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Fuzzy Inference System & Fuzzy Cognitive Maps based Classification

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***Abstract*—Fuzzy classification is very necessary because it has the ability to use interpretable rules. It has got control over the limitations of crisp rule based classifiers. This paper mainly deals with classification on the basis of soft computing techniques fuzzy cognitive maps and fuzzy inference system on the lenses dataset. The results obtained with FIS shows 100% accuracy. Sometimes the data available for classification contain missing or ambiguous data so Neutrosophic logic is used for classification to deal with indeterminacy.**

Keywords—Classification; Fuzzy cognitive maps; Fuzzy inference system.

I. INTRODUCTION

Kosko introduced the concept of fuzzy cognitive maps (FCM)[1]. Cognitive maps are extended and FCM is introduced that consists of nodes which describe the attributes of the system. In FCMs, the nodes represent the concepts and the signed weights represent the types and magnitudes of the causalities between concepts[2]. FCMs deal with unsupervised data. The FCMs work on the experts opinion[3]. FCM is a simple and effective tool which is used in lots of applications like politics [4], banking [5], medical field [6, 7], sports [8], robotics [9], expert systems [10], etc. A simple FCM is shown in Fig. 1.

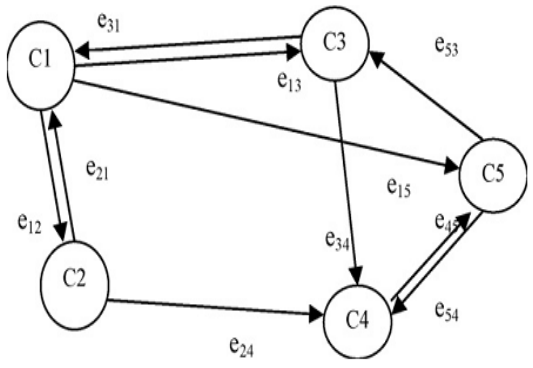

Fig. 1. A Simple FCM

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

To calculate the output of FIS, one must follow the given six steps[11]:

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 of Mamdani FIS[11].

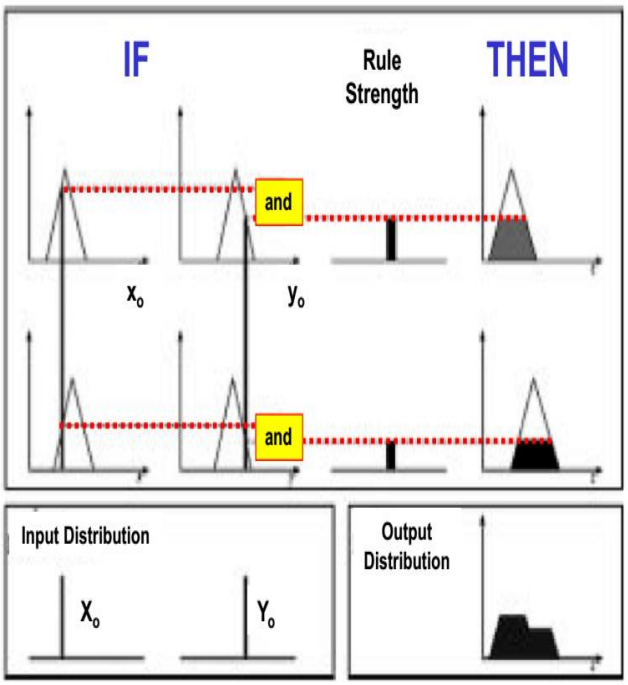

Fig. 2. Mamdani FIS with two crisp inputs and two rules

Consider the example of Tip problem as shown in Fig. 3.

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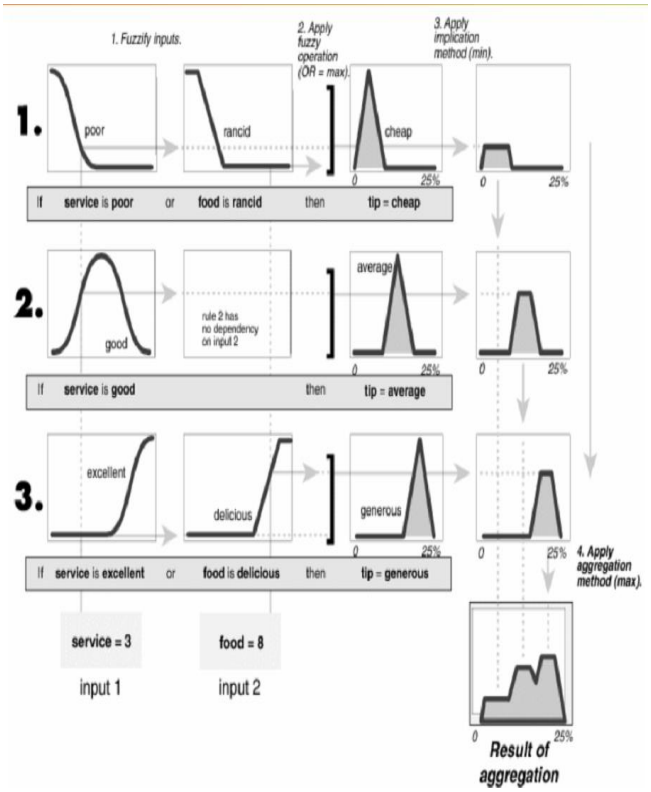

Fig. 3. Tip problem using Mamdani FIS

II. LITERATURE REVIEW

A. Classification

Classification is the process in which various objects are identified, distinguished and concluded[12]. Different types of Classification are shown in Table I.

TABLE 1. TYPES OF CLASSIFICATION

Classification	Definition
Statistical Classification	It 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. Example is assigning an email into "spam" or "non-spam" classes[13].
Biological Classification	It is a method of scientific catalogused to group& classify organismshierarchically[14].
Library Classification	It is a system according to which library materials (suchas books,documents etc.) are arranged on library shelves, according to subject or call number[15].
Data Classification	It is a process that can be used for grouping of data to allow an organization to answer the following questions[16]: What types of data are accessible? Where are specific data available?
Document Classification	It is to allot a document to one or more classes or categories. This can be done manually or algorithmically[17].
Medical Classification	It is the process of transforming descriptions of medical diagnoses and procedures into universal medical code numbers[18].

B. Fuzzy Logic

Conventional logic is a subset of Fuzzy logic.Fuzzy Logic was introduced in 1965, by Dr. Lotfi A. Zadeh, professor for computer science at the university of California in Berkley[19].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[20].

According to the set theory of classical logic, a subset B of set A can be described as a mapping from the elements of A to the elements of the set {0, 1}[21],

$$B : A \text{ --> } \{0, 1\}$$

This association can be described as a set of ordered pairs in which the primary element is from set A, and the secondary element is from set {0, 1}. Non-membership is represented by value 0 and membership is represented by value 1[21].

Membership Functions representing three fuzzy sets for the variable "speed" is represented in Fig. 4.

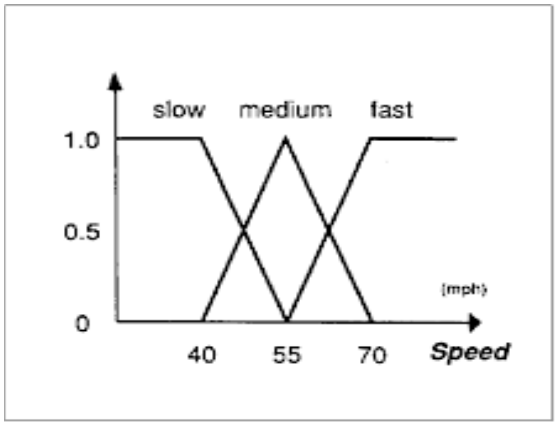

Fig. 4. Fuzzy set for Speed

C. 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[22].An instance can have membership in various classes to varying degrees[23]. Fuzzy classification can be seen in various fields[24,25,26,27,28].

III. FUZZY CLASSIFIER

A classifier is any algorithm that allocates a class label to an entity, depending upon the entity. Fuzzy classifier is any classifier that utilizes fuzzy sets in its working or operation[29].

A. Models of Fuzzy Classifiers

1)Fuzzy Rule Based Classifiers

a)Class label as the consequent

Fuzzy if-then system is the simplest rule-based classifier. Consider an example with 2 classes. A fuzzy classifier is explained with classification rules, e.g.[29],

IF y_1 is small AND y_2 is medium THEN class is A

IF y_1 is large AND y_2 is medium THEN class is B

b)Linguistic labels as the consequent

The resultant part of the rule may consist of linguistic values,eg.[29],

IF y_1 is small AND y_2 is large THEN class A is small AND class B is medium.

Human expert is used to form rules. Mamdani-type fuzzy system is used as classifier here.

c)Function as the consequent

Takagi-Sugeno fuzzy systems is used as classifier here.

IF y_1 is B_1 and AND y_2 is B_2 AND ... AND y_n is B_n

THEN $h_1 = \sum_{i=0}^{n} a_{i1}x_i$ AND … $h_c = \sum_{i=0}^{n} a_{ic}x_i$,

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

d)Training fuzzy rule-based classifiers

It mainly deals with certain questions like how training of fuzzy classifiers is done, how the various membership functions are taken, how various rules are formed etc.[29].

2)Fuzzy prototype-based classifiers

There are various models which are motivated by the concept of "fuzzifying" classical classifiers. K-nearest neighbour classifier (K-nn) is an example of such classifier[29].

B. 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 apraxiaof 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].

Prashant Sharma et.al.has presented a paper which is based on vehicle classification. Authors have made an algorithm to test the accuracy of classification using different techniques. The results obtained using Type-1 fuzzy logic system was not satisfactory. Authors have adjusted the shape and changed the membership function of input variables. Then it was tested using adaptive neuro-fuzzy inference system and accuracy was increased. At last, type-2 fuzzy inference system is used and vagueness in the vehicle data is handled by type-2 fuzzy system[28].

C. Proposed Work

Authors have experimented the soft computing techniques FIS and FCM on lenses dataset from UCI. It has four attributes: age, spectacle prescription, astigmatic and tear production rate. It has three classes: the patient should be fitted with hard contact lenses, soft contact lenses or no lenses. It has 24 instances out of which 14 are used for training and 10 are used for testing.

1)Fuzzy inference system

Authors have implemented FIS on lenses dataset on Matlab7.Triangular membership function is used for it. Membership function for attribute age is shown in Fig. 5.

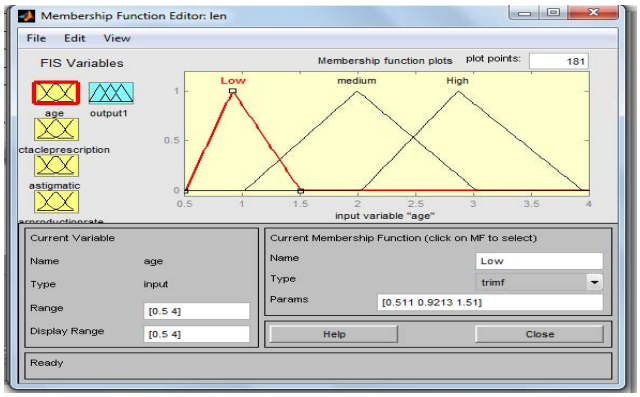

Fig. 5. Membership function for attribute age

Corresponding membership function for other attributes are shown in Fig. 6,7,8. Membership function for output classes is shown in Fig. 9.

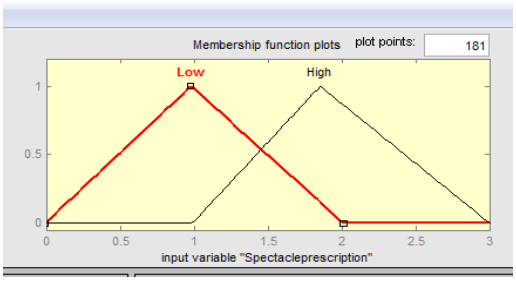

Fig. 6. Membership function for attribute Spectacle prescription.

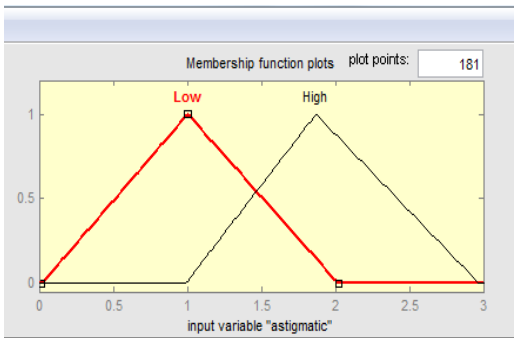

Fig.7. Membership function for attribute astigmatic.

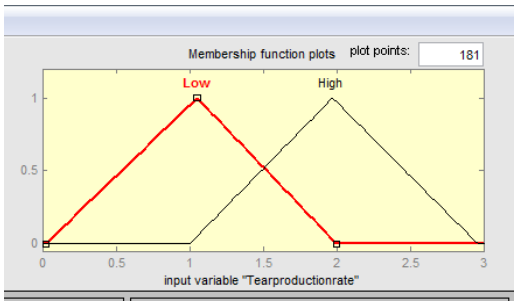

Fig.8. Membership function for attribute tear production rate.

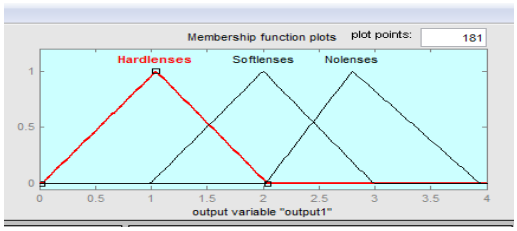

Fig.9. Membership function for output classes.

Rules are formed in such a way that there is no overlapping of rules as shown in Fig. 10.

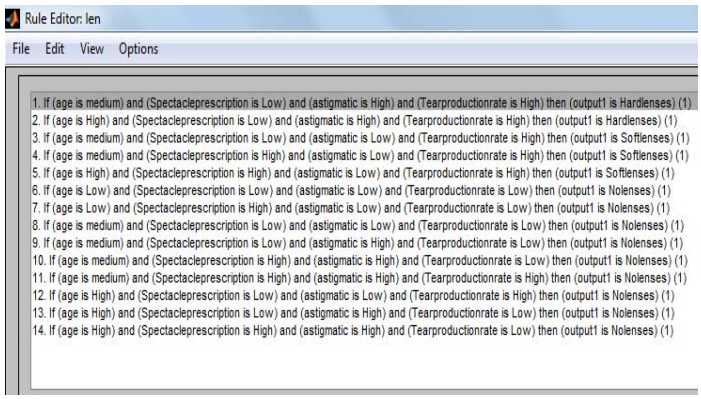

Fig.10. Rule set for lenses dataset

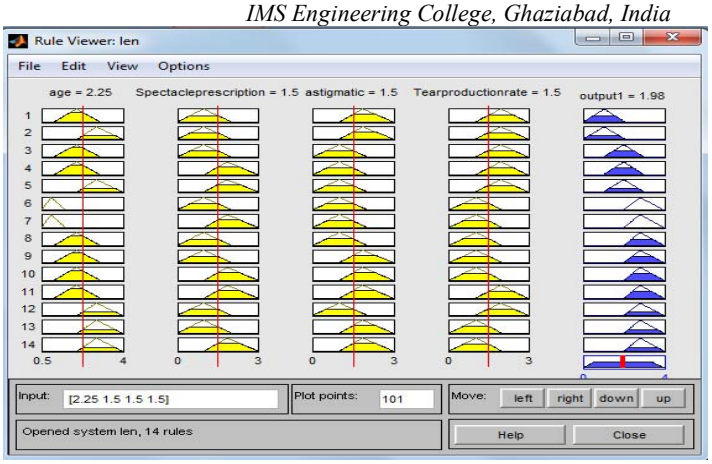

Fig.11. Rule viewer for lenses dataset

The results obtained after testing shows 100% accuracy in classification of lenses classes.

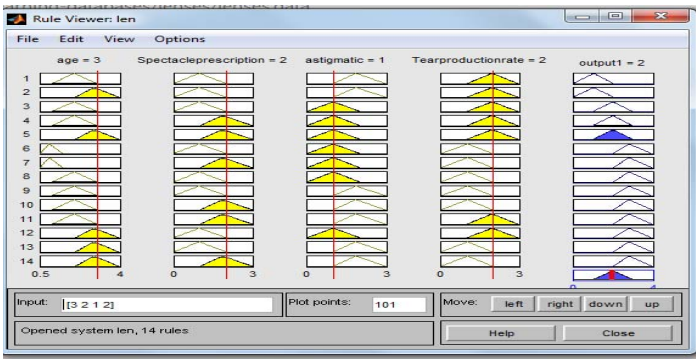

Fig.12. Testing for lenses dataset

2)Fuzzy cognitive maps

A property of FCM i.e. Fuzzy relational maps(FRM) can also be used to classify the lenses dataset. FRM can be described as, the problem space is divided into a domain space *D* and a range space *R* which contain completely different concepts.The number of concepts in the domain and range space may not be equal. In FRMs the causal relations are separated into two different groups for example the relationship between doctor and patient.

In the same way, attributes of lenses dataset can be considered as domain space and classes of lenses dataset can be considered as range space. Consider the attributes as concepts i.e. C_1, C_2, C_3, C_4 and classes as R_1, R_2, R_3 as shown in Fig. 13. This can be implemented using Matlab in future.

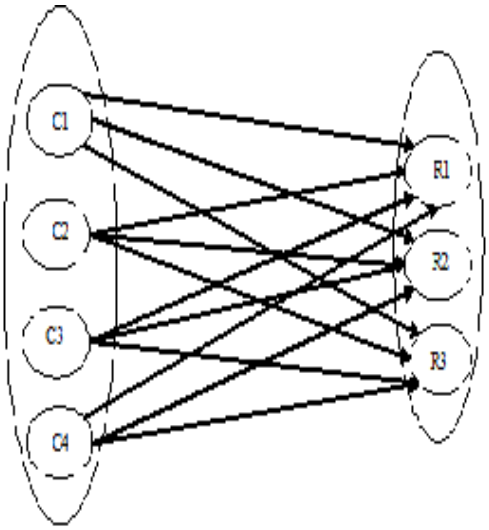

Fig.13. FRM for lenses dataset

IV. 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. FIS and FRM is implemented on lenses dataset which has shown accurate results for classification. Fuzzy classification has become very essential 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 an extension of fuzzy logic. It is considered as more accurate as it also deals with positive, negative and indeterminate relations.

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