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Neuro-Fuzzy Based Fake Currency Detection System

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Abstract: ***This paper presents a Adaptive Neuro Fuzzy inference system for the detection of fake currency.The proposed system works with all the types of denominations of Indian paper currency. It is composed of two parts: digital image processing and Adaptive Neuro Fuzzy inference System. In the first part the scanned image of note is processed by using MATLAB programming. In second part, using first part as input, the fuzzy rules are used to determine whether currency is original or fake. It is expected that this proposed System can provide a faster, cheaper and more accurate result. Fake currency detection system can be a very good utility in banking systems and other fields of commerce.***

Keywords- Fake Currency, ANFIS, Histogram Processing, Earth mover'distance.

I. INTRODUCTION

The fake currency detection system is developed to detect the fake currency by applying different techniques and methods on currency note. Due to great technological advancement counterfeiting problems have become more and more serious. Therefore the issue of efficiently distinguishing counterfeit banknotes from genuine ones via automatic machines has become more and more important. So the fake currency detection system should be able to recognize the note quickly and correctly and also able to recognize currency note from any side[12]. In this study, we present a Adaptive Neuro Fuzzy inference system for the detection of fake currency.The proposed system works with all the types of denominations of Indian paper currency. It is composed of two parts: In the first part the scanned image of note is first preprocessed by resizing it, then converting to gray level image then calculating and comparing normalized histogram of input currency with that of genuine currency by using MATLAB programming. In second part, using first part as input, the fuzzy rules are used to determine whether currency is original or fake. It is expected that this proposed Fuzzy Inference System can provide a faster, cheaper and more accurate result.

This paper is organized as follows: section 2 describes the overview of Histogram processing, section 3 describes the overview of Adaptive Neuro Fuzzy inference system, section 4 describes ANFIS architecture, section 5 describes design and implementation of Fake currency detection system, results are shown in section 6 and hence conclusion is drawn in section 7.

II. HISTOGRAM PROCESSING

The histogram of a digital image with L total possible intensity levels in the range [0,G] is defined as the discrete function:

$$h(r_k) = n_k$$

where r_k defines the kth gray level, n_k defines the number of pixels in the image having gray level r_k and G: [*255* for images of class *uint8*, *65535* for images class *uint16* and *1.0* for images of class *double*]. Normalized histograms can be obtained by dividing all elements of $h(r_k)$ by the total number of pixels in the image: total no. of pixels[15].

$$p(r_k) = h(r_k)/n \text{ ; for } k=0,1,\ldots..,L$$

The earth mover's distance (EMD) is a measure of distance between two probability distributions. In mathematics, this is known as the Wassertein metric. The EMD is valid only if the two distributions have the same integral as in normalized histograms or probability distribution functions. So EMD can be used to measure distance between two normalised histograms or to compare two normalised histograms. The EMD of two probability distributions P and Q is given by:

$$EMD(P,Q) = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} f_{ij}\, d_{ij}}{\sum_{i=1}^{m}\sum_{j=1}^{n} f_{ij}}$$

Where f_{ij} is the amount moved from P to Q and d_{ij} is the distance moved from P to Q.

III. ADAPTIVE NEURO FUZZY INFERENCE SYSTEM (ANFIS)

ANFIS(Adaptive neuro fuzzy inference system)is used as a teaching method for sugeno type fuzzy systems. Adaptive neuro fuzzy inference system is a feedforward adaptive neural network which implies a fuzzy inference system through its structure and neurons. It is a hybrid neuro fuzzy technique that brings learning capabilities of neural networks to fuzzy inference systems. Using a given input-output data set, the toolbox function anfis constructs FIS whose membership function parameters are tuned using back propagation algorithm alone or in combination with least square type of method.

IV. ANFIS ARCHITECTURE

In ANFIS, takagi-sugeno type fuzzy inference is used. The output of each rule can be a linear combination of input variable plus a constant term or can be only a constant term. The final output is weighted average of each rule's output. Basic ANFIS structure with first order sugeno type of rule base with two inputs x1,x2 and one output O, the structure of ANFIS is shown in Fig.1

The rule base contains two if then rules:

Rule 1: if x1 is A1 AND x2 is B1, THEN f1=p1x1+q1x2+r1

Rule 2: if x1 is A2 AND x2 is B2 , THEN f2=p2x1+q2x2+r2

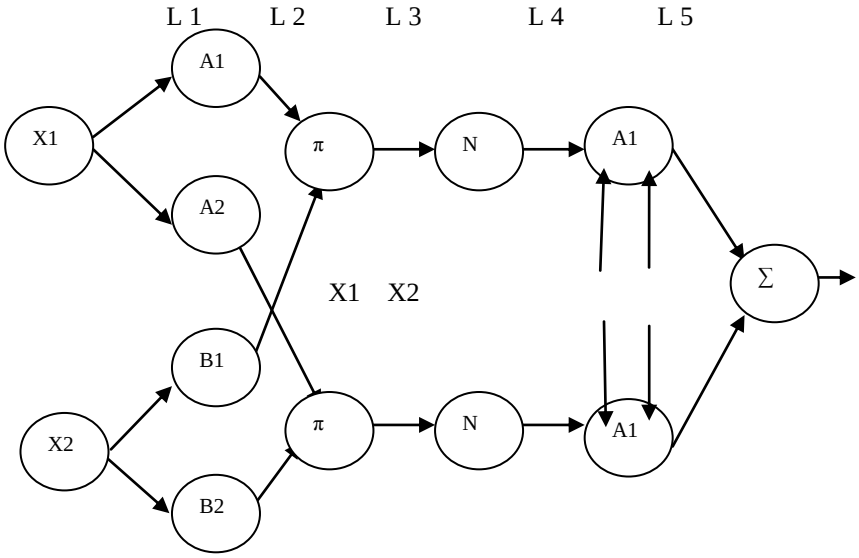

Fig. 1 ANFIS architecture

LAYER 1: $O_{1,i}$ is the output of the *i*th node of the layer 1. Every node i in this layer is an adaptive node with a node function. The output of each node is:

$$O_{1,i} = \mu_{Ai}(x1) \text{ for i=1,2}$$
$$O_{1,i} = \mu_{Bi-2}(x2) \text{ for i=3,4}$$

X1 or X2 is the input node i and A_i (or B_{i-2}) is a linguistic label associated with this node. The membership function given by:

$$\mu_A(x) = \frac{1}{1+\left|\frac{x-c_i}{a_i}\right|^{2bi}}$$

Where a_i , b_i , c_i are precise parameters.

LAYER 2: every node in third layer is fixed node labelled prod(π). The output is the product of all the incoming signals.

$$O_{2,i} = w_i = \mu_{Ai}(x1)\mu_{Bi}(x2) \qquad \text{i=1, 2}$$

LAYER 3: every node in third layer is fixed node labelled Norm (N). The *i*th node calculates the ratio of the *i*th rule's firing strength to the sum of all rule's firing strengths.

$$O_{3,i} = \overline{w_i} = \frac{w_i}{w_1 + w_2}$$

Outputs are called normalized firing strengths.

LAYER 4: every node *i* in this layer is a adaptive node with a node function:

$$O_{4,1} = \overline{w_i}\, f_i = \overline{w_i}\,(p_i x1 + q_i x2 + r_i)$$

LAYER 5 :this layer has one fixed node which computes the overall output as the summation of all incoming signals:

$$O_{5,i} = \sum \overline{w_i}\, f_i = \frac{\sum w_i f_i}{\sum w_i}$$

First the information is propagated forward in the network until layer 4 where parameters are identified by a least squares estimator. Then the parameters in layer 2 are modified using gradient descent.

V. DESIGN AND IMPLEMENTATION

The Fake Currency Detection system will work on two images, one is original currency image and other is the image of currency which is under testing. The design flow of Indian paper currency detection system is given below-

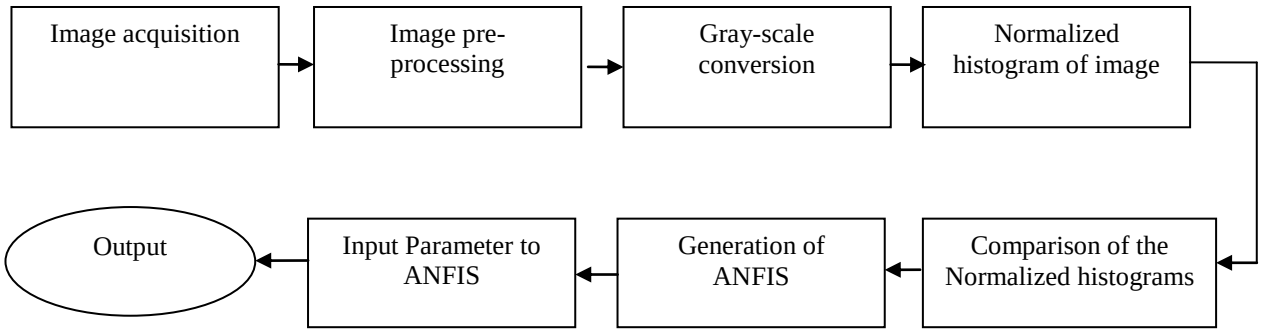

Fig.2 Design Flow of Indian Paper Currency Detection system

The above approach for currency detection system consists of the following steps-

5.1 Image acquisition

The first step is to acquire image of testing paper currency by using simple scanner at same resolution as in case of original currency. Fig. 3, 4 shows the scanned images of original currency and testing currency

Fig.3 Original Indian 500 Denomination

Fig.4 Indian 500 Denomination Under Testing

5.2 Image pre-processing

The second step is image pre-processing. Pre-processing of image are normally required before the main data analysis and extraction of information of image. In this work image resizing is performed because the scanned currency image is too large to process[7]. Result is shown in fig. 5 and 6.

Fig.5 Original Indian 500 Denomination after resizing

Fig.6 Indian 500 Denomination Under Testing after resizing

5.3 Gray-scale conversion

The third step, is to convert the image into pure gray scale image. The image acquired is in RGB color which is converted into gray scale because it carries only the intensity information which is easy to process instead of processing three components R(Red), G(Green), B(Blue)[7].

Fig.7 Gray Scale Image Of Original Indian 500 Denomination

Fig.8 Gray Scale Image of Indian 500 Denomination Under Testing

5.4 Normalized histogram of image

The fourth step, is to find the Histogram of a gray level image and then Normalized histogram is obtain as mentioned in section 2.

5.5 Comparison of the Normalized histograms

The fifth step of fake currency detection system, is to compare the Normalised histogram of input currency image with that of original currency image by using the concept of EMD as earlier mentioned in section 2.

5.6 Generation of Adaptive Neuro Fuzzy Inference System

The sixth step,is to generate the adaptive neuro Fuzzy Inference System for fake currency detection. Fig. 9 shows the Adaptive Neuro Fuzzy Inference System for fake currency detection, the names of input and output variable are shown on the left and right side of system respectively.

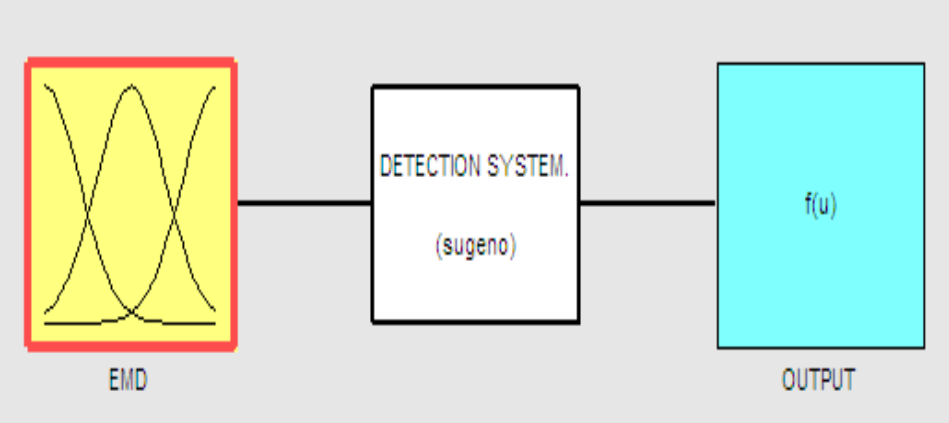

Fig.9 Fake Currency Detection system using ANFIS

The input membership function EMD is referred to as low and high have been implemented by using Gaussian function. Fig. 10 shows the input membership function EMD.

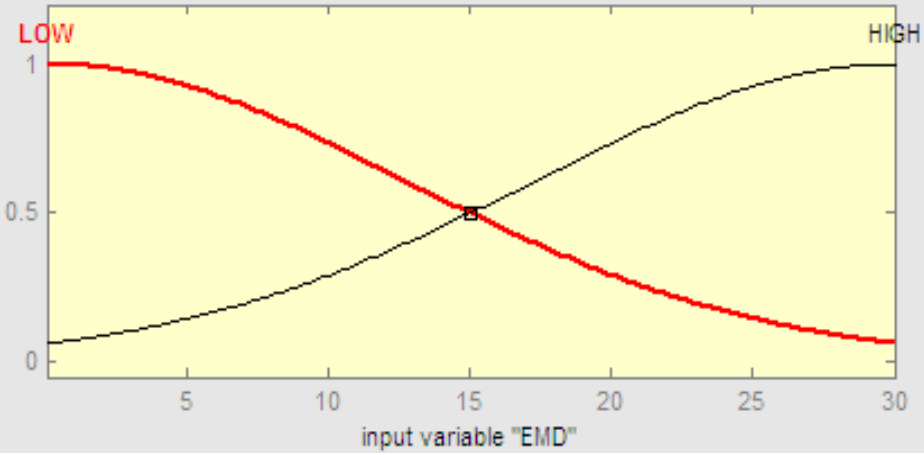

Fig.10 Input Membership function editor

The output membership function is referred to as original or fake. The output membership function shows in fig. 11.

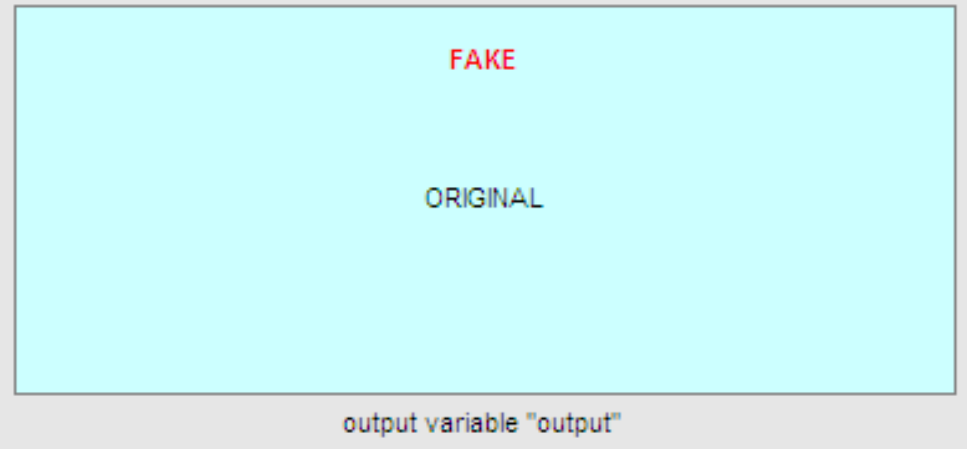

Fig.11 Output membership function editor.

Fuzzy Rule base is shown in table 1. Two rules are used in this system.

Table 1: Fuzzy Rule Base

Input	Output
Low	Original
High	Fake

In fuzzy control toolbox, a useful command called *anfis* exists. After this, load the input output data pairs from the workspace and generate new FIS. After new FIS is generated, train FIS using hybrid method of optimization. The structure of ANFIS for fake currency detection system is shown in fig 12.

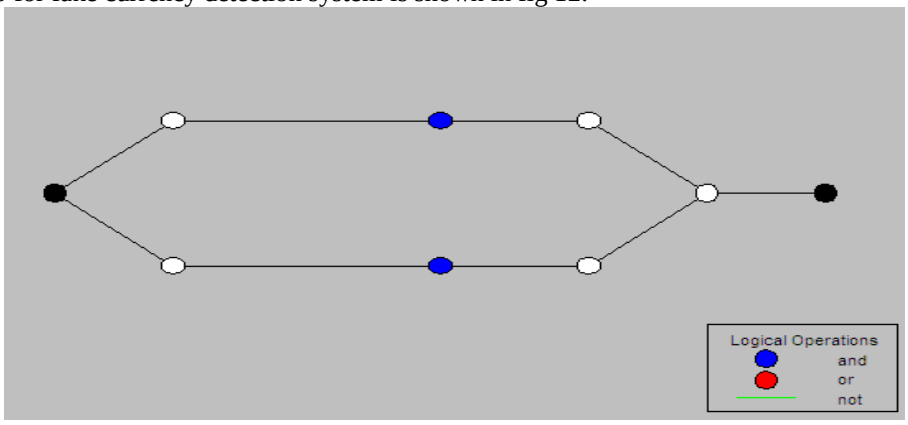

Fig.12 ANFIS structure

Rule viewer of fake currency detection system is shown below in fig. 13. It shows the result for the OUTPUT i.e output at EMD is 6.57. Hence, the OUTPUT is 0.116.

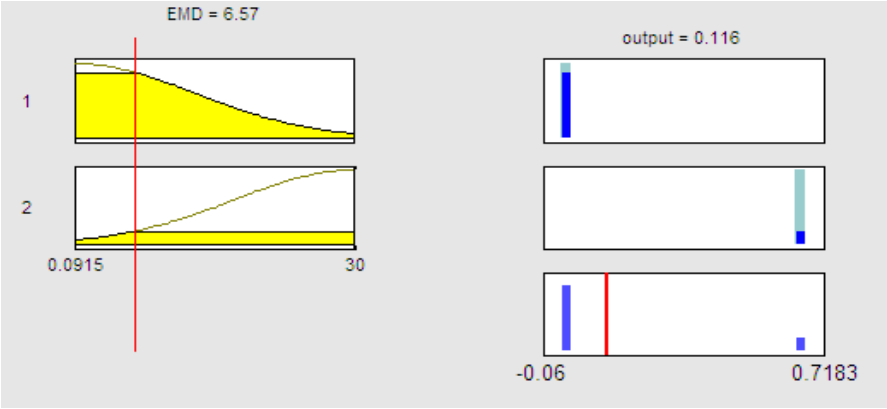

Fig.13 FIS Rule Viewer

Surface viewer of adaptive neuro fuzzy inference system is shown in fig.14, which shows the relation between OUTPUT and EMD.

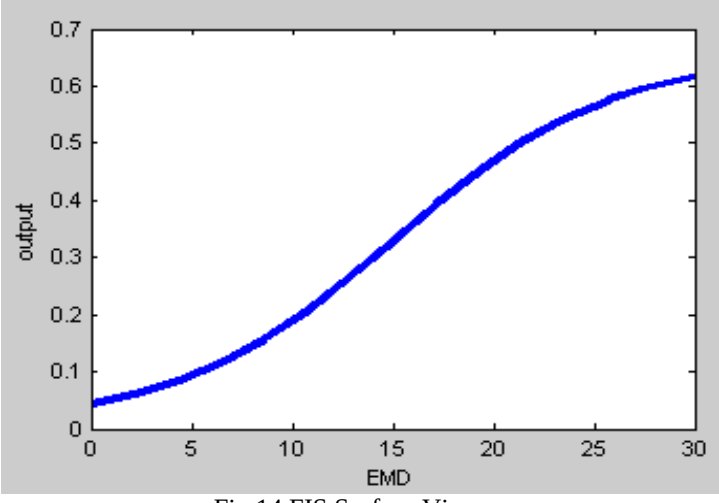

Fig.14 FIS Surface Viewer

5.7 Input parameter to ANFIS

This is the last step in which generated FIS is interfaced with the .m-file in MATLAB to pass the parameter EMD through ANFIS. When input is given, according to the fuzzy rule base output will be generated of whether the given currency under testing is fake or original.

VI. RESULTS AND DISCUSSION

The Histogram and Normalized histogram of input currency image under testing are compared with that of original currency image. The comparison of histograms and Normalized histograms are shown in fig.15 and 16.

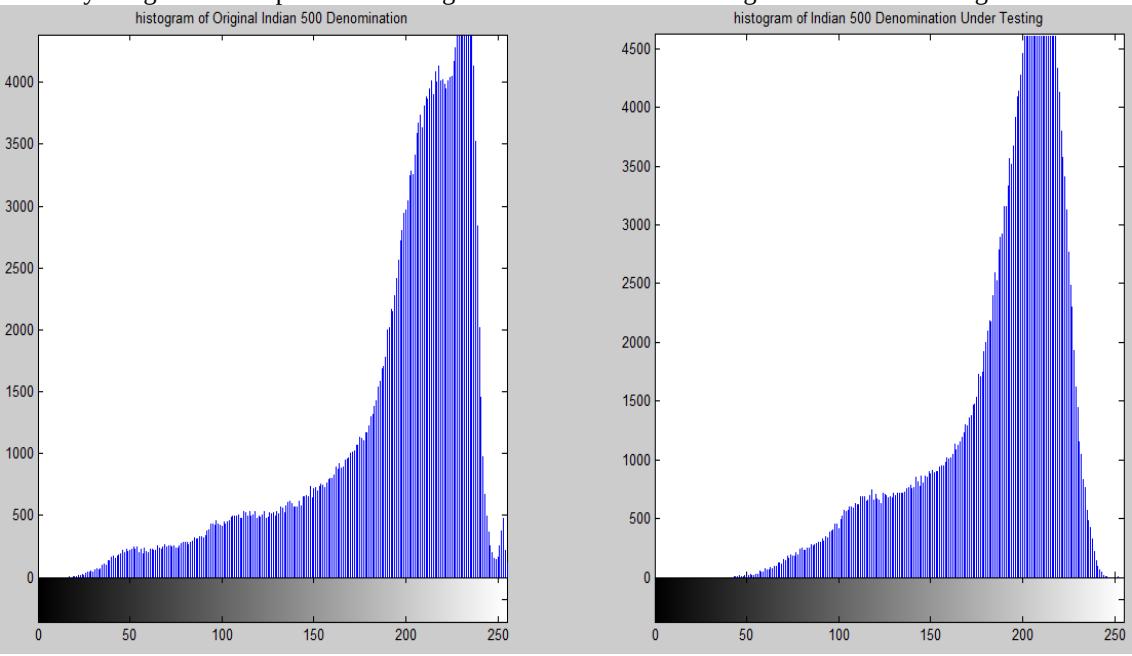

Fig.15 Histogram of original and test currenc

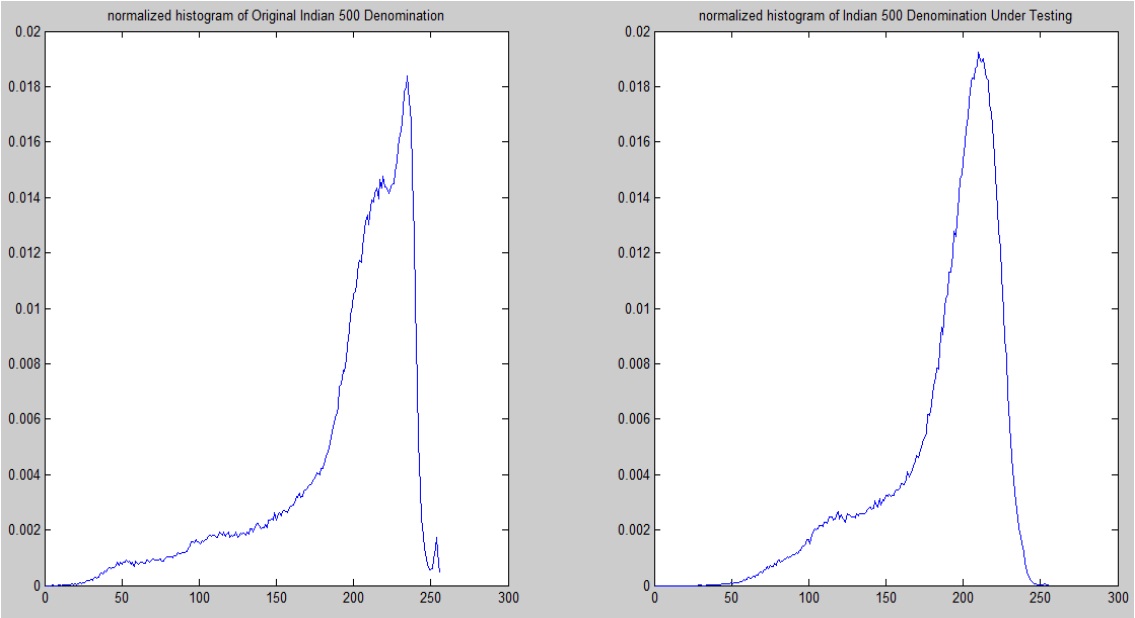

Fig.16 Normalized histogram of original and test currency

Further these Normalized histograms are compared on the basis of EMD. In this study, Testing is done on notes of each denomination (Rs.100, Rs.500, Rs.1000), which includes original and fake notes. Original notes further differentiating under categories: new notes, old notes, notes on which something written with pen and also the notes which were torn and glued with tape.

VII. CONCLUSION

In this paper, an Adaptive Neuro Fuzzy Inference System is presented for Detection of Fake Currency. Complete system works for Indian denomination Rs.100, Rs.500 and Rs.1000. By employing hybrid learning procedure, ANFIS can refine fuzzy if-then rules obtained from human experts to describe the input output behaviour of system. This is a very efficient, less time consuming and more accurate method for fake currency detection.

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