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Marathi Handwritten Numeral Recognition Using Adaptive Neuro-Fuzzy System

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Abstract—**Handwritten Character Recognition (HCR) is one of the areas in Pattern Recognition Field in which many researchers are attracted across the globe. This attraction is due to applications of HCR in many fields of daily use in real life. This paper investigates the problem of Marathi Handwritten Numeral Recognition (MHNR). The proposed System has mainly two modules: A Feature extraction module and Classification Module. In the feature extraction module, three different statistical features have been extracted and used for recognition systems. In the classification module, Adaptive Neuro Fuzzy System (ANFIS) has been proposed. It combines the advantages of ANN and Fuzzy Logic both. Hence it is found that the Neuro-Fuzzy hybrid system approach is effective in recognition of HCR. The Testing of the proposed system is done using 5-fold cross validation technique on a Local Database. Experimental Results shows the high recognition accuracy.**

Keywords- Neuro-Fuzzy, Handwritten Recognition.

I. INTRODUCTION

Handwriting recognition is one of widely researched areas due to its potential applications in numerous areas such as banking, posts, transport, etc. [1]-[3]. Many Technologies have been proposed by the researchers for different scripts like English, Chinese, Arabian, Etc. A very few researchers have also worked on Marathi Handwritten Numeral Recognition (MHNR) for general purpose. There are many challenges faced by researchers are that the Handwritten Characters / numerals are unconstrained, Vague, varies in appearance from person to person. These challenges create fuzziness in the process. The Figure 1 shows some handwritten numeral samples:

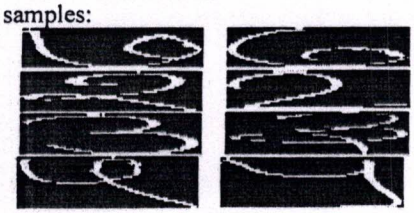

Fig.1: Handwritten numeral Samples

From the figure 1, it can be easily observed how different writers used to write the same numeral in different ways. Furthermore; Parameters like Writing Style, Curve, Stroke Pen Width, Scanning Device used adds more complexity to this problem [4].

So, There is a need for development of a reliable handwritten recognition system which has a high recognition rate and low error rate. Recent developments in Classifier and Feature Extraction technologies have significantly contributed towards this achievement.

The problem of unconstrained handwriting was handled. The system used topological, geometrical and local measurements to identify input characters or to leave it as unrecognizable [5]. Alphanumeric character recognition system was proposed. The experimental results reported were up to the mark with reduction in computing time [6]. Handwriting recognition system has been developed using the less used Adaptive Neuro-Fuzzy Inference System. Seven different types of feature vectors were generated and given to the Classifier module. System was implemented on the MNIST database and a high recognition rate was reported [7]. Problem of recognizing Handwritten Hindi modifiers was discussed. The Neuro-Fuzzy system was modelled for recognition which gave recognition results up to 97% [8].

II. NEURO-FUZZY SYSTEM

A Variety of classifiers have been used by researchers. Artificial Neural Networks and Fuzzy Logic are two mostly used classifiers in this area. Artificial Neural Networks are collections of large numbers of processing elements called neurons organized in layers and interconnected to one another by links. Each Link has given Weight. ANN learns by adjusting weights in layers [9]. It simulates working of Human brain in computers and therefore ANN is the favorite choice of researchers in Recognition / Prediction Tasks.

Fuzzy Logic is an idea coined by Prof. Zadeh. According to Zadeh [10], Fuzzy logic is an extension of

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traditional Two-Valued logic which deals with Uncertainties in the real world. Humans used to take decisions many times upon information which is vague, Incomplete and uncertain. Fuzzy Logic is a Modern Technique which can be used to solve real world problems which involves such Fuzziness.

In this paper; Combination of Artificial Neural Networks and Fuzzy Logic has been used to incorporate advantages of both Paradigms. In the Neuro-fuzzy approach; both ANN and Fuzzy Logic work together in order to perform desired tasks. Fuzzy rules are interpreted by Neural Networks through its well-defined Learning algorithm.

Adaptive Neuro-Fuzzy System is a Hybrid type of Neuro-Fuzzy system which is less frequently used but found to be very useful in pattern matching, classification, approximation tasks [11]-[13]. ANFIS implements Takagi Sugeno Fuzzy Inference System which has Five Layers. First Layer maps Input to Fuzzy Membership functions. The Second hidden layer calculates firing strength of Fuzzy Rules. Third Layer is responsible for Normalizing rule strengths while Fourth layer deals with determining output of fuzzy rules. Output layer calculates overall output as a summation of all outputs coming to this layer.

III. PROPOSED SYSTEM

The proposed method includes four phases: A: Data Collection and Scanning, B: Preprocessing and Normalization, C: Feature Extraction and D: Classification. The Figure 2 shows the block diagram for the proposed system.

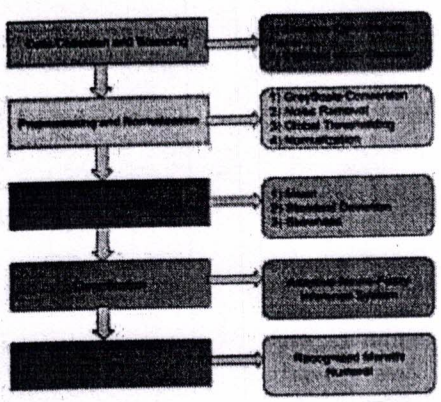

Fig.2: Block Diagram of Proposed System

A. *Data Collection and Scanning*

The primary database has been prepared for the study. In the development of the primary database for Marathi numerals five people with different writing styles, different age, and different regions have been selected. Ten digits from the Devanagari script have been collected. The selected people have asked to write the digit script of Devanagari on a paper. So, the primary database consists of 5 samples of each numeral from different persons. The Total 50 samples have been collected. The samples are as shown in figure 3.

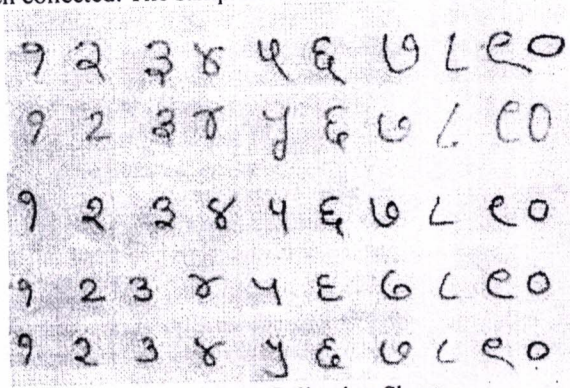

Fig.3: Data Collection Sheet

Samples collected are real-time samples & with different pens. Source document was scanned at 600 dpi using the HP scanner in the form of the RGB image.

B. *Preprocessing and Normalization*

In this phase, Individual digits are extracted from the scanned image of a person and stored in the form of the RGB image. Following low-level operations done on input samples of digits for normalization:

1) Grayscale Conversion

RGB image of an Input digit of a single sample is converted to a Grayscale image to make it ready for further processing.

2) Noise Removal

Median Filter is used for noise removal from input samples. It is a non-linear spatial filter which efficiently removes with less blurring.

3) Global Thresholding

Input sample image is then converted to binary format using global thresholding using Otsu's method.

4) Normalization

All input sample images are normalized to a common size by resizing it to 70*50 pixels.

Result of Preprocessing and normalization step is as shown in figure 4:

Fig.4: (a) Input Numeral (b) Preprocessed Numeral

C. *Feature Extraction*

It is a process of extracting important information from the input sample and used to give as an input to the classification module. There are several types of features that can be extracted from input samples. In this study, three methods have been selected, Mean, Skewness and Standard Deviation.

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1) Mean

It is one of the basic Statistical measures. It returns the arithmetic mean of all elements. Mathematical formula is derived as in equation 1:

$$\mu = \frac{1}{N}\sum_{i=1}^{N} A_i \qquad (1)$$

2) Skewness

This feature makes judgement about image surfaces. Mathematical formula for Skewness given in equation 2:

$$\tilde{\gamma}(x,y) = \frac{\frac{1}{mn-1}\sum_{(r,c)ew}\left(\frac{1}{mn-1}\sum_{(r,c)ew}\left(g(r,c) - \frac{1}{mn-1}\sum_{(r,c)ew} g(r,c)\right)\right)^3}{\left(\frac{1}{mn-1}\sum_{(r,c)ew}\left(\frac{1}{mn-1}\sum_{(r,c)ew}\left(g(r,c) - \frac{1}{mn-1}\sum_{(r,c)ew} g(r,c)\right)\right)^2\right)^{3/2}} \qquad (2)$$

3) Standard Deviation

This feature gives measure of variability or diversity. It shows how much dispersion exists from Mean in the sample. Mathematically formula for Standard Deviation is as shown in equation 3:

$$\tilde{\gamma}(x,y) = \sqrt{\frac{1}{mn-1}\sum_{(r,c)ew}\left(g(r,c) - \frac{1}{mn-1}\sum_{(r,c)ew} g(r,c)\right)^2} \qquad (3)$$

D. Classification

The proposed method uses Adaptive Neuro-Fuzzy Inference System for recognition tasks as shown in the figure 5. It contains 3 inputs representing 3 Features namely Mean, Standard Deviation and Skewness. These 3 inputs are then fuzzified into three input membership functions. These membership functions are then fed to the rule base constructed by ANFIS. The proposed system uses the backpropagation learning algorithm of the Artificial Neural Network to select which rules to fire and which not. Once; set of rules to fire is determined then Result of these rules are determined which are aggregated at the output membership function. This Output is then defuzzified to get our Recognized class.

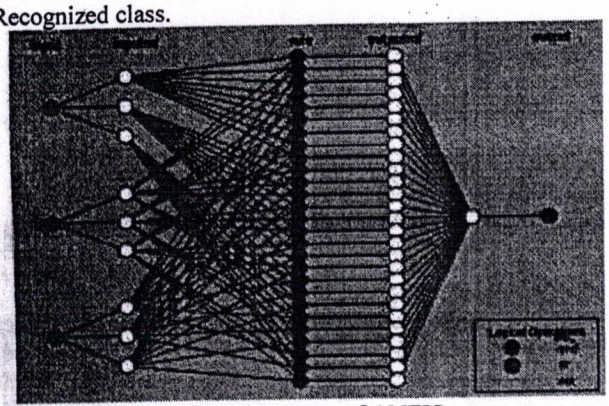

Fig. 5: Structure of ANFIS

The following parameters have been set for the ANFIS tool:
Number of Nodes in input layer: 3
Number of nodes in input membership function layer: 9
Type of Input Membership Functions: gbelimf
Number of nodes in Rule Layer: 27
Number of nodes in Output membership function Layer: 27
Type output membership function layer: Linear
Number of nodes in Output Layer: 01
Training Algorithm Used: Backpropagation

The proposed system was implemented using a neuro- fuzzy hybrid system tool i.e. ANFIS using MATLAB R2015a. The following algorithm shows the steps for MHNR using the ANFIS tool.

Algorithm : ANFIS for Marathi Handwritten Numeral Recognition

Input : ***Marathi Numeral*** RGB image

Output : ***Recognized Class of Numeral***

1: Load RGB image

$$\mathbf{I} \leftarrow \sum_{x=1}^{m} \sum_{y=1}^{n} img_{xy}(r,g,b)$$

2. Convert image to grayscale

img_gray ← rgb2gray (I)

3. Remove noise present in the image using median filter
img_filter ← median (img_gray)

4. Convert image to binary format :

img_bw ← im2bw(img_filter)

5. Resize image 70*50 size

6. Compute Mean, Standard Deviation and Skewness of Image

7. Define feature vector F

F← [mean standard deviation skewness]

8. Create training data set using above Feature vector

9. Create ANFIS with training data and 3 number of generalized bell shaped membership functions

in_fis ← [training_data 3 gbelimf]

10. Train ANFIS **out_fis ← train (in_fis)**

11. Modify weight as per error

11. Repeat step 10,11 till goal or specified number of epoch is reached

12. Evaluate ANFIS against Test data set and collect results

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IV. EXPERIMENTAL RESULTS

The Primary Database Collected was used to test the performance of ANFIS classifier. The database consists of 5 samples of each numeral from 0 to 9. The K-fold cross validation technique was used in the experiments with k=5 which ensures that every sample gets a chance to appear in training and testing data sets. Since k=5; the data set was therefore divided into 5 sets. Four sets used as training data sets and one as a testing data set. The ANFIS training runs 5 times so that every set appears in testing data.

The figure 6 shows graphical representation of Recognition rate of each numeral class

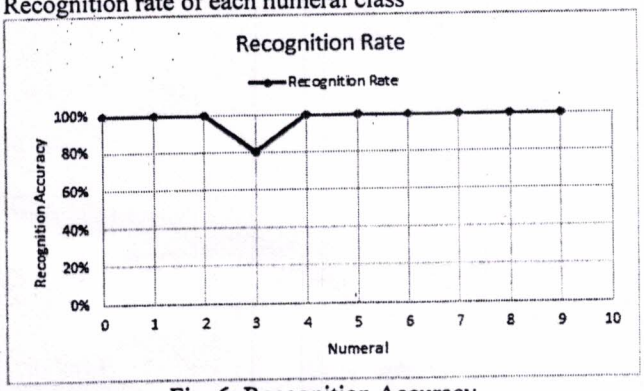

Fig. 6: Recognition Accuracy

The precision recall classification measure has been used for evaluation of performance of the neuro - fuzzy hybrid system. From figure 6, it is observed that all digits give 100 % recognition accuracy except digit 3 using the ANFIS tool.

V. CONCLUSION

In this paper, the Primary database for MHNR has been used as an input to the system. A neuro- fuzzy hybrid system is implemented using the ANFIS tool of MATLAB R2015a. It is observed that a combination of neuro fuzzy approach is more effective than the individual classifiers. It gives 98% average recognition accuracy of the Marathi numerals which is better than the existing neuro fuzzy hybrid system for digit recognition which has 97 % recognition accuracy [8].

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