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Description of Fuzzy Associative Memories Model (FAM) and Their Applications

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Abstract: Fuzzy Associative Models (FAMs) are powerful tools for knowledge representation and reasoning in uncertain and complex environments. By integrating fuzzy logic with associative memory, FAMs provide an interpretable and robust framework for modeling nonlinear relationships and handling imprecise information. This study explores the capabilities of FAMs in analyzing complex real-world problems, including socio-economic and environmental issues. The model enables effective prediction, decision-making, and control by capturing uncertain relationships among variables through fuzzy associations. The results demonstrate that FAMs offer improved flexibility, transparency, and accuracy compared to conventional approaches. Therefore, FAMs serve as an efficient methodology for addressing dynamic and uncertain problems across various domains, supporting better decision-making and intelligent system design.
Keywords: FAM, Fuzzy Logic, HIV/AIDS, Environmental Pollution, Decision Making, Fuzzy Sets, Associative Memory, Uncertainty Analysis, Dyeing Industries, Socio-Economic Factors**.**

I. INTRODUCTION

Fuzzy associative Models (FAMs) are a type of fuzzy logic -based model that enables the representation of uncertain and imprecise knowledge in a compact and interpretable from FAMs are particularly useful in applications where the relationships between variables are complex, nonlinear and uncertain.

Fuzzy set: FAMs use fuzzy sets to represent the input and output variables, allowing for the modelling of uncertain and imprecise data.

Associative Memory: FAMs are based on associative memory which enables the model to learn and recall patterns are relationships between variables.

Rule-based structure: FAMs consist of a set of fuzzy rules that describe the relationships between the input and output variables.

Control system: FAMs can be used to model and control complex system with uncertain and nonlinear dynamics.

Pattern recognition: FAMs can be used for pattern recognition and classification tasks, such as image and speech recognition.

Decision- making: FAMs can be used to support decision-making in uncertain and complex environments.

II. Benefits of FAMs

Improved accuracy: FAMs can provide more accurate results than traditional modelling approaches, especially in applications with uncertain and nonlinear relationships.

Increased interpretability: FAMs provide a transparent and interpretable representation of the relationships between variables, enabling uses users to understand the underlying dynamics of the system.

Flexibility: FAMs can be used in a wide range of applications, from control systems to decision-making and pattern recognition. The introduce FAM and in subsection two FAM is used to study the socioeconomic problem of women with HIV/AIDS. In subsection three we study the environmental pollution due to dyeing industries using the FAM model.

Application of Fuzzy Associative Model: A fuzzy associative model (FAM) is primarily used in applications where imprecise or uncertain data needs to be associated and recalled, making it valuable in fields like medical diagnosis, pattern recognition, control systems, and decision making, allowing for flexible reasoning with "degrees of membership "rather than strict binary classifications; some specific applications include

Medical diagnosis: Analyzing patient data with the fuzzy logic to identity potential disease patterns based on symptoms, where certain symptoms may not be clearly present or absent, but rather fall within a fuzzy range

Image processing: Recognizing objects and images with partial occlusion or noise, where fuzzy logic can handle ambiguity in pixel values.

Robot control: Adapting robot movements to charging environmental conditions, where fuzzy logic can handle uncertainty in sensor readings and provide smooth control actions.

Financial forecasting: Predicting market trends based on complex economic indicators, where fuzzy logic can incorporate imprecise or subjective information.

Natural language processing: Interpreting ambiguous language, where fuzzy logic can assign degrees of membership to different interpretations of a phrase

Traffic light control: Adjusting traffic light timings based on real-time traffic conditions, where fuzzy logic can handle varying levels of congestion.

Handling uncertainty: Fuzzy logic allows for partial membership in sets, enabling the model to deal with vague or imprecise input data.

Robustness to noise: Due to the fuzzy nature of the associations, FAMs can tolerate noisy input data and still provide meaningful outputs.

Interpretability: Fuzzy rules can often be easily understood by humans, making it easier to explain the models decision-making process.

III. Introduction to Fuzzy Associative Memories

A fuzzy set is a map $\mu: X \rightarrow [0, I]$ where X is any set called the domain and [0, I] the range i.e., μ is thought of as a membership function i.e., to every element $x \in X$ μ assigns membership value in the interval [0, I]. But very few try to visualize the geometry of fuzzy sets. It is not only of interest but is meaningful to see the geometry of fuzzy sets when we discuss fuzziness. Till date researchers over looked such visualization [Kosko, 108-112], instead they have interpreted fuzzy sets as generalized indicator or membership functions mappings μ from domain X to range [0, I]. But functions are hard to visualize. Fuzzy theorist often picture membership functions as two dimensional graphs with the domain X represented as a one dimensional axis.

The geometry of fuzzy sets involves both domain $X = (x_1 \ldots \ldots x_n)$ and the range [0, I] of mappings $\mu : X \rightarrow [0, 1]$. The geometry of fuzzy sets aids us when we describe fuzziness, define fuzzy concepts and prove fuzzy theorems. Visualizing this geometry may by itself provide the most powerful argument for fuzziness. An odd question reveals the geometry of fuzzy sets. What does the fuzzy power set F(2X), the set of all fuzzy subsets of X, look like? It looks like a cube, what does a fuzzy set look like? A fuzzy subsets equals the unit hyper cube $I^n = [0, 1]^n$. The fuzzy set is a point in the cube In. Vertices of the cube In define a non-fuzzy set. Now with in the unit hyper cube $1^n = [0, 1]^n$ we are interested in a distance between points, which led to measures of size and fuzziness of a fuzzy set and more fundamentally to a measure. Thus within cube theory directly extends to the continuous case when the space X is a subset of Rn. The next step is to consider mappings between fuzzy cubes. This level of abstraction provides a surprising and fruitful alternative to the prepositional and predicate calculus reasoning techniques used in artificial intelligence (AI) expert systems. It allows us to reason with sets instead of propositions.

The fuzzy set framework is numerical and multidimensional. The AI framework is symbolic and is one dimensional with usually only bivalent expert rules or propositions allowed. Both frameworks can encode structured knowledge in linguistic form. But the fuzzy approach translates the structured knowledge into a flexible numerical framework and processes it in a manner that resembles neural network processing. The numerical framework also allows us to adaptively infer and modify fuzzy systems perhaps with neural or statistical techniques directly from problem domain sample data. Between cube theory is fuzzy-systems theory. A fuzzy set defines a point in a cube. A fuzzy system defines a mapping between cubes. A fuzzy system S maps fuzzy sets to fuzzy sets. Thus a fuzzy system S is a transformation $S: 1^n \rightarrow 1^p$. The n dimensional unit hyper cube in houses all the fuzzy subsets of the domain space or input universe of discourse $X = \{x_1 \ldots \ldots x_n\}$. 1^p houses all the fuzzy subsets of the range space or output universe of discourse, $Y = \{y_1 \ldots \ldots y_p\}$. X and Y can also denote subsets of R^n and R^p. Then the fuzzy power sets F (2^X) and F (2^Y) replace In and 1^p. In general a fuzzy system S maps families of fuzzy sets to families of fuzzy sets thus $S: I^{n1}X \ldots . XI^{nr} \rightarrow I^{p1}X \ldots . XI^{ps} \ldots$ Here s too we can extend the definition of a fuzzy system to allow arbitrary products or arbitrary mathematical spaces to serve as the domain or range spaces of the fuzzy sets. We shall focus on fuzzy systems $S: I^n \rightarrow I^p$ that map balls of fuzzy sets in to balls of fuzzy set in Ip. These continuous fuzzy systems behave as associative memories. The map close inputs to close outputs. We shall refer to them as Fuzzy Associative Maps or FAMs. Fuzzy associative memories are primarily used in applications where dealing with uncertain or imprecise information is crucial, including: pattern recognition, control systems, prediction, image processing, decision making, and medical diagnosis.

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IV. USE OF FAM MODEL TO STUDY THE SOCIO ECONOMIC PROBLEM OF WOMEN WITH HIV/AIDS:

At the outset we first wish to state that these women are mainly from the rural areas, they are economically poor and uneducated and majority of them are infected by their husbands. Second we use FAM because only this will indicate the gradations of the causes, which are the major cause for women being affected by HIV/AIDS followed in order of gradation the causes. Further among the fuzzy tools FAM model alone can give such gradations so we use them in this analysis. Another reason for using FAM is they can be used with the same FRM that is using the attributes of the FRM, FAMs can also be formulated. Already FAMs are very briefly described in section one of this chapter. We now give the sketch of the analysis of this problem with a view that any reader with a high school education will be in a position to follow it.

Example: The illustrate two expert's opinion though we have used several experts' opinion for this analysis. Using the problems of women affected with HIV/AIDS along the rows and the causes of it along the column we obtain the related fuzzy vector matrix M.

The following are taken as the attributes (concepts) related with women, which is taken along the rows.

W_1 →Child marriage / widower marriage / child married to men twice or thrice their age
W_2 →Causes of women being infected with HIV/AID
W_3 →Disease untreated till it is chronic or they are in last stages of life due to full-blown AIDS
W_4 →Women are not traditionally considered as breadwinners for the work they do and the money they earn to protect the family is never given any recognition
W_5 →Free of depression and despair in spite of being deserted by family when they have HIV/AIDS
W_6 → Faith in god / power of god will cure
W_7 → Married women have acquired the disease due to their husbands.

The concepts associated with society, men /husband is taken along the columns.

$R_{1\rightarrow}$ Female child a burden so the sooner they get her married off, the better relief economically
R_2 → Poverty / not owners of property
R_3 → Bad habits of the men / husbands
R_4 → Infected women are left uncared by relatives, even by husbands
R_5 → No Guilt or fear of life
R_6 → Not changed religion and developed faith in god after the disease
R_7 → No moral responsibility on the part of husbands and they infect their wives wilfully
R_8 → Frequent, natural abortion / death of born infants
R_9 → STD / VD infected husbands
R_{10} → Husbands hide their disease from their family so the wife becomes HIV/AIDS infected.

The gradations are given in the form of the fuzzy vector matrix M which is as follows.

–	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
W_1	0.9	0.8	0.7	0	0	0	0	0	0	0.7
W_2	0.5	0.8	0.6	0	0	0	0	0	0	0
W_3	0	0.3	0.6	0	0	0	0	0	0	0
W_4	0	0	0	0.6	0	0	0	0	0	0
W_5	0	0	0	0	0.9	0.6	0.7	0	0	0
W_6	0	0	0	0	0	0.7	0.5	0	0	0
W_7	0	0	0	0	0.6	0	0	0	0	0

Now using the expert's opinion, we get the fit vectors. Suppose the fit vector B is given as B = (0 1 1 0 0 0 0 0 1 0). Using max min in backward directional we get FAM described as A = M o B that is ai =max min (mij, bj) $1 \leq j \leq 10$. Thus A = (0.8, 0.8, 0.6 0 0 0 0) since 0.8 is the largest value in the fit vector in A and it is associated with the two nodes vide W1 and W2 child marriage / widower child marriage etc finds it first place also the vulnerability of rural uneducated women finds the same states as that of W1. Further the second place is given to W3, disease untreated till it is chronic or they are in last stages, all other states are in the off state. Thus we see the major cause being infected by HIV/AIDS is R1 and R5 having the maximum value. viz. female child a burden so the sooner they get married off the better relief economically; and women suffer no guilt and fear for life. The next value being given by R2 and R3, poverty and bad habits of men are the causes of women becoming HIV/AIDS victims. The next value being R6, R7 and R10 taking the value 0.7, women have not changed religion and developed faith in god after the disease, lost faith in god after the disease. Husbands hide their disease from family so wife becomes HIV/AIDS infected. Several conclusions can be derived from the analysis of similar form. Now we proceed on to describe one more model using FAM. Using the attributes related with women affected with HIV/AIDS along the rows and the causes of it along the column we obtain the fuzzy rector matrix M1. The gradations are given in the form of the fuzzy vector matrix which is as follows.

–	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
W_1	.9	.8	.6	0	.5	.7	0	0	.4	0
W_2	.8	.7	.8	0	0	0	0	0	.7	0
W_3	.7	.6	.5	0	0	.8	0	0	0	0
W_4	.9	.7	0	0	0	0	0	.8	.7	0
W_5	.8	.6	.7	0	0	0	0	.7	0	0
W_6	0	0	.4	0	0	0	0	.6	0	0
W_7	.4	0	.6	0	0	0	0	0	0	0
W_8	.6	.5	0	0	.4	.3	0	0	0	0
W_9	0	0	0	0	0	0	.8	0	.4	.6

Now using the experts opinion we get the fit vectors B, given as B = (1 1 1 0 0 0 0 0 1), using max-min backward direction we get FAM described as A = M1 o B. That is a_j= max min (mij bj), $1 \le j \le 10$ = (0.9, 0.8, 0.8, 0, 0.5, 0.8, 0.8, 0, 0.7, 0.6). Since 0.9 is the largest value in the fit vector A and it is associated with W1 and W4, we see the root cause or the major reason of women becoming HIV/AIDS infected is due to no basic education, no recognition of their labour. One may be very much surprised to see why the coordinate "no recognition of labour" find so much place the main reason for it if they (men i.e., the husband) had any recognition of their labour certainly he would not have the heart to infect his wife when he is fully aware of the fact that he is suffering from HIV/AIDS and by having unprotected sex with his wife certainly she too would soon be an HIV/AIDS patient. Thus W1 and W4 get the highest value. The next value is 0.8, which is got by the nodes W2 and W5. W2 – No wealth and property and W5 – No protection from their spouse. If wealth and property was in their hands (i.e., in the name of women) certainly they would fear her untimely death for the property may be taken by her relatives. Further these women cannot protect themselves from their husbands even if they are fully aware of the fact that their husbands are infected by HIV/AIDS.

V. USE OF FAM MODEL TO STUDY THE ENVIRONMENTAL POLLUTION DUE TO DYEING INDUSTRIES:

We now give the description of the problem. Dyeing industries of Tamil Nadu, especially the ones situated in and around Tiruppur have become the concern of environmentalists, government, public and courts. For the safety, social, moral and ethical considerations of their functioning are questionable. The environmental pollution caused by these dyeing industries is unimaginable. It is reported on 2 September 2005 in the New Indian Express that 120 tonnes of dead fish have been removed from the dam site. It was further advised that people who consume these fish have the risk of being food-poisoned. A team lead by a retired PWD Chief Engineer to study the desilting of the Orathupalayam dam was to be taken. As per the orders of the Madras High Court the release of the entire volume of water into the Cauvery River resulted in the death of 120 tonnes of fish that could have yield profit in lakhs. Here, the labour situation and wages for the workers are in general bad and their issues are never taken up by anyone. Further no proper procedure is adopted in treating the wastes from the dyeing units. Thus very recently, on 27 August 2005 the Tamil Nadu government has planned with the help of Russian institutes to set up a centre for treating the wastages from these dyeing industries for Rs.323 crores. Not only fish, earlier it was reported on 28 August 2005 that several lakhs worth of betel leaves were damaged because the water had been contaminated by the dyeing unit's wastages. Over 100 acres of crop was damaged beyond use. The people in and around these units suffer several untold health problems. The politicians, public and the government are keeping quiet. The main reason attributed is the amount of revenue the nation gets because of these dyeing industries. But as our study is only about environmental pollution by these dyeing industries, so we do not indulge about the problems related with labour/wages/ hours of work. A "FAM Model" in the context of environmental pollution studies usually refers to a "Family – based Air Pollution Model," which allows researchers to examine how environmental pollution exposure varies within different family structures and can impact the health of family member, particularly children, by considering factors like household income, parental behaviours, and residential location in relation to pollution sources.

Example: Now we use FAM model to analyse the environmental pollution caused by dyeing industries Since the environmental problems faced due to the wastages from these dyeing industries cannot be put in as a data for it pollutes, the living creatures of the water (dead fish due to poisoning came to 120 tonnes) including crabs and other aquatic plants and animals, it also destroyed plantations, crops and above all the health conditions of people at large cannot be comprehended. Hence we are justified in using fuzzy theory in general and FAM in particular to analyze this problem. As the analysis involves lots of uncertainty and unpredictability, we felt FAM will be the best tool and also it is a model in which the resultant vectors are graded. We had been to the neighbourhoods of these dyeing units and collected the data from people and also visited the spots of havoc. This data was obtained in the form of linguistic questionnaire. The expert's opinion was transformed into a FAM model. The attributes given by majority of the experts which are consolidated as follows:

Attributes related with the dyeing industries.

D_1 →No proper labour standard

D_2 →No proper means to treat the poisonous dyeing waste

D_3 → No moral responsibility of polluting the land and water resources etc

D_4 →Money making is the only motive
D_5 →Refusal to follow any industrial acts / trade union acts
D_6 → Not followed any norms of Tamil Nadu Pollution Control Board
D_7 → Legal remedies favouring them due to powerful economic strata
D_8 → No moral responsibility of any of the problems be it material / ethical/ human
D_9 →Very dangerous total environmental pollution
D_{10} → Increases migrant labourers.

The attributes related to the environmental pollution are
E_1 →Death of over 120 tonnes of fish
E_2 → All living creations in water destroyed or slowly destroyed due to the mixing of wastages from these dyeing units with water resources in and around the industries
E_3 → Death of plantations
E_4 →Health hazards suffered by the labourers employed in these industries
E_5 →Health hazards suffered by the people living in and around these industries
E_6 →Pollution of soil
E_7 →Pollution of ground water.

Here it is important to mention that it is the liberty of one to work with more or less number of attributes. We have selected these attributes and we work with them using the FAM model. We illustrate here only one expert's opinion, though we have used several of the expert's opinions for the study. Using the attributes related with the industry along the rows and the environmental pollution by the dyeing industries along the columns we obtain the related fuzzy vector matrix M^T.

The gradations are given in the form of the fuzzy vector matrix M^T which is as follows.

$$M^T = \begin{bmatrix} 0.9 & 0.8 & 0.7 & 0 & 0 & 0 & 0 & 0 & 0 & 0.7 \\ 0.5 & 0.8 & 0.6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.3 & 0.6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.9 & .6 & .7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.7 & 0.5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Thus A = (0.8, 0.8, 0.6, 0 0 0 0) since 0.8 is the largest value of the fit vector A and it is associated with the two nodes E1 and E2, Death of over 120 tonnes of fish and All living creations in water destroyed or slowly destroyed due to the mixing of wastages from these dyeing units with water resources in and around the industries finds its first place, also this is due to the fact local people have become very much affected by the death of 120 tonnes of fish and this is fresh in their memories, so they are also naturally agreeing to the fact that the natural water resources are highly polluted. Likewise, the complete destruction of crops (betel leaves) has also affected them which are worth several lakhs. It is a pity they forget their own health hazards. Suppose we consider the resultant vector A = (0.8, 0.8, 0.6, 0 0 0 0) Thus the major cause of being affected by these dyeing industries and D1 and D5 having the Maximum value viz. No proper labour standard and Refusal to follow any industrial acts / trade union acts.

The next higher value being given by D2 and D3, i.e., No proper means to treat the poisonous Dyeing Waste and No moral responsibility of polluting the land and water resources etc. The next value being D6, D7 and D10 taking the value 0.7, that is the industries have not followed any norms of Tamil Nadu Pollution Control Board, Legal Remedies favouring them due to powerful economic start and increase of migrant labourers. From our study we see that the major reason for the chaotic behaviour of these dyeing industries is that they do not follow any labour standards and their refusal to follow the industrial acts/ trade union acts has resulted in the dangerous pollution of the environment resulting in the death of fish and crop which is a major and only source of the livelihood of the natives of that place. Secondly we see that they do not follow any method to treat the waste, we see that the two reasons which can be attributed are:

1. Treatment of these wastes is very costly.
2. They know that they can do anything and get away with it, if they are economically powerful.

Also the death of fish and crop are very strong in the memories of the public so whatever is spoken about the pollution ends in their description of the tragedy. It is high time the owners of the dyeing industries take up moral responsibilities and stop further pollution. They do not imagine the harm they do to the nation which is irreparable damage to the soil and water and can have disastrous consequences for people's health. Unless very strong laws are made to punish the erring industries it would be impossible to save the nation from the environmental pollution.

VI. CONCLUSION

Fuzzy associative models (FAMs) have been demonstrated to be a powerful tool for knowledge representation and reasoning in uncertain and complex environments. By leveraging fuzzy logic and associative memory. FAMs provide a robust and interpretable framework for modelling nonlinear relationships and making predictions. Fuzzy associative models have the potential to revolutionize the way we approach complex problems in uncertain and dynamics environments. By providing a robust and interpretable framework for knowledge representation and reasoning, FAMs can enable users to make more accurate predictions, better decisions, and more effective control actions.

Author contribution Statement

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Software: J.Vimala
Validation: Dr.C.Venkatesan
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