

# Classification using Fuzzy Cognitive Maps & Fuzzy Inference System

Kanika Bhutani<sup>1</sup> and Yogita Gigras<sup>2</sup>

<sup>1</sup>CSE & IT Dept. ITM University Gurgaon, India

<sup>2</sup>CSE & IT Dept. ITM University Gurgaon, India

E-mail: <sup>1</sup>kanikabhutani91@gmail.com, <sup>2</sup>yogitagigras@itmindia.edu

**Abstract**— Fuzzy classification has become very necessary because of its ability to use simple linguistically interpretable rules and has get control over the limitations of symbolic or crisp rule based classifiers. This paper mainly deals with classification on the basis of soft computing techniques Fuzzy cognitive maps and fuzzy inference system. But the data available for classification contain some missing or ambiguous data so it is better to use the Neutrosophic logic for classification.

**Keywords:** Classification; Fuzzy cognitive maps; Fuzzy inference system.

## 1. INTRODUCTION

FUZZY cognitive maps (FCMs) are reasoning networks represented by directed graphs. FCM is described by a directed graph with feedback, which contains a collection of nodes and directed weighted arcs connecting nodes. In FCMs, the nodes represent the concepts. The signed weights associated with the directed arcs represent the types and magnitudes of the causalities between concepts[1]. FCMs are more applicable when the data in its initial state is an unsupervised one. The FCMs work on the opinion of experts. FCM is a simple and effective tool which is used in lots of applications like politics [3], banking [4], medical field [5, 6], sports [7], robotics [8], expert systems [9], etc. A simple FCM is shown in Fig. 1.

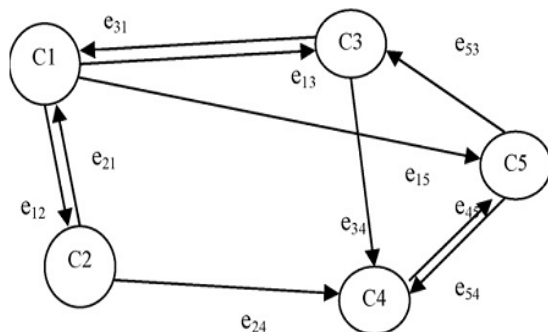


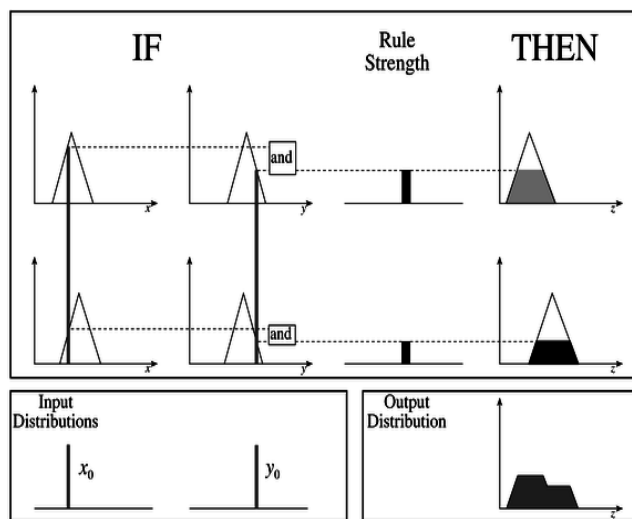
Fig. 1: A simple FCM

A fuzzy inference system (FIS) is any system that utilizes fuzzy logic to relate inputs (features in the fuzzy classification) to outputs (classes in the fuzzy classification)[10].

To calculate the output of FIS, one must follow the given six steps[10]:

1. Finding a set of fuzzy rules.
2. Fuzzify the inputs using the input membership functions.
3. Combine the fuzzified inputs using fuzzy rules to establish a rule strength.
4. Determine the consequence of the rule by integrating the strength of rule and membership function of output.
5. Merge the consequences to get an output distribution.
6. Defuzzify the output distribution.

Fig. 2 shows the detailed process[10].



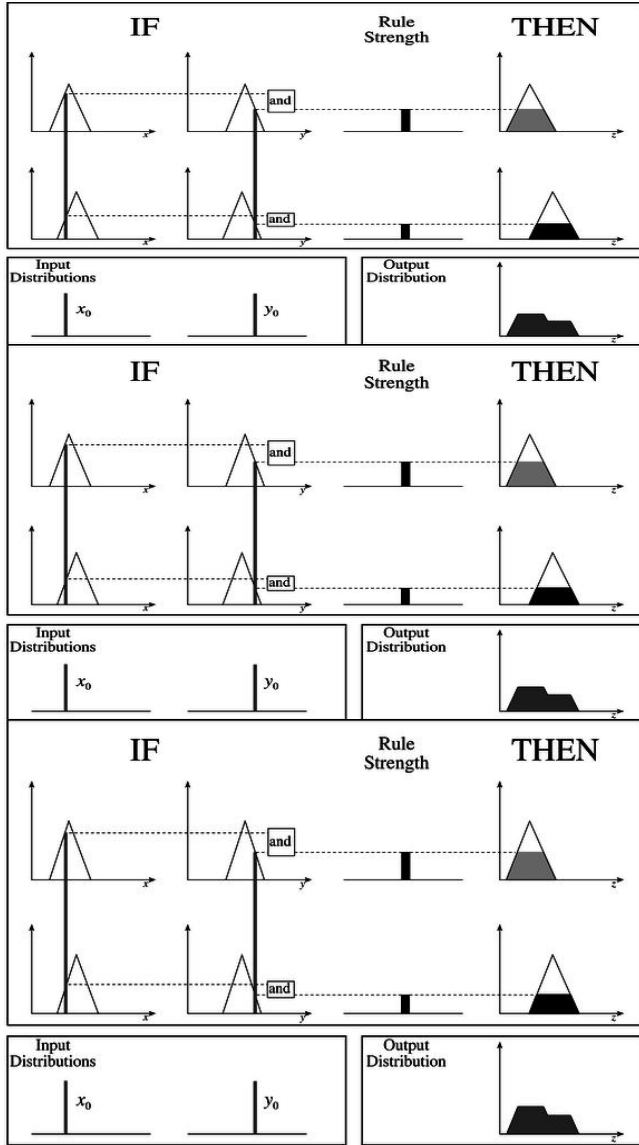


Fig. 2: Mamdani FIS with two crisp inputs and two rules

2. LITERATURE REVIEW

Classification

Classification may refer to the process in which various objects are identified, distinguished and concluded[11]. Different types of Classification are shown in Table I.

Table 1: Types of Classification

Classification	Definition
Statistical Classification	Classification is the process of identifying an instance to which category it belongs to, on the basis of a training set whose category membership is known. An example is to assign an email into "spam" or "non-spam" classes[12].

Biological Classification	It is a method of scientific catalog used to group and classify organisms hierarchically[13].
Library Classification	It is a system according to which library materials (such as books, maps, audiovisual materials, computerfiles, manuscripts, documents) are arranged on library shelves, according to subject, and allocating a call number[14].
Data Classification	Data classification as a part of Information Lifecycle Management (ILM) process can be described as a tool for grouping of data to allow an organization to effectively answer following questions[15]: What data types are available? Where are certain data located? What access levels are implemented? What protection level is implemented and does it adhere to compliance regulations?
Document Classification	It is to allot a document to one or more classes or categories. This can be done manually or algorithmically[16].
Medical Classification	Medical classification, or medical coding, is the process of transforming descriptions of medical diagnoses and procedures into universal medical code numbers[17].

3. FUZZY LOGIC

Conventional logic is a subset of Fuzzy logic. Fuzzy Logic was started off in 1965, by Dr. Lotfi A. Zadeh, professor for computer science at the university of California in Berkley[18].

Fuzzy logic is a many-valued logic that deals with reasoning which is approximate not exact. Comparing with traditional binary sets, fuzzy logic variables may have a truth value that ranges between 0 and 1. Fuzzy logic has been elaborated to cover the idea of partial truth, where the truth value may vary between completely true and completely false[19].

In classical set theory, a subset  $B$  of a set  $A$  can be described as a mapping from the elements of  $A$  to the elements of the set  $\{0, 1\}$ [20],

$$B : A \rightarrow \{0, 1\}$$

This association can be described as a set of ordered pairs, with exactly one ordered pair for every element of  $A$ . The first element is an element from set  $A$ , and the second element is an element from set  $\{0, 1\}$ . The value zero represents non-membership, and the value one represents membership. The statement is either true or false

$$a \text{ is in } B$$

is calculated by determining the ordered pair with first element as  $a$ . The statement is true if the second element is 1, and is false if 0.

Similarly, a fuzzy subset  $S$  of a set  $A$  can be described as a set

of ordered pairs, having first element from  $A$ , and the second element from the interval  $[0,1]$ . This describes the association between elements of the set  $S$  and all the values in the interval  $[0,1]$ . The value zero represents complete non-membership, the value one represents complete membership, and values in between represent intermediate degrees of membership. The set  $A$  is used as the universal set for the fuzzy subset  $S$ . Frequently, the association of one element with another is called the membership function of  $F$ . The degree to which the statement

$$a \text{ is in } F$$

is true is deduced by finding the ordered pair with first element as  $a$  and the second element is the degree of truth[20].

Membership Functions representing three fuzzy sets for the variable “height” is represented in Fig. 3.

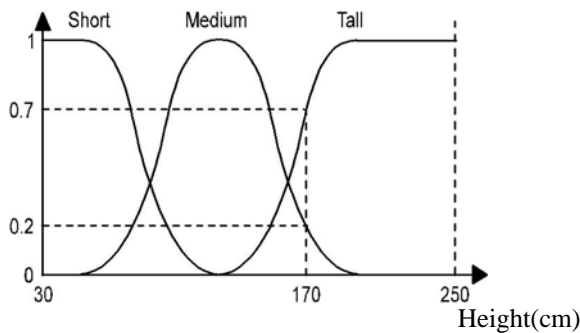


Fig. 3: Fuzzy set for Height

#### 4. FUZZY CLASSIFICATION

Fuzzy classification is the process of collecting elements into a fuzzy set whose membership function is described by the truth value of a fuzzy propositional function[21]. In fuzzy classification, a sample can have membership in various classes to varying degrees. Typically, the membership values are restricted so that all of the membership values for a specific sample sum to Linguistic rules related to the control system composing two parts; an antecedent part (between the IF and THEN) and a consequent part (after THEN). Optimum evaluation is usually done by experienced operators. The inputs are integrated logically using the AND operator to produce output response values for all expected inputs. The results are then merged to logical sum for each membership function.

Finally, all that remains is joined in defuzzification process to produce the crisp output[22].

#### 5. FUZZY CLASSIFIER

A classifier is any algorithm that allocates a class label to an object, depending upon the object. It also projects the class label. Fuzzy classifier is any classifier that utilizes fuzzy sets or fuzzy logic in its training or operation[23].

#### 6. MODELS OF FUZZY CLASSIFIER

##### 1) Fuzzy Rule Based Classifier

##### a) Class label as the consequent

Fuzzy if-then system is the simplest fuzzy rule-based classifier. Consider an example with 4 classes. A fuzzy classifier is described with classification rules, e.g.[23],

IF  $y_1$  is large AND  $y_2$  is medium THEN class is 1

IF  $y_1$  is medium AND  $y_2$  is small THEN class is 2

IF  $y_1$  is large AND  $y_2$  is small THEN class is 3

IF  $y_1$  is small AND  $y_2$  is large THEN class is 4

An example of such classifier is shown in Fig. 4.

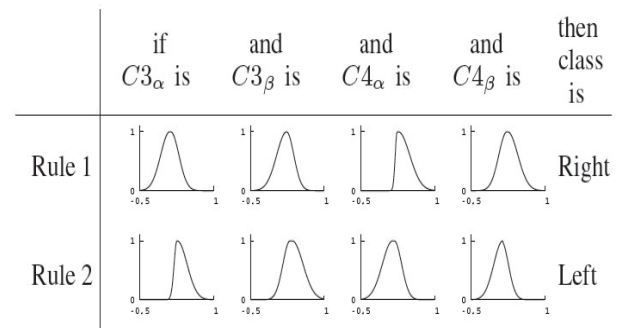


Fig. 4: Fuzzy rule based classifier

##### b) Linguistic label as the consequent

The consequent part of the rule may consist of linguistic values, e.g.[23],

IF  $y_1$  is medium AND  $y_2$  is small THEN class 1 is large AND class 2 is medium AND class 3 is small AND class 4 is small.

This rule can be easily obtained from a human expert. Here the classifier is Mamdani-type fuzzy system (Mamdani, 1977). The output contains the values of  $c$  different functions.

##### c) Function as the consequent

Here the classifier is Takagi-Sugeno fuzzy systems (Takagi and Sugeno, 1985).

$$\text{IF } y_1 \text{ is } B_1 \text{ and AND } y_2 \text{ is } B_2 \text{ AND ... AND } y_n \text{ is } B_n$$

$$\text{THEN } h_1 = \sum_{i=0} a_{i1} x_i \text{ AND ... } h_c = \sum_{i=0} a_{ic} x_i ,$$

where  $B_i$  are linguistic values and  $a_{ij}$  are scalar coefficients.

#### d) Training fuzzy rule-based classifiers

The crucial question is how training of fuzzy classifiers is done. How the various membership functions are determined? How are the rules formed? How are the consequents defined[23]?

#### 2) Fuzzy prototype-based classifiers

There are many models which are inspired by the concept of "fuzzifying" classical classifiers. K-nearest neighbour classifier (K-nn) is a representation of such classifier. In the conventional K-nn, the object  $a$  is classified as the major part of its K nearest neighbours in the referred data set. The estimations of the posterior probabilities for different classes are primitive, referred by the distribution of neighbours out of k objects voting for a specific class. Fuzzy K-nn utilizes the distances to the neighbours[23].

## 7. PRESENT WORK

V. C. et.al. presented a research based on the classification system used by speech and language pathologists for diagnosis of the dysarthrias and apraxia of speech. The dysarthrias and apraxia are complicated problems of speech because it can affect each part of speech production. So the authors used Fuzzy Cognitive Maps (FCMs) as a "second opinion" or training system and they have tested the system upon real patients and differentiated six types of dysarthria and apraxia[24].

Arthi Kannappan et.al. presented a paper based on artificial immune systems (AIS) which perform classification based on fuzzy cognitive map learning. The algorithm proposed in this paper which is motivated by theoretical immunology considered FCM network for categorization. The algorithm is applied in classification problem of autism and in some other machine learning datasets to check its functionality[25].

Mukesh Kumar et.al. described the DNA microarray classification. In the analysis of microarray data, only those features are taken which have high relevance with the classes and importance in the feature set. Authors used the t-statistic for selecting the feature having high relevance and Fuzzy inference system (FIS) is used for classification. Authors made a comparative study of Fuzzy inference system (FIS) for a set of genes on the basis of parameters such as: precision, recall, specificity, F-Measure, ROC curve and accuracy. The results are compared with the existing classifiers and it is shown that the proposed system has more accuracy rate[26].

Uraiwan Inyaem et.al. presented a research on classification in terrorism domain using fuzzy inference systems and adaptive neuro-fuzzy inference system (ANFIS) Authors used FIS settings and made two comparisons. The first analysis is done by comparing the structured and unstructured events using the same FIS setting. The second analysis is done for classifying structured events between FIS and ANFIS. The data set contains the news articles relating terrorism events. The results have shown that the classification performance of the structured events using FIS is better and more accurate as compared to the unstructured events. Also, high performance is achieved using ANFIS for the classification of structured events[27].

E.I. Papageorgiou et.al. has described a research for determining the brain tumor by following the thinking process of patient using FCM. The proposed method used 100 instances for validation. FCM model acquired an accuracy of 90.26% (37/41) and 93.22% (55/59) for determining the brain tumors of low-grade and high-grade. The proposed model is compared with the decision trees on same dataset. The proposed FCM model is more interpretable and transparent in making a decision, which proved it as a suitable consulting tool in characterizing brain tumor. The results are shown in Table II.

**Table 2: Comparison of different techniques**

Comparative results				
Technique/ accuracy	FCM grading tool (%)	ID3 (%)	J48 (%)	Fuzzy decision trees (%)
Low	90.3	72.2	81.3	90.3
High	93.2	88.2	89.5	94.9
Overall	92	80	85.71	93

## 8. CONCLUSION

This paper discusses various research done in the field of classification using FCM and FIS. This can also be done using FCM with if-then rules. Fuzzy classification has become very popular in various field but if the dataset contain missing, uncertain values then it is better to use Neutrosophic logic that deals with indeterminacy. Neutrosophic logic is a logic in which three relations are considered- positive, negative and indeterminate relations.

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