INTRODUCTION

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Fuzzy Cognitive Map is a well established artificial intelligence technique that incorporate ideas from artificial neural network and fuzzy logic. At first, in 1976 a political scientist Robert Axelrod [2] introduced cognitive maps for representing social scientific knowledge and describing the methods that are used for decision making in social and political systems. Then in 1986, Bart Kosko [14] enhanced the power of cognitive maps considering fuzzy values for the concepts of the cognitive map and fuzzy degrees on interrelationships between concepts. After this pioneering work, Fuzzy Cognitive Maps attracted the attention of scientists in many fields and have been used in a variety of different scientific and socio-economic problems.

Fuzzy Cognitive Maps have a major role to play mainly when the data concerned is an unsupervised one. Suppose some unsupervised data having two sets of disjoint attributes is to be analyzed using fuzzy cognitive maps, they would have two directed graphs. To work for such types of models and construct such models, Fuzzy Cognitive Bimaps are introduced.

The new concept of Fuzzy Interval Maps and fuzzy interval matrices are introduced by Florentin Smarandache and Vasantha Kandasamy, W.B [25]. These fuzzy interval maps are mainly useful when the data is an unsupervised one and when one needs a multi-expert model.

Suppose n experts want to work with a problem using a FCM model, then to form an integrated dynamical system which can function simultaneously using the n experts opinion, Super Fuzzy Cognitive Maps are used.

Suppose there are situations in which no relation can be determined between some of the nodes of an unsupervised data, then indeterminacy is involved in that model. To introduce indeterminacy in Fuzzy Cognitive Maps, a

generalized structure called Neutrosophic Cognitive Maps are introduced by Florentin Smarandache [17].

The notion of neutrosophic logic play a vital role in several of the real world problems like law, medicine, industry, finance, IT, stocks and shares etc. Uncertainty or indeterminacy happens to be one of the major factors in almost all real-world problems. When uncertainty is modeled one uses fuzzy theory and when indeterminacy is involved one uses neutrosophic theory.

The main aim of this thesis is to study Fuzzy Cognitive Maps, Fuzzy Cognitive Bimaps, Fuzzy Cognitive Interval Maps, Super Fuzzy Cognitive Maps and Neutrosophic Cognitive Maps with applications to Real World Problems.

The first chapter is devoted to the study of definitions and basic concepts of fuzzy matrices, bimatrices, fuzzy bimatrices, interval matrices, interval bimatrices, fuzzy interval matrices and neutrosophic matrices which are needed for this study.

A **fuzzy matrix** is a matrix with elements having values in the closed unit interval [0,1].

A **bimatrix** A_B is defined as the union of two rectangular array of numbers A_1 and A_2 arranged into rows and columns. It is written as follows $A_B = A_1 \cup A_2$ where $A_1 \neq A_2$ with

$$A_1 = \begin{bmatrix} a^1_{11} & a^1_{12} & \cdots & a^1_{1n} \\ a^1_{21} & a^1_{22} & \cdots & a^1_{2n} \\ \cdots & & & \cdots \\ a^1_{m1} & a^1_{m2} & \cdots & a^1_{mn} \end{bmatrix} \quad \text{and} \quad A_2 = \begin{bmatrix} a^2_{11} & a^2_{12} & \cdots & a^2_{1n} \\ a^2_{21} & a^2_{22} & \cdots & a^2_{2n} \\ \cdots & & & \cdots \\ a^2_{m1} & a^2_{m2} & \cdots & a^2_{mn} \end{bmatrix}$$

'$\cup$' is just the notational convenience (symbol) only.

Given matrices $B = (b_{ij})$ and $C = (c_{ij})$ of order n such that $b_{ij} \leq c_{ij}$, $i, j = 1, 2, \ldots, n$. Then the **interval matrix** $A_I = [B, C]$ is defined by

$$A_I = [B, C] = \{A = (a_{ij}) \mid b_{ij} \leq a_{ij} \leq c_{ij} \; ; \; i, j = 1, 2, \ldots, n\}.$$

In this Chapter all these definitions and their properties are given with some interesting examples.

Chapter II deals with the basic definitions and properties of Fuzzy Cognitive Maps (FCMs), Fuzzy Cognitive Bimaps (FCBMs), Fuzzy Cognitive Interval Maps (FCIMs), Super Fuzzy Cognitive Maps (Super FCMs) and Neutrosophic Cognitive Maps (NCMs).

A **Fuzzy Cognitive Map** (FCM) is a directed graph with concepts like policies, events etc., as nodes and causalities as edges or arcs. It represents causal relationship between concepts. Each arc is accompanied by a weight that defines the type of causal relation between the two nodes (Definition 2.1)

The definitions of Fuzzy Cognitive Interval Maps (FCIMs), Super Fuzzy Cognitive Maps (Super FCMs) and Neutrosophic Cognitive Maps (NCMs) are given in 2.13, 2.14, 2.15 and 2.16 respectively.

Application of Fuzzy Cognitive Maps in real life problems facilitates deriving scientific and logical solutions.

The following are such real life problems selected for the study:

1. Application of **Fuzzy Cognitive Maps** in the analysis of the factors influencing Investment decision.
2. Application of **Fuzzy Cognitive Bimaps** in the analysis of factors influencing the academic performance of higher secondary students.
3. Application of **Fuzzy Cognitive Interval Maps** in the analysis of the problems encountered by the coffee cultivators in Kodai hills.
4. Application of **Super Fuzzy Cognitive Maps** in the analysis of opinion about the employments in 'Information Technology Sector'.
5. Application of **Neutrosophic Cognitive Maps** in the analysis of the problems faced by girl students who got married during the period of study.

It is worth mentioning that the author of this thesis published three articles related to this topic as detailed below:

1. "Application of Super Fuzzy Cognitive Maps in the analysis of opinion about the employments in Information technology sector" , **International Journal of Mathematical Sciences and Applications** [10].
2. "Application of Fuzzy Cognitive Interval Maps in the analysis of the problems encountered by the coffee cultivators in Kodai hills" , **Proceedings of the 2nd National Conference on Recent Advancements in Science and Humanities** , March 18-19, 2011, organized by Department of Science and Humanities , United Institute of Technology, Coimbatore [11].
3. "Application of Fuzzy Cognitive Maps in the analysis of the factors influencing Investment decision" , **Proceedings of the National Conference on Scientific Computing and Applied Mathematics**, June 29-30, 2011, organized by Department of Science and Humanities, V.L.B.Janakiammal College of Engineering And Technology, Coimbatore [12].

Another article "Application of Fuzzy Cognitive Bimaps in the analysis of factors influencing the academic performance of higher secondary students" was presented in the **International Seminar on New Trends in Application of Mathematics**, January 31, February 1-2, 2011, organised by Department of Mathematics, Bharata Mata College, Thrikkakara, Kochi, Kerala.

Chapter III deals with "Application of Fuzzy Cognitive Maps in the analysis of the factors influencing Investment decision". Investment decisions are influenced by different factors. While choosing a particular avenue of investment, investors need to consider various factors such as liquidity, safety of principal, rate of return, stability of return, capital appreciation and tax concessions. An attempt

has been made to analyse such factors influencing investment decision of female employees working in both government and private sector undertakings using Fuzzy Cognitive Maps. The details are presented in this chapter.

Chapter IV is devoted to the study of "Application of Fuzzy Cognitive Bimaps in the analysis of factors influencing the academic performance of higher secondary students". High score in higher secondary examination is the primary task of every student in Tamil Nadu who aspires to gain entry into a professional course of his / her choice. The importance of high score in higher secondary examination gained much significance especially after lifting the common entrance test for professional courses in Tamil Nadu. At this juncture, a research has been conducted to study the factors influencing the academic performance of higher secondary students and inferences were drawn using Fuzzy Cognitive Bimaps. The details are presented in this chapter.

Chapter V deals with "Application of Fuzzy Cognitive Interval Maps in the analysis of the problems encountered by the coffee cultivators in Kodai hills".

The coffee industry of India is the sixth largest producer of coffee in the world. Indian coffee is said to be the finest coffee grown in the shade rather than direct sunlight anywhere in the world. Three southern states of South India (Karnataka, Kerala and Tamil Nadu) account for 98 % of coffee production in India. Well known varieties of coffee grown are the Arabica and Robusta. In the study area Arabica variety is grown. Coffee is a labour-intensive crop and in Kodai Hills coffee is grown under monsoon rainfall conditions. As the coffee contributes significantly for the national economy and the growers face many hardships in coffee cultivation, a research has been conducted to study the problems encountered by them and inferences were drawn using fuzzy cognitive interval maps. The details are given in this chapter.

Chapter VI is devoted to the study of "Application of Super Fuzzy Cognitive Maps in the analysis of opinion about the employments in Information Technology Sector".

At present, IT sector provides ample employment opportunities to the educated youth in India and plays a significant role in the socio-economic development of our country. It has become the aspiration of most of the educated youth in India to become a software engineer. The new education policy in India facilitated enormous growth in the number of institutions, offering higher education in the fields of medicine, engineering, arts and science. The lucrative jobs in IT sector and the existence of more number of educational institutions motivated Indian youths to prefer IT profession. Such human resource elevated the status of our country to new heights in the global arena. An attempt has been made to analyse the opinion about the employments in IT Sector using Super Fuzzy Cognitive Maps. The details are given in this chapter.

Chapter VII deals with "Application of Neutrosophic Cognitive Maps in the analysis of the problems faced by girl students who got married during the period of study".

India still continues to be one of the countries in Asia having the lowest female literacy rate .This low rate of female literacy not only has negative impact on the welfare of the women but also on the family welfare and the economy of the country as a whole. Thanks to the government's commitment to improve literacy rates, there has been progress in educational attainment of both sexes over the past several decades. As per 1971 censes only 22 per cent of women were literate but the rate improved to 39 per cent (1991 census) (Register General and Census Commissioner (RGCC), 1993) . Despite such growth in female literacy rates, there are many barriers to female education in India. Poverty, lack of adequate educational institutions, illiterate parents and early marriage are

some of such barriers. The girls who got married during the period of study, face many problems such as changes in family environment, health condition, economic condition and mainly in academic performance. An attempt has been made to analyse such problems using Neutrosophic Cognitive Maps and the details are given in this chapter.