

REVIEW OF LITERATURE

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Fuzzy Cognitive Maps are fuzzy structures that strongly resemble neural networks and they have powerful and far-reaching consequences as a mathematical tool for modeling complex systems. Bart Kosko, the guru of fuzzy logic, introduced Fuzzy Cognitive Maps [14] in the year 1986. It was a fuzzy extension of the cognitive maps pioneered in 1976 by Robert Axelrod [2], who used it to represent knowledge as an interconnected, directed, bilevel-logic graph. Till today there are over a hundred research papers which deal with Fuzzy Cognitive Maps, and the tool has been used to study real-world situations.

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 bimap are introduced [18].

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, Super Fuzzy Cognitive Maps are used [26].

The notion of neutrosophic logic is created by Florentin Smarandache, which is an extension / combination of the fuzzy logic in which indeterminacy is included. The introduction of neutrosophic theory has put forth a significant concept by giving representation to indeterminates. Uncertainty or indeterminacy happen 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 neutrosophic models play a significant role and utilizes the concept of Neutrosophic Cognitive Maps.

Fuzzy cognitive maps have been used in a variety of scientific and socio-economic problems in real life. The details of some of them are given below:

1. Hidden patterns of diseases in children using Fuzzy Cognitive Maps.

Vasantha Kandasamy, W.B and Ram Kishore, (1998) [32]

In this paper, the hidden pattern depicting the interrelations between disease in children using Fuzzy Cognitive Maps (FCMs) are obtained. FCMs are basically matrices, which predict the feelings of all attributes under considerations. The symptoms of the diseases are considered as attributes and using the opinions of the experts the hidden patterns are obtained.

2. Applications of Fuzzy Cognitive Maps to determine the maximum utility of a route

Vasantha Kandasamy, W.B and Indra.V (2000) [27]

In this paper, the authors identified the maximum utilization time period of a route and estimate its overall utility rate by initiating the study of raw data analysis. The effective tools that they are used to analyze the data are Fuzzy Cognitive Maps. To illustrate and check the validity of their research model they have assessed it in the real data got from the Pallavan transport corporation and gave beneficial results.

3. Applications of Fuzzy Cognitive Maps to study drop outs in primary education.

Vasantha Kandasamy, W.B and Promodth, P, (1999)[30]

In this paper, Fuzzy Cognitive Maps are used to study the drop outs in primary education.

Using some basic nature of teachers – like devoted teacher, trained teacher, untrained teacher, friendly approach of the teacher towards the student etc., a teacher student model in primary education is constructed.

4. Analysis of social aspects of migrant laborers living with HIV/AIDS using Fuzzy theory and Neutrosophic Cognitive Maps.

Vasantha Kandasamy, W.B and Florentin Smarandache, (2004)[23]

The first chapter of this book is introductory in nature and it speaks about the migrant laborers. In chapter two Fuzzy Cognitive Maps are used to analyze the socio-economic problems of HIV/AIDS infected migrant laborers in rural areas of Tamil Nadu. In chapter three the role played by the government helping these migrant laborers with HIV/AIDS and factors of migration and their vulnerability in catching HIV/AIDS are analyzed. In chapter four socio-economic problems of HIV/AIDS affected migrant laborers are studied using Neutrosophic Cognitive Map.

5. FCM applied in the Design of Hybrid Models for Complex Systems

Hadjiski,M.B., Christova,N.G., and Groumpos,P.P. [7]

The paper considers an approach to design adequate models for plants with large uncertainties. Hybrid modelling schemes are described combining the First Principles based models, Fuzzy Logic models, Neural Network models and Statistical models. Several methods of aggregation are proposed: (i) Fuzzy gain scheduling of particular parameters of the First Principles model by most important input factors; (ii) Weighted sum of output signals from First Principles gain scheduled model and Fuzzy Logic model; (iii) A hybrid architecture for Hammerstein type model.

A Fuzzy Cognitive Map (FCM) is used to aggregate Separate Models and to fit more precisely the plant behaviour at different operational conditions. The presented methods are applied to the modelling of Steam Boiler Mill-Fan.

**6. Use of FCMs to model and analyse Business Performance Assessment
Kardaras, D., and Mentzas,G (1997) [13]**

This paper, proposes a framework for developing business metrics and discusses the suitability of Fuzzy Cognitive Maps (FCMs) to model and analyse the business performance indicators. Researchers and practitioners have stressed on the importance of assessing business performance particularly with respect to business and Information Systems (IS) strategic planning as well as to business process re-engineering. The authors approach to develop business metrics considers an internal as well as an external organisational perspective while it recognises the strategic potential of Information Technology (IT). FCMs have been successfully used in decision making and simulation of complex situation. Additionally, they allow for the simulation and analysis of data.

7. Use of FCM in Legal Rules

Adams, E.S., and Farbers, D.A (1999) [1]

In this Article, the authors construct a more functional model of judicial decision making by focusing on complex problems. They use cognitive psychological research on expert reasoning and techniques from an emerging area in the field of artificial intelligence, Fuzzy logic, to construct their model. To probe the complex interactions between judicial interpretation, the business and legal communities, and the legislature, the

authors apply their model to true important bankruptcy cases written by prominent formalist judges. They demonstrate how cognitive psychology and Fuzzy logic can reveal the reasoning processes that both formalist and antiformalist judges use to interpret complex statutes.

8. Creating Metabolic and regulatory Network Models using FCMs

Dickerson, J.A., Cox,Z., Wurtele, E.S and Fulmer,A.W [6]

This paper describes a model of metabolic networks that uses Fuzzy Cognitive Maps .Nodes of the map represent specific biochemicals such as proteins, RNA, and small molecules, or stimuli, such as light , heat, or nutrients. Edges of the map capture regulatory and metabolic relationships found in biological systems. These relationships are established by a domain expert, the biological literature, and extracted from RNA microarray data. This work is part of the development of a software tool, FCModeler, which models and visualizes metabolic networks. A model of the metabolism of the plant hormone gibberellin in Arabidopsis is used to show the capabilities of the Fuzzy model.

9. Fuzzy Mechanisms for Causal Relations

Carvalho, J.P., and Jose A.B.Tome., (1999) [5]

This paper presents a method to implement Fuzzy Causal Relations that can be used in Rule Based Fuzzy Cognitive Maps (RBFCM). This method introduces a new fuzzy operation that simulates the accumulative property associated with causal relations – the Fuzzy Carry Accumulation(FCA). The FCA allows a great flexibility in the addition and removal of concepts and links among concepts while keeping compatibility with classic fuzzy operations.

10. Fuzzy Cognitive Mapping: Applications in Education

Jason R.Cole and Kay.A.Persichitte (2000) [9]

This paper proposes the use of Fuzzy Cognitive Maps as a tool for creating metaknowledge and exploring hidden implications of a learner's understanding. Two specific educational applications of FCMs are explored in detail and recommendations are included for further investigations within educational contexts.

11. Intuitionistic Fuzzy Cognitive Maps for Medical Decision Making

Iakovidis.D.K and Papageorgiou.E , (2010) [8]

In this paper, medical decision making is regarded as a process, combining both analytical cognition and intuition. It involves reasoning within complex causal models of multiple concepts, usually described by uncertain, imprecise, and/or incomplete information. Aiming to model medical decision making, the authors proposed a novel approach based on cognitive maps and intuitionistic fuzzy logic. The new model, called intuitionistic Fuzzy Cognitive Map (iFCM), extends the existing Fuzzy Cognitive Map (FCM) by considering the expert's hesitancy in the determination of the casual relations between the concepts of a domain.

12. Fuzzy Cognitive Map of socio-economic model

Vasanth Kandasamy,W.B and Uma,S (1999) [34]

In this paper, the authors use Fuzzy Cognitive Map to study the hidden pattern for a socio-economic model constructed with population, crime, economic condition, poverty and unemployment as the five nodes. To study this model, they have taken only the opinion of three experts. One can take several other nodes and several experts opinion. By increasing the

nodes of the problem under study certainly the results will be sensitive and also by taking several experts opinion , the authors got a medium and a normal opinion not shooting to extremes.

13. Symptom Disease Model in children Using Fuzzy Cognitive Maps

Vasantha Kandasamy,W.B and Ram Kishore (1999) [33]

In this paper, the authors studied the symptom – disease model in children. The FCM is used to obtain the hidden pattern existing between symptom and disease in children, because FCM allows experts to represent factual and evaluative concepts in an inter active frame work. In this paper, they have taken only eight symptoms of a child and using the doctors (who are taken in this paper as experts) opinion results are derived. Further the study is free from any prejudice as all experts are given equal weightages.

14. Parent Children model using Fuzzy Cognitive Map to study dropouts in primary education

Vasantha Kandasamy,W.B and Promodth,P (2001) [31]

In this paper, the authors studied how parents are one of the causes for the increase in dropouts in primary schools. Here they have taken 10 attributes related to the parents, several experts opinion were sought. The experts were teachers, parents, educationalists and NGO's who work for the prevention of child labour (as most of the drops out are child laborers in bars, petty shops or servers or helpers). An analysis was carried out using FCM and the hidden pattern of the FCM indicated some conclusions.

15. Cancer Among Rural Men Due To Use Of Tobacco– A FCM Analysis

Vasantha Kandasamy,W.B., Nirmala,K and Nallasamy,R (2006)[29]

In this paper , the authors have investigated the relation between use of tobacco and cancer of tongue, salivary gland, pharynx, larynx and lungs of 121 male patients from rural areas who belong to an economically poor status. All the 121 of them had used tobacco both as cigar and spit tobacco. Of the 121, 60 of them acknowledged that they had used tobacco and smokeless tobacco. The use of tobacco by them is social and psychological problem. So here the authors used Fuzzy Cognitive Maps (FCMs) to study the effect of cancer among these men.

16. Study of Problems Faced By Bonded Labourers Near Kodainal Forests using Fuzzy Cognitive Maps

Vasantha Kandasamy,W.B., Narayanamoorthy,S and Mary John (2007) [28]

In this paper, the authors studied the problems faced by the bonded labourers near Kodaikanal forests using FCMs. This paper has four sections. In the first section they just recall the definition of Fuzzy Cognitive Maps (FCMs) and Combined Fuzzy Cognitive Maps (CFCMs). They described the problem in section two. Analysis of the problem using FCMs and CFCMs is carried out in section three. In the final section they gave the suggestions and conclusions based on their study.

17. Modeling supervisory systems using Fuzzy Cognitive Maps

Stylios,C.D., and Groumpos,P.P (1998)[15]

This paper examines fuzzy cognitive map (FCM) theory and its use in supervisory control systems. An FCM is a graph used to depict

cause and effect between concepts that stand for the states and variables of the system. FCM representation, construction and a mathematical model are examined; a generic system is proposed and the implementation of FCM in a process control problem is illustrated and a model for supervisors of manufacturing systems is discussed. Although an FCM seems to be a simple model of system behaviour, it appears to be a powerful and effective tool describing the behaviour of a system and representing the accumulated knowledge of a system.

In the next part of this Review of Literature, a brief survey of some of the articles and books published on Bimatrices, Interval bimatrices, Bigraphs, Neutrosophic bigraphs, Fuzzy cognitive maps, Neutrosophic Cognitive Maps are given.

1.Fuzzy Cognitive Maps

Kosko, B, (1986) [14]

Fuzzy Cognitive Maps (FCMs) are fuzzy-graph structures for representing causal reasoning. Their fuzziness allows hazy degrees of causality between hazy causal objects (concepts). Their graph structure allows systematic causal propagation, in particular forward and backward chaining and it allows knowledge bases to be grown by connect in different FCMs. FCMs are especially applicable to soft knowledge domains and several examples of FCMs are given. Causality is represented as a fuzzy relation on causal concepts. A fuzzy causal algebra for governing causal propagation on FCMs is developed. FCM matrix representation and matrix operations are presented.

2.Elementary fuzzy matrix theory and fuzzy models for social scientists

Vasantha Kandasamy, W.B., Florentin Smarandache and Ilanthenral, K, (2007)[20]

This book aims to assist social scientists to analyze their problems using fuzzy models. The basic and essential fuzzy matrix theory is again.

This book has two chapters. In chapter one, basic concepts about fuzzy matrices are introduced. Basic properties of fuzzy matrices are given.

In chapter two deals with the description of simple fuzzy models and their applications to real-world problems.

3.A Unifying field in logics : Neutrosophic logic

Smarandache Florentin, (1990)[17]

The author makes an introduction to non-standard analysis, then extends the dialectics to “ neutrosophy ” – which became a new branch of philosophy. Thus new concept helps in generalizing the intuitionistic, Paraconsistent, dialothoic, fuzzy logic to “ neutrosophic logic ” which is the first logic that comprises paradoxes and distinguishes between relative and absolute truth. Similarly, the fuzzy set is generalized to “neutrosophic set ”. Also, the classical and imprecise probabilities are generalized to “ neutrosophic probability ”

4. Introduction to bimatrices

Vasantha Kandasamy, W.B., Florentin Smarandache and Ilanthenral,K., (2005) [19]

This book introduces the concept of bimatrices, and studies several notions like bieigen values, bieigen vectors, characteristic bipolynomials, bitransformations, bioperators and bidiagonalization. Further, we introduce and explore the concepts like fuzzy bimatrices, neutrosophic

bimatrices and fuzzy neutrosophic bimatrices, which will find its application in fuzzy and neutrosophic logic.

5. Special Fuzzy matrices for Social Scientists

Vasantha Kandasamy, W.B., Florentin Smarandache and Ilanthenral, K., (2005) [21]

This book introduces special classes of Fuzzy and Neutrosophic Matrices. These special classes of matrices are used in the construction of multi-expert special fuzzy models using FCM, FRM and FRE and their Neutrosophic analogues (simultaneous or otherwise according to ones need). Using the six basic models, the authors have constructed a multi-expert multi-model called Super Special Hexagonal Fuzzy and Neutrosophic Model. Given any special input vector, these models can give the resultant using special operations.

6. Fuzzy Cognitive Maps and Neutrosophic Cognitive Maps

Vasantha Kandasamy, W.B. and Florentin Smarandache (2003) [22]

In this book, the authors studied the concepts of Fuzzy Cognitive Maps (FCMs) and their Neutrosophic analogue, the Neutrosophic Cognitive Maps (NCMs). This book has been written with two aims: First, they seek to consolidate the vast amount of research that has been done around the concepts of FCMs, and also try to give an inclusive view of the various real-world problems to which FCMs have been applied. Though there are over a hundred research papers relating to FCMs, there is no book that deals exclusively with them and they hope that this book possibly bridges that gap. Second, we introduce here (for the first time) the concept of Neutrosophic Cognitive Maps (NCMs), which are a generalization of Fuzzy Cognitive Maps. The special feature of NCMs is their ability to handle indeterminacy in

relations between concepts, which is denoted by 'I'. This new structure — the NCM is capable of giving results with greater sensitivity than the FCM. It also allows a larger liberty of intuition by allowing an expert to express not just the positive, negative and absence of impacts but also the indeterminacy of impacts.

7. Basic Neutrosophic algebraic structures and their application to Fuzzy and Neutrosophic models

Vasanth Kandasamy, W.B. and Florentin Smarandache (2004) [24]

Study of neutrosophic algebraic structures is very recent. The analysis in this book is application of neutrosophic algebraic structure and the authors found it deem fit to first introduce and study neutrosophic graphs and their applications to neutrosophic models. In Chapter One they introduced some of the basic neutrosophic algebraic structures essential for the further development of the other chapters. Chapter Two recalls basic graph theory definitions and results which has interested us and for which we give the neutrosophic analogues. Chapter Three introduces many new neutrosophic concepts in graphs and applies it to the case of neutrosophic cognitive maps and neutrosophic relational maps. The final chapter gives some problems about neutrosophic graphs which will make one understand this new subject.

8. Fuzzy interval matrices, Neutrosophic interval matrices and their applications

Vasanth Kandasamy, W.B. and Florentin Smarandache (2006) [25]

The new concept of fuzzy interval matrices has been introduced in this book for the first time. The authors have not only introduced the notion of fuzzy interval matrices, interval neutrosophic matrices and fuzzy neutrosophic interval matrices but have also demonstrated some of its applications when the data under study is an unsupervised one and when

several experts analyze the problem. Further, the authors have introduced in this book multiexpert models using these three new types of interval matrices. The new multi expert models dealt in this book are FCIMs, FRIMs, FCInMs, FRInMs, IBAMs, IBBAMs, nIBAMs, FAIMs, FAnIMS, etc. Illustrative examples are given so that the reader can follow these concepts easily.

9. Super Fuzzy Matrices and Super Fuzzy models for Social Scientists

Vasantha Kandasamy, W.B. and Florentin Smarandache (2008) [26]

The concept of super matrix for social scientists was first introduced by Paul Horst. The main purpose of this book was to introduce this concept to social scientists, students, teachers and research workers who lacked mathematical training. This book introduces the concept of Fuzzy Super matrices and operations on them. The author has provided only those operations on Fuzzy Super matrices that are essential for developing Super Fuzzy multi expert models. They illustrate the working by simple examples. This book will be highly useful to social scientists who wish to work with multi expert models.