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Identification of Forged Indian Banknotes using Image Processing and Fuzzy Inference System

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Abstract— In this paper an image processing and Fuzzy Inference System based technique is proposed to improve the recognition ability and the transaction speed for the classification of Indian paper currency. Canny edge detection operator is used for the purpose of feature extraction. On the basis of pixel values the identification mark of the Indian paper currency is extracted. The two images are processed simultaneously. The extracted feature is compared with that of the original banknote. In the second part of the system Adaptive Neuro Fuzzy Inference system is used as classifier. The set of Fuzzy rules decide whether the currency is genuine or fake. The proposed system can be used in banking industry or other fields.

Keywords— Counterfeit currency, Correlation, Canny edge detection, FIS

I. INTRODUCTION

With the advent of money started it's counterfeiting. Since then the battle against counterfeiting has been ongoing. It became a serious threat to our society with the advancement in the field of technology as it became easier for the counterfeiters to replicate the banknotes. And it became a dire need to develop an automated system for the detection of spurious banknotes [1]. The speed and efficiency of the system are very crucial [10]. In this study we present an automated system for the detection of forged Indian banknotes consisting of two parts. First is the image processing in which the scanned image of the banknote is pre-processed so as to remove noise and resizing of the image is performed. Then image is segmented using canny edge detection operator. The identification mark and the national emblem are extracted and the extracted features are compared with that of the test currency using correlation. In the second part, of the system Fuzzy Inference System is used as classifier. The input of first part is fed to it and on the basis of fuzzy rules it gives the output that whether the input currency is genuine or fake. It has been observed that the proposed system is very efficient and fast.

This paper is organized as follows: section 2 describes the edge detection, section 3 gives the overview of Fuzzy Inference System, section 3 gives the design of the proposed currency detection system, section 4 shows the results and section 5 draws the conclusion.

II. EDGE DETECTION

In image processing and computer vision Edge detection is very crucial. An edge is defined by the abrupt changes in the pixel intensity which characterise boundaries of objects in a scene. Edges in images are areas with strong intensity contrast. Many parameters describe the shape of edges in an image: the geometrical and optical properties of an image, the illumination conditions, and the noise level in images. Edge detecting an image filters out useless information thus reducing the amount of data to be processed [2] [3].

The tool for finding the Edge strength and direction at location (x, y) of an image, f, is gradient, denoted by Δf, and defined by the

$$\Delta f = grad(f) = \begin{bmatrix} gx \\ gy \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \quad 2.1$$

This vector has an important geometrical property that it points in the direction of the greatest rate of change of f at location (x, y). The magnitude of vector Δf, denoted as M(x, y) where

$$M(x,y) = mag(\Delta f) = \sqrt{{g_x}^2 + {g_y}^2} \quad 2.2$$

is the value of the rate of change in the direction of the gradient vector. It is to be noted that gx, gy and M(x, y) are the images of the same size as the original created when x and y are allowed to vary over all pixel locations in f. The direction of the vector gradient is given by the angle measured with respect to the x-axis [4].

$$\alpha(x,y) = tan^{-1}\left[\frac{g_y}{g_x}\right] \quad 2.3$$

In the proposed approach Canny edge detector has been used. It is a multistage algorithm to detect wide range of edges in the image. Edges are detected by finding local maxima of the gradient f(x, y). The gradient is calculated using the Gaussian filter [2].

III. FUZZY INFERENCE SYSTEM

The term 'Fuzzy Logic' was introduces in 1965 by Lotfi and Zadeh. Fuzzy logic is a form of many- valued logic in which the truth values of variables may be any real numbers between 0 and 1. By contrast in Boolean logic the values are only 0 and 1. Fuzzy logic is capable of handling approximate information in a systematic way and therefore it is suitable for controlling non-linear systems. The FIS formulates suitable rules and based upon the rules decision is made this is mainly based on the concepts of Fuzzy set theory, IF-THEN rules and Fuzzy reasoning. FIS uses "IF-THEN" statements, and the connectors present in the rule statement are "OR" or "AND" to make the necessary decision rules. The basic FIS can take either fuzzy inputs or crisp inputs, but the outputs it produces are almost always fuzzy sets [5]

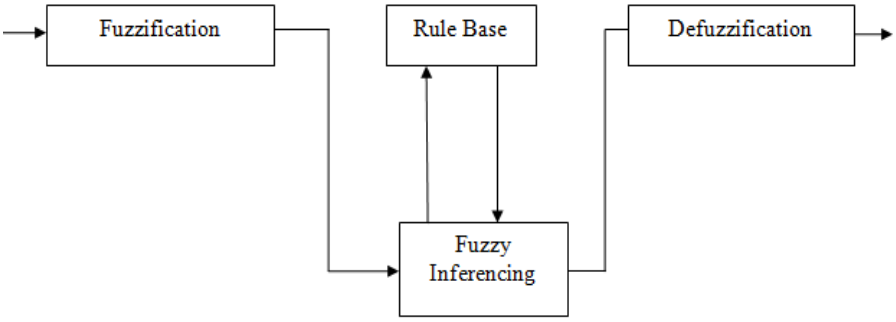

Fig.1 Example of Fuzzy Inference System

The components of the Fuzzy Inference System are:

- **Fuzzifier**: It takes the crisp inputs, and determine the degree to which these outputs belong to each of the appropriate fuzzy sets.
- **Fuzzy Rule Base**: It takes the fuzzified inputs, and apply them to the antecedents of the fuzzy rules. If a given rule has multiple antecedents, a fuzzy operator is used to obtain a single number that represents the result of the antecedent evaluation. This number is then applied to the consequent membership function
- **Rule Evaluation:** Taking the fuzzified inputs, and applying them to the antecedents of the fuzzy rules. If a given fuzzy rule has multiple antecedents, a fuzzy operator (AND or OR) is used to obtain a single number that represents the result of the antecedent evaluation. This number is then applied to the consequent membership function.
- **Aggregation of the rule outputs**: this is the process of combining of the outputs of all the rules. This is done by taking the membership functions of all the rule consequents, after all the rule evaluation process and unifying them into a single fuzzy set.
- **Defuzzifier**: This is the last step in Fuzzy inference system. Here the output fuzzy set is turned into a crisp number.

In the present paper fuzzy inference system has been used as a classifier to which correlation is fed as input and depending upon the threshold fuzzy output is generated that whether the currency under test is genuine or fake.

VI. DESIGN AND IMPLEMENTATION

The proposed counterfeit currency detection system will simultaneously process the two images i.e; genuine currency and the currency under test. The design flow of the proposed system is given below-

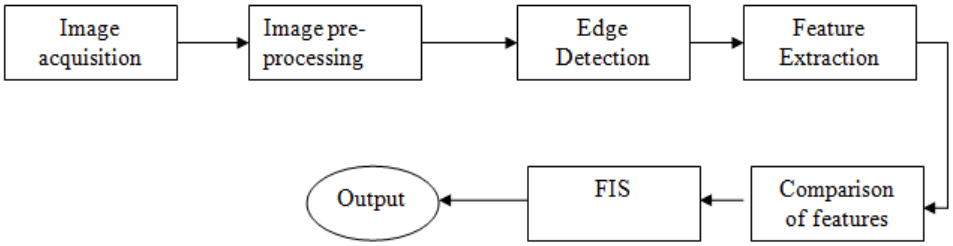

Fig 2. Design Flow of Indian Paper Currency Detection System

The following steps have been undertaken for the above approach-

4.1 Image Acquisition

Image acquisition is the first step in which the image of the paper currency under test is acquired by a simple scanner at same resolution as in case of the genuine currency. Fig. 3, 4 shows the scanned images of original currency and testing currency

Fig. 3 Original Indian 500 Denomination

Fig. 4 500 Denomination under Testing

4.2 Image pre-processing

This is the second step in which the operations that are normally required before the main data analysis and extraction of information of image are done. We have performed resizing of the image as the acquired image after scanning is too large to process. Resizing of the image saves memory and also the processed images must be of the same size [7]. Resultant images after resizing as shown in figure 5 and 6:

Fig. 5 Original Indian 500 Denomination after resizing

Fig. 6 Indian 500 Denomination under test after resizing

4.3 Edge Detection

Edge detection is the third step. Edge detection is a local image processing method to detect edge pixels. Edge pixels are the pixels at which the intensity of an image function changes abruptly, and edges are the sets of connected edge pixels.. The images after edge detection are as in fig 7 and 8


Fig. 7 Original 500 Dnomination after edge detection

Fig.8 Indian 500 Denomination under Test after edge detection

4.4 Feature Extraction

This is the fourth step in which we extract the identification mark and the emblem of the currency note. The edge detected images are segmented in order to obtain the region of interest. Segmentation reduces the area under processing as only the desirable feature is extracted [8]. The identification mark and the emblem in the paper currency are one of the main security features of Indian paper currency. Segmented images of the original currency and test currency are shown in fig 9 and 10

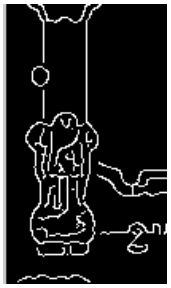

Fig.9 Identification mark of original 500 Denomination

Fig.10 Identification mark of the 500 Denomintaion under test

4.5 Comparison of the Segmented Images

This is the fifth step in which the segmented images of the input currency is compared with that of the original currency and parameters like correlation, number of black and white pixels are calculated.

4.6 Generation of Fuzzy Inference System

This is the sixth step in which the Fuzzy Inference System for fake currency detection is generated using IF-THEN rules. Figure 11 shows the fuzzy currency detection system, the names of input are on the left whereas of output are on the right hand side of the system [9].

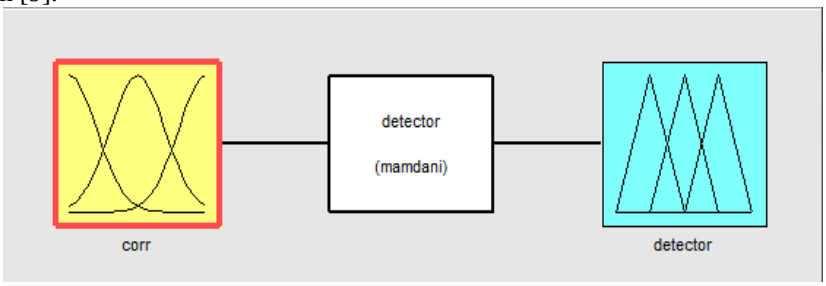

Fig. 11 Fuzzy based currency Detection System

4.7 Input parameter to Fuzzy Detection System

This is the last step in which generated FIS is interfaced with the m-file in MATLAB to pass the parameter Correlation and Pixels through Fuzzy Currency Detection System. When the input is given to the Fuzzy Currency Detection System, according to the fuzzy rule base output will be generated of whether the given currency under test is counterfeit or genuine.

V. RESULTS AND DISCUSSION

The system proposed for the detection of counterfeit currency detection is tested on the Indian denominations of Rs.100, Rs.500 and Rs.1000. Original notes further differentiated under categories: new notes, old notes, notes on which something is written with pen, torn notes glued with tape, notes marked with marker or highlighter, children notes and Fake notes have been tested using the proposed system. In total 40 samples have been tested. The below figure shows the results of various denominations-

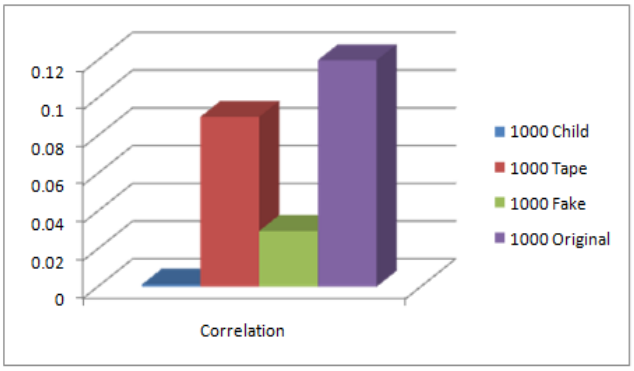

Fig.12 Graphical comparison between correlation of various 1000 Denominations.

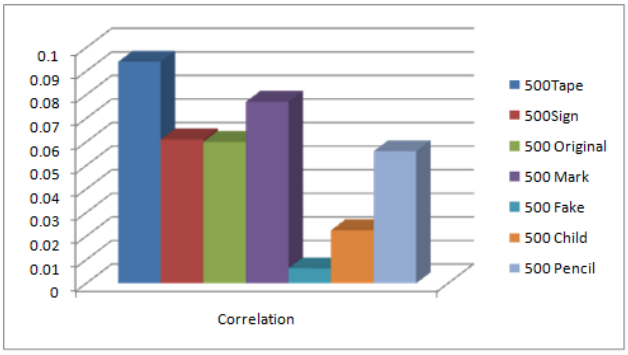

Fig.13 Graphical comparison between correlation of various 500 Denominations

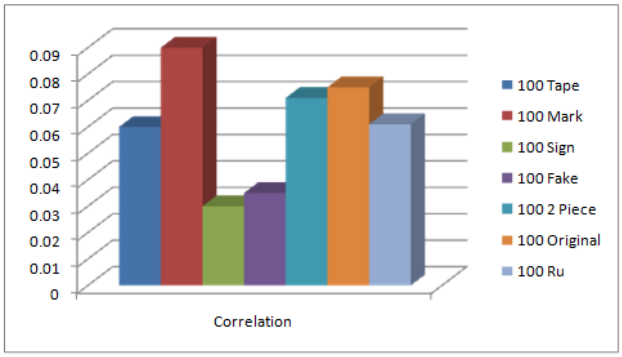

Fig 14 Graphical comparison between correlation of various 100 Denominations.

VI. CONCLUSION AND FUTURE SCOPE

In this paper, an image processing and Fuzzy Inference System based counterfeit currency detection system has been presented. The proposed system works for Indian denomination of Rs.100, Rs.500 and Rs.1000. The proposed system does not consume much time and the output is displayed that whether the currency under test is genuine or fake in no time. The system has been tested on 40 samples and it gives 91.17% accuracy which makes the system to be very efficient. But the proposed system is not able to distinguish between two piece and three piece notes. So, in future the system can be further improved in terms of accuracy and a method may be developed to distinguish two piece and three piece notes. Also the proposed system can be implemented on foreign currencies but the extracted feature has to be changed.

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