INTERNATIONAL JOURNAL FOR TRENDS IN ENGINEERING & TECHNOLOGY
VOLUME 6 ISSUE 1 – JUNE 2015 - ISSN: 2349 - 9303

Z-Score based Fuzzification process for pattern Classification

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Abstract— Fuzzification is the process of converting the crisp value into fuzzy value by using membership function. In the proposed classification model, Fuzzification is done by using Z-score method. Membership matrix is formed as the result of Fuzzification process and it contains the membership of each feature value to the given classes. This membership matrix is given as an input to the Multilayer Feedforward Neural Network (MFNN) uses a Backpropagation learning algorithm for training. The MFNN classifies the pattern based on the fuzzy value computed by Z-score method and it assigns the degree of membership for each pattern to the given class. Then, the target class for each pattern is predicted using the MAX defuzzification method. The proposed classification model is applied to the Statlog Heart dataset. It was obtained from the University of California at Irvine (UCI) machine learning repository. The performance measures used by the Neuro fuzzy classifier are Accuracy and Training Speed. The experimental results show that the neuro fuzzy approach consistently outperforms and gives higher accuracy than the artificial neural network

Index Terms— Artificial Neural Network, Accuracy, Back propagation, Classification, Fuzzification, Membership Function, Multilayer Feedforward Neural Network, Defuzzification, Training Speed, Z-Score.

1 INTRODUCTION

1.1 Neuro Fuzzy Model

Pattern Classification is the process of assigning class label from predetermined set of classes to the pattern. The goal of the classifier is used to assign the class label with smallest possible error. Artificial Neural network (ANN) is one of the commonly used classifier technique. ANN can model complex non linear relationships and are appropriately suited for classification phenomena. ANN has properties such as learning from examples, generalization beyond the training data and also they have universal approximation property. On the other hand, the precision of output is quite often limited and it does not admit to zero error.

While performing the classification, uncertainty can arise at any stage due to incomplete or imprecise input data. Fuzzy systems are suitable for handling the imprecision, uncertainty of inputs and outputs directly by defining those using fuzzy sets. Fuzzy logic systems allow a pattern to belong to multiple classes with different degrees. Therefore, the fuzzy logic system is used to process imprecise and incomplete data which gives accurate result.

To deal with uncertainty in a manner more like humans, one can hybrid the techniques of fuzzy system into neural network. This hybrid system is called fuzzy neural, neuro-fuzzy, neural fuzzy network. The hybrid system should have the merits of both ANN and fuzzy logic system. The hybridization can be done in two ways. One way is to endow neural network with fuzzy capabilities, based on this the network's expressiveness and flexibility to uncertain environment is increased. The second way is to apply NN learning capabilities to fuzzy systems to make it more adaptive to changing environment. This hybrid fuzzy neural system are more popular for application in many areas including engineering design, process control, credit evaluation, financial trading, and medical diagnosis.

1.2 Backpropagation Algorithm

There are several architectures available in ANN. Among them, Multilayer Feedforward Neural Network with a single hidden layer has been chosen as the best neural network architecture for nonlinear classification problem. The BackPropagation (BPN) is the most popular supervised training algorithm has been used to train MFNN.BPN make use of gradient descent method to update the weight of the network and it is the generalized form of Root mean Squared (RMS) algorithm[6]. The back propagation learning algorithm can be divided into two phases: propagation and weight update.

Phase 1: Propagation

1. Forward propagation of a training pattern's input through the neural network in order to generate the output.
2. Calculate the error and backward propagation of it, from output layer to input layer.

Phase 2: Weight update

1. Recalculate the weight and bias value.
2. Update the weight and bias value.

Repeat phase 1 and 2 until the performance of the network is satisfactory.

2 RELATED WORKS

Anandakumar .K et al [1] proposed efficient cancer classification using Fast Adaptive Neuro-Fuzzy Inference System (FANFIS) based on statistical technique involves two steps, namely analysis of variance and classification capability was tested for all samples combination using a better classifier. An ANN model is used to analyze the service quality [3] perceived by the passengers of a public transportation system. Kulkarni and Shinde [5] proposed the supervised classification of data using Neuro-fuzzy classification model. In this model, Membership matrix is formed which contains the membership of each feature value to the given classes. This matrix is given as an input to the ANN for training and membership of each pattern to the given classes was obtained. Therefore, the target class for each pattern was predicted by using Defuzzification method.

Multilayer Feedforward Neural Network had been trained by Levenberg-Marquardt (LM) algorithm [7] to develop an ANN model for predicting highway traffic noise. Patricia Melin et al [8] described the application of competitive neural network with learning vector quantization algorithm for classification of electrocardiogram signals. Taskin kavzoglu et al. [11] described the use of representative training data sets and its importance for the performance of all classification methods. The representativeness is related to the size and quality of the training data. Quality analysis of training data helps to identify outlier. Training data selection is an iterative process conducted to form representative data after some refinements. Quang Hung do et al [12] implemented Neuro-Fuzzy approach in the classification of students' academic performance into different groups. It uses previous exam results and other related factors as input variables and labeled students based on the student expected performance.

3 PROPOSED METHODOLOGY

3.1 Overview of Neuro Fuzzy Classifier

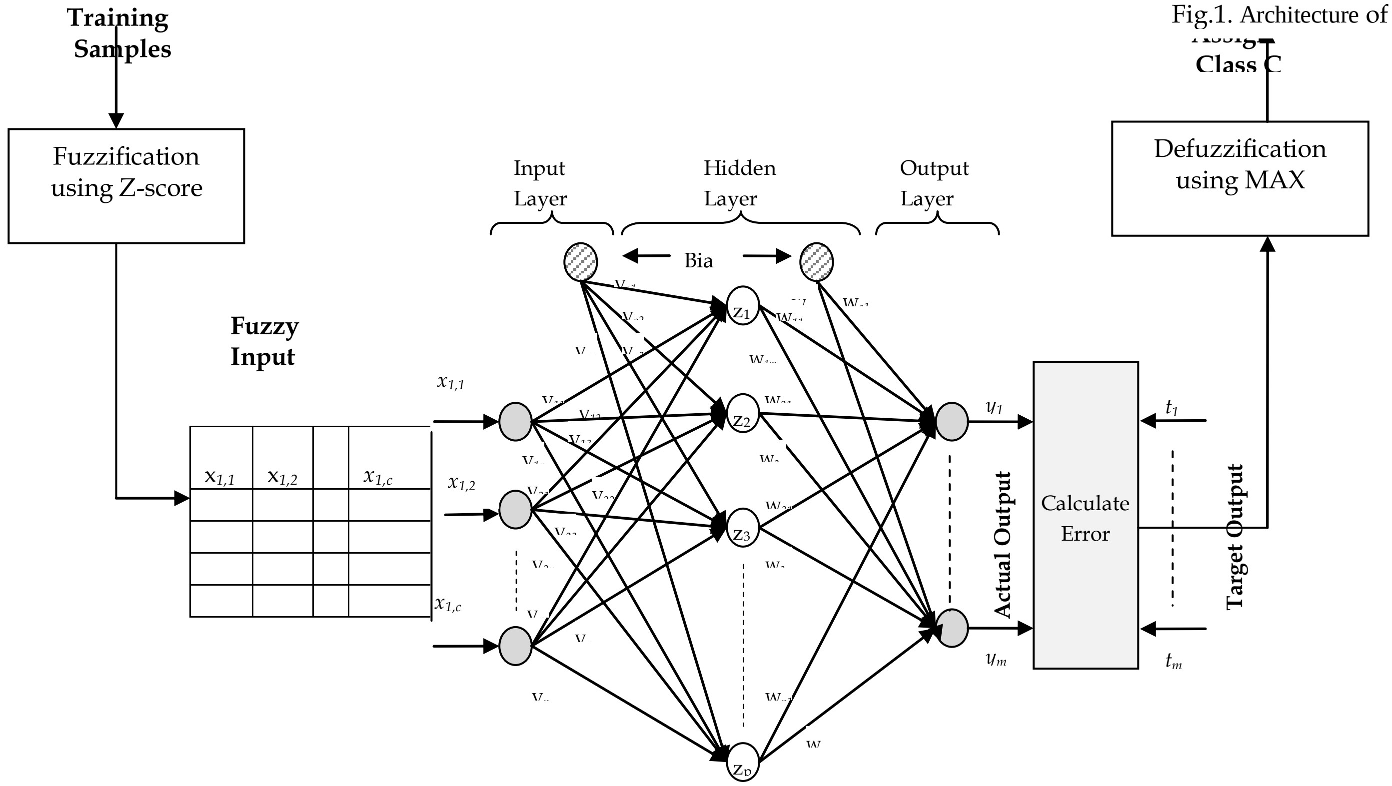
The architecture of Fuzzy neural network classifier for pattern classification consists of various blocks as specified in Fig. 1.It consists of three steps[5], Fuzzification, ANN training with the backpropagation algorithm and Defuzzification.

In first step, the given input data is fuzzified using the Z-score method. The output of this Fuzzification process is the membership matrix of size S×(D×C) , where S is the number of rows equal to the number of instances present in the given dataset and (D×C) is the number of columns which is equal to the product of number of features and number of class.

The ANN which operates on fuzzy data is called Fuzzy Neural Network (FNN).The input to the FNN training is the membership matrix which contains the membership value of each feature to the given classes. FNN training is done by using the standard backpropagation algorithm and then the membership value of each pattern to the given class is obtained as an output of the training.

In last step, the output of FNN training is defuzzified by using the MAX defuzzification method. In this process, the pattern is assigned to the class which has the highest membership value.

Fig.1. Architecture of Neuro F



3.2 Fuzzification process

A Membership Function (MF) is used in the Fuzzification process to convert the crisp values into the fuzzy value. MF shows how each data point in the input space is mapped to the interval ranges between 0 and 1. MF generates the membership value of each feature vector to the given classes in the form of membership matrix.

For modeling input values in fuzzy system various MF are used. In the proposed model, new method named Z-score[13] is used for fuzzifying the input values. Z-score is modeled mathematically as

$$Z(x;c;\sigma) = \begin{Bmatrix} e^{\left(\frac{-(x-c)}{\sigma}\right)}, \frac{x-c}{\sigma} > 0 \\ e^{\left(\frac{(x-c)}{\sigma}\right)}, \frac{x-c}{\sigma} < 0 \end{Bmatrix} \quad (1)$$

x – Feature value, C – MF centre and σ is the MFs width. C is given by,

$$C_d = \frac{1}{S}\sum_{j=1}^{S} x_{jd} \quad (2)$$

where d=1, 2… D, j=1, 2… S and x_{jd} is the dth feature of sample j. σ is given by,

$$\sigma_d = \frac{1}{S-1}\left(|x_{1d} - c_d| + |x_{2d} - c_d| .... |x_{sd} - c_d|\right) \quad (3)$$

where $x_{1d}, x_{2d}, ..., x_{sd}$ are the dth feature of the sth pattern and C_d denote the mean value of dth feature given in Eq.(2)

The Z-score given in Eq. (1) generates the membership matrix Z(X) of size SX (DXC) as given in Eq. (4). In this matrix, $g_{s,c}(d)$ represent the membership value of dth feature of sth pattern to the c^{th} class. Z(X) is given as

$$\begin{pmatrix} z_{1,1}(x_1) & z_{1,2}(x_1) & ... & z_{1,C}(x_1)... & z_{1,1}(x_D) & z_{1,2}(x_D) & ...z_{1,C}(x_D) \\ z_{2,1}(x_1) & z_{2,2}(x_1) & ... & z_{2,C}(x_1)... & z_{2,1}(x_D) & z_{2,2}(x_D) & ...z_{2,C}(x_D) \\ . & . & . & . \; . & . & . & . \; . \\ . & . & . & . \; . & . & . & . \; . \\ z_{S,1}(x_1) & z_{S,2}(x_1) & ... & z_{S,C}(x_1)... & z_{S,1}(x_D) & z_{S,2}(x_D) & ...z_{2,C}(x_D) \end{pmatrix} \quad (4)$$

3.3 FNN training with the BPN algorithm

The ANN used here is referred as FNN because it takes input in the form of fuzzy and gives the fuzzy output. The standard Backpropagation (BPN) learning algorithm is used to train the FNN.

Architecture of FNN consists of three layers as illustrated in the Fig.2: namely input, output and one hidden layer. The number of nodes present in the input layer is equal to the number of feature present in the membership matrix Z(X) given in Eq. (4) Which is of (D×C) and the numbers of nodes in the output layer are equal to the number of classes present in the given dataset.

The pseudocode of Neuro Fuzzy classifier is given as:

1. For each feature vector, center and standard deviation is calculated using (2) and (3)
2. The input vectors are fuzzified using Z-score method given in Eq. (1)
3. Intialize weight and biases.
4. Feed the training sample to the input layer
5. Propagate the input forward by computing the net input and output of each unit in the hidden and output layer
6. Calculate the error which is the difference between actual output and target output
7. Backpropagate the error form output layer to the input layer
8. Update weight and bias to reflect the propagated error
9. Until required error repeat the steps from 4 to 8 for all samples
10. To assign the class label, defuzzify the output of FNN by using MAX Defuzzification method

The output of each unit present in the hidden and output layer is calculated by using sigmoidal activation function as follows:

$$o_j = \frac{1}{1 + e^{-\sum_j w_{ij} O_i}} \quad (5)$$

Where w_{ij} is the weight of the connection from unit i in the previous layer to the unit j; O_i is the output of unit i from the previous layer. For unit j in the hidden layer, the error is calculated as follows:

(6)

For a unit j in the output layer, the error is calculated as follows:

$$E_j = O_j(1 - O_j)\sum_k E_k w_{jk} \quad (7)$$

Where O_j is the network actual output and T_j is the target output. Weight and bias are updated by the equation as follows:

$$E_j = O_j(1 - O_j)(T_j - O_j) \quad (8)$$

Where l is the learning rate.

$$W_{ij} = W_{ij} + l * E_j * O_i$$

The output given by the FNN training assigns membership degree for each pattern to the given classes and it is in the following form.

$$A = \begin{bmatrix} O_{1,1} & O_{1,2} & .... & O_{1,C} \\ O_{2,1} & O_{2,2} & .... & O_{2,C} \\ . & . & . & . \\ . & . & . & . \\ O_{S,1} & O_{S,2} & .... & O_{S,C} \end{bmatrix} \quad (9)$$

Where $O_{s,c}$ is the output of sth pattern to the cth class.

3.4 Defuzzification process

To defuzzify the output of FNN, the proposed classification model makes use of MAX Defuzzification method. The input for this process is given in the Eq. (9) represent the membership value for each pattern to the given classes.MAX operation is applied to this matrix to predict the target class for each pattern. It assigns the pattern to the class which has highest membership value.

3.5 Workflow of Neuro Fuzzy classifier

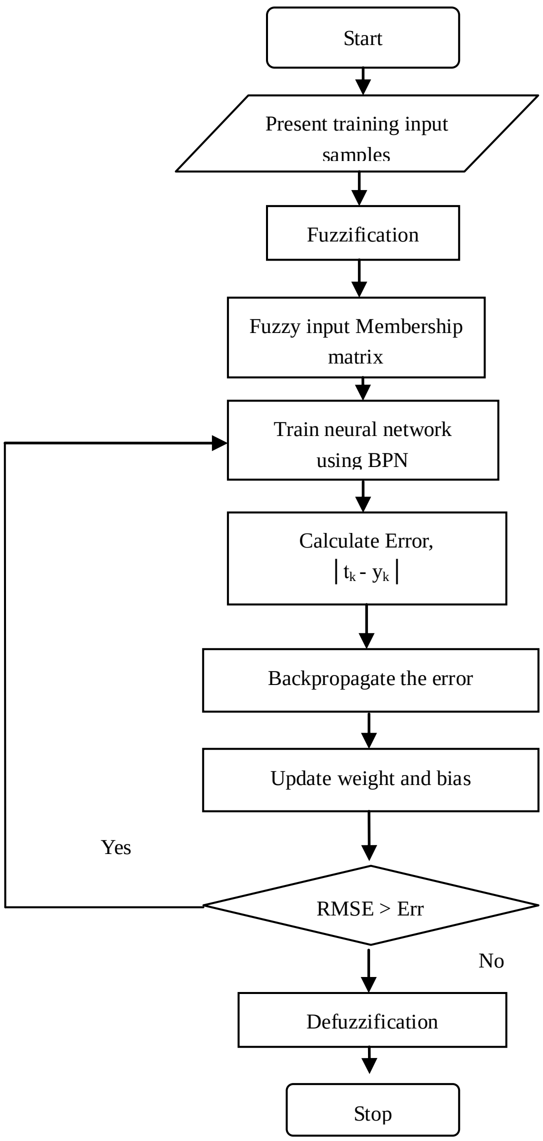


Fig.3. Flow diagram of Neuro Fuzzy Classifier

4 PERFORMANCE MEASURES

The measures used to analyze the performance of the fuzzy neural network classifier for medical database are

1) Accuracy
2) Training Speed

The accuracy of an individual program is defined as the ratio of the correctly classified samples to the total number of samples and is evaluated by the equation as follows:

$$Accuracy = \frac{t}{n} \times 100 \qquad (10)$$

where t is the total number of correctly classified samples and n is the total number of samples present in the given dataset

The training speed is defined in terms of training time. The training time is the amount of time required in training the input samples provided to the neuro fuzzy network to produce the desired output.

5 EXPERIMENTAL RESULTS AND ANALYSIS

5.1 Dataset properties

In this section, the performance of proposed algorithm is evaluated on the benchmark dataset. The benchmark dataset used for classification problem are statlog Heart dataset. The characteristic of the training dataset used in the proposed model is summarized in the table Table 1.

Table 1 SPECIFICATION OF STATLOG HEART DATASET

Datasets	No. of Patterns	No. of Features	No. of classes	Class-wise samples	
Heart	270	10	2	C1	120
				C2	150

5.2 Experimental Design

A 3-layer feed forward neural network is adopted for the simulations with the selected training architecture of 26x10x2 and training parameters such as momentum of 0.8 and the learning rates of le-4(0.0001). The simulations of the above training algorithm is done using MATLAB R2011a on a machine with the configuration of Intel[@] core I5-2410M processor,4 GB of RAM and CPU speed 2.90GHZ.

5.3 Statlog Heart Dataset description

The dataset contains 2 classes of 120 and 150 samples each, where each class refers to the sensitivity of the disease either positive or negative. There are 13 numerical attributes and no missing value in the dataset.

5.4 Experimental Analysis

Table 2 provides the comparison between ANN ,Gaussian based FNN and Z-score based FNN in terms of Accuracy,Training Time.

As given in figure 3, the accuracy of the Neuro Fuzzy classifier achieved by Gaussian Membership function(GMF) is 95.7% and Z-score for Heart dataset is 97.0%. This accuracy is greater than the Artificial Neural Network Classifier. The training speed of the network is low for Z-score method and high for GMF. Out of 270 samples, 200 samples are chosen as training vectors and 70 samples are testing vectors. The training time of Neuro Fuzzy classifier is higher due to independent

TABLE 2 HEART DATASET CLASSIFICATION RESULTS

VARIOUS METHODS	ACCURACY	TRAINING TIME
ANN	84.28	33.3
GMF BASED NEURO FUZZY APPROACH	95.71	41.76
Z-SCORE BASED NEURO FUZZY APPROACH	97.0	35.0

handling of two classes. So, the training speed of Neuro Fuzzy method is reduced than ANN.

5.4.1 Training Time comparison

The comparison result of the training time consumed by BPN, Neuro Fuzzy by GMF and Neuro Fuzzy BY Z-score with the learning rate of le-4 is show in Figure 3.

From the Fig.3, it is proven that the total amount of training time consumed by neuro fuzzy by GMF for training is reduced by an average of nearly 20% of Neuro fuzzy approach by Z-score respectively

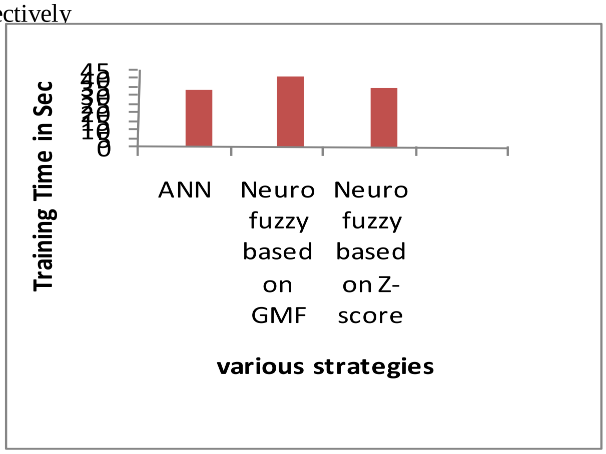


Fig. 3. Training time comparison

5.4.2 Accuracy comparison

The comparison result of accuracy for various approaches such as BPN, Neuro fuzzy by GMF and by Z-score is shown in the Figure 4.

From Fig. 4 it is portrayed that the Accuracy provided by neuro neuro fuzzy approach by Z-score is 2% greater than that of Neuro fuzzy by GMF and 12% higher than that of BPN.

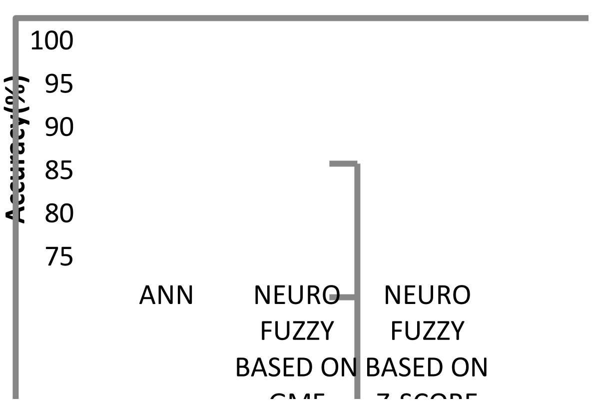


Fig. 4. Accuracy comparison

6 CONCLUSION

The proposed hybrid classification model based on the Z-score is able to handle the supervised classification of data. From the experimental analysis, it is shown that the accuracy of Neuro fuzzy approach is higher than the ANN.

However, if the two neuro fuzzy approaches are compared, the training time of Z-score technique is lower than that of GMF .So, the training speed of neuro fuzzy approach based on the Z-score method is increased than the training speed of neuro fuzzy approach by GMF. The future work should be focused on how to improve the training speed of the network.

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