
C_4	(0,0,0)	(0.8,0.967,1.2)	(0,0.133,0.4)	(1.2,2.267,3.2)	(-1.5,0.833,2)	(1.8,2.067,2.4)	(1.5,1.967,2.4)
C_5	(0,0.13,0.4)	(0.8,1.2,1.6)	(3,3.4,4)	(2,2.63,3.2)	(0,0.133,0.4)	(3,3.4,4)	(0.9,1.77,2.8)
C_6	(0,0,0)	(0,0,0)	(-4,-2.3,0.3)	(1.2,1.47,1.6)	(0,0.1,0.3)	(0,0.1,0.3)	(0.8,1.43,2)
C_7	(-4,-3.67,-3)	(3,3.67,4)	(0.4,0.7,0.9)	(1.5,2.23,3.2)	(0,0.2,0.6)	(0,0,0)	(0.4,0.9,1.5)
C_8	(0.8,1.033,1.5)	(0.9,2.57,3.6)	(2,2.5,2.8)	(1.5,3.17,4)	(2,2.17,2.4)	(1.2,1.33,1.6)	(1.5,1.83,2)
C_9	(1.5,1.56,1.6)	(1.2,2.27,3.2)	(1.6,2.13,2.4)	(2.1,3.1,4)	(2.4,2.73,3)	(1.6,1.8,2)	(0.8,1.2,1.6)

The relational matrix thus obtained is given by *M*

$$
\begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ M = C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \end{array}
\begin{array}{c}
\begin{array}{cccccccccccccc} P_1 & P_2 & P_3 & P_4 & P_5 & P_6 & P_7 & P_8 & P_9 & P_{10} & P_{11} & P_{12} & P_{13} & P_{14} \end{array} \\
\begin{pmatrix}
1.6 & 0.1 & 2.1 & 3.3 & 0.9 & -3 & 0.1 & 0.7 & 1.8 & 2 & 3.5 & -1.2 & -1.8 & 0 \\
0.1 & -2.3 & 2.8 & 1.4 & 1.6 & -3.6 & 1.9 & 0.2 & 1.1 & 0.2 & 3.3 & 0.36 & -3.4 & -1.2 \\
1.8 & -3.3 & 3.3 & 2 & 0.1 & -3.6 & 2.4 & 1.7 & 1.4 & 0.2 & 2.1 & -0.8 & 2.2 & 3.6 \\
0.6 & 0.6 & 2.4 & 2.5 & 2 & 0.2 & 1.8 & 0 & 1 & 0.2 & 2.2 & 0.4 & 2.1 & 2 \\
2.2 & 3.5 & 1.46 & 2 & 1.8 & 3.6 & 2.3 & 0.2 & 1.2 & 3.5 & 2.6 & 0.2 & 3.5 & 1.8 \\
0.1 & 0.9 & 1.8 & 0 & 3.3 & -3.5 & 1.8 & 0 & 0 & -2 & 1.4 & 0.1 & 0.1 & 1.4 \\
1.7 & 1.4 & 2.3 & 2.2 & 0 & 0 & 3.6 & 3.6 & 3.6 & 0.7 & 2.3 & 0.3 & 0 & 0.9 \\
3.5 & 1.3 & 1 & 3.5 & 2 & 0 & 3.6 & 1 & 2.4 & 2.4 & 2.9 & 2.2 & 1.4 & 1.8 \\
3.6 & 1 & 1.5 & 3.5 & 1.7 & 0 & 3.6 & 1.6 & 2.2 & 2 & 3 & 2.7 & 1.8 & 1.2
\end{pmatrix}
\end{array}
$$

Consider an input vector (1 0 0 0 0 0 0 0 0) where the first attribute *mental well-being and resilience* is kept in ON state. We proceed as follows to obtain the limit point of the dynamical system:

$$S(X_k) = (1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0)$$
$$S(X_k)\cdot M = (1.6 \quad 0.1 \quad 2.1 \quad 3.3 \quad 0.9 \quad -3 \quad 0.1 \quad 0.7 \quad 1.8 \quad 2 \quad 3.5 \quad -1.2 \quad -1.8 \quad 0)$$
$$\to (0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0) = y_{k+1}$$
$$S(y_{k+1})\cdot M^T = (6.8 \quad 4.7 \quad 4.1 \quad 4.7 \quad 4.6 \quad 1.4 \quad 4.5 \quad 6.4 \quad 6.5)$$
$$\to (1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1) = X_{k+2}$$
$$S(X_{k+2})\cdot M = (5.2 \quad 1.1 \quad 3.6 \quad 6.8 \quad 2.6 \quad -3 \quad 3.7 \quad 2.3 \quad 4 \quad 4 \quad 6.5 \quad 1.5 \quad 0 \quad 1.2)$$
$$\to (0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0) = y_{k+3}$$
$$S(y_{k+3})\cdot M^T = (6.8 \quad 4.7 \quad 4.1 \quad 4.7 \quad 4.6 \quad 1.4 \quad 4.5 \quad 6.4 \quad 6.5)$$
$$\to (1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1)$$

The binary pair {(00010000001000), (100000001)} gives the limit point for the dynamical system. The following table gives different limit points when we take different input vectors.

Input vector	**Limit point**
(100000000)	(00010000001000), (100000001)
(010000000)	(00100000001000), (110000000)
(001000000)	(00100000000001), (001100000)
(000100000)	(00010010000000), (000100111)
(000010000)	(10000010000000), (000010011)
(000001000)	(00000010001000), (000001011)
(000000100)	(00000010100000), (000000110)
(000000010)	(10000010000000), (000000011)
(000000001)	(10000010000000), (000000011)

5. Conclusion

Inferences can be made from the list of limit points enumerated in the table above. For the first input vector, the limit point implies that when C_1 is kept in ON state, it pushes C_9 also to ON state and they, together, affect P_4 and P_{11} in the range space. That is, the capabilities Mental well-being and Resilience and Self-reorganization affect Decision making power and Self-esteem of women which are vital for their empowerment.

It can be observed that when C_4 is kept in ON state, it turns ON four more attributes in the domain space itself, which is the maximum, and two nodes P_4 and P_7 in the range space. Therefore C_4 (Emotion stability) plays a crucial role in women empowerment.

Next in the list are C_5 and C_6 which, when kept in ON state, push three nodes in the domain and two in the range space to ON state. Therefore they, Social sensitivity and Recreational activity assume the next importance. Similar inferences can be made from the table.

References

[1] Alkire, S. and Black, R. (1997). A Practical Reasoning Theory of Development Ethics: Furthering the Capabilities Approach, Journal of International Development, 9(2), 263-79.

[2] Dalkey, N., & Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. Management Science, 9, 458–467.

[3] Kosko, B. (1988). Bidirectional Associative Memories, IEEE Transactions on systems, man, and cybernetics, Vol. 18, No. 1, January/February 1988.

[4] Linstone, H. A., & Turoff, M., ed, (2002). The Delphi Method: Techniques and Applications, ISBN 0-201-04294-0.

[5] Martinetti, C. E. (2006). Capability Approach and Fuzzy Set Theory: Description, Aggregation and Inference Issues, in Fuzzy Set Approach to Multidimensional Poverty Measurement, ed. by A. Lemmi and G. Betti, New york: Spring Verlag, 93–114.

[6] Murray, T. J., Pipino, L. L., & Gigch, J. P. (1985). A pilot study of fuzzy set modification of Delphi. Human Systems Management, 6–80.

[7] Nussbaum, M. (2003). Capabilities as fundamental entitlements: Sen and social justice, Feminist Economics, 9(2/3), 2003, 33-59.

[8] Robeyns, I. (2003). Sen's capability approach and Gender inequality: selecting relevant capabilities, Feminist Economics 9(2/3), 2003, 61-92.

[9] Sen, A. K. (2003). Development as capability expansion. In Sakiko Fukuda-Parr and A. K. Shiva Kumar, editors, Readings in Human Development. Concepts, Measures and Policies for a Development Paradigm, Oxford University Press, 2003, 3-16.