2019 5th International Conference for Convergence in Technology (I2CT)
Pune, India. Mar 29-31, 2019

Detection of Counterfeit Currency using Image Processing Techniques

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***Abstract*—The growth in the number of fake notes in the system has been tremendous over the past few years. The counterfeiters have keep developing new ways to get as close to the real paper currency as possible. This puts the common masses under grave danger of being robbed of their hard earned money. To overcome this issue, various researchers have tried to come up with different procedures to detect fake notes. In this paper, we will try to understand some of the techniques that are based on image processing and perform a comparative study of the same.**

Keywords—image processing; counterfeit currency; detection; SVM, feature extraction; ANN

I. INTRODUCTION

Counterfeit means to imitate a commodity for earning personal benefits. Counterfeit currency is to replicate the denomination in such a manner that it resembles the original currency of the country but it exists without legal sanction from the government. Thus, it is a vulnerable threat on the economy and it enhances inflation.

According to a survey conducted, 6,32,000 fake notes were discovered in the year 2015-2016. The number took a jump of 20% by the end of 2017 summing to a total of 7,64,072 fake notes. To overcome this issue, there was an urgent need for a system that could easily be implemented and provide an accurate method for counterfeit notes detection.

Various methods have been introduced to detect existence of counterfeit notes. One of them is a non-visual approach that involves chemical analysis to check the quality of the paper used. Second approach is based on manual examination. Manually examining these notes is a tedious method and requires a lot of effort and time. Thus, we need an automated method for detection of counterfeit currency that provides an high accuracy and quicker results.

Section I of the Literature Review describes in detail the procedure that is required before the genuinity of the currency notes can be verified. This section elaborates on the preprocessing step and the extraction of features . In Section II we have described various methods employed for determining the authenticity of the notes such as MSE, SVM, C4.5, HSV and ANN. The results of the same are displayed and compared in the Inferences section.

II. LITERATURE REVIEW

SECTION I

Creating Database:

A database of 1000 samples is considered. The reference database has 500 fake notes and 500 genuine notes. The dataset consists of notes of denomination 500 and 1000.

Image Acquisition:

There are various methods for capturing a banknote;to train a model and also to determine fakeness of image under consideration. Lightning conditions and a white background are considered best acquisition techniques. A different approach would be to use a machine like VSC 5000 [7] (Visual Spectral Comparator). It uses spectrometer and other built-in light sources for capturing different areas of a banknote. A UV light of the machine is apt for the central design of the note. Hence this region can be scanned with UV rays. Similarly various other light sources can extract distinct required parameter or latent marks. The pre-processing done to enhance important features and suppress the unrequired distortions can be overcome using VSC 5000.

Extraction of Features:

Extraction of features is the most important and challenging part. How efficiently we process the security features of the notes will itself determine the efficiency of our algorithms. Replicating these features is very difficult. It's quite possible that a fake note might get a few of them almost right but getting all of them correct is not possible which is why it is better to take more number of features into account.

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1) Method of Printing:

In India, intaglio printmaking technique is utilized for currency notes. It is very difficult to replicate the printed features because of special characteristics of the Intaglio print. Following are some of the important features:

Dominant intensity (f_p^1) is used to record banknotes brightness variations. The intensities are plotted on a Histogram and the intensity which has the maximum frequency is chosen to be the dominant intensity. Mathematically, represented as:

$$f_p^1 = x: f(x) = max(intensity\ histogram)$$

Hole count (f_p^2), inspects the character strokes textural similarity in a note.It is computed by calculating the number of eight-connected white pixel cluster(called hole) divided by area of character stroke. [7]

$$f_p^{2} = \frac{\#\, holes\ in\ char\ stroke}{Area\ of\ character\ stroke}.$$

Average hue (f_p^3) tells the colour quality. It is calculated on Hue(H) in HSV space [7] as:

$$f_p^{3} = Average(H)$$

Other features that can be extracted from the printing are:

i) To find the difference between the brightness of fake and genuine note, we use R.M.S contrast.

ii) After masking we calculate the mean of the intensity profile as it gives us information about where the most of information is stored.

iii) Average color is computed by reconstituting a color matrix based on scalar parameters.

iv) Edge roughness, area difference and coefficient correlation are calculated by first binarising the image using Otsu's method and then again binarize it with another threshold.

2) Ink Properties:

The way a particular type of ink reacts to a particular kind of paper is unique and can be used to detect the genuinity or ingenuity of a note. The ink used in the intaglio printing technique will react to the currency paper differently as opposed to the ink used in counterfeit notes.

CCRatio (f_i^1) The conformation of colours of the central zone (Fig. 1) of a note is examined by performing an independent component analysis followed by a filtration method. This filtration method puts a transparent mask on the central area of the note and selects the number of pixels whose green component index in the RGB color space is highest followed by blue and the lowest one being red. These selected pixels are termed as "ON". The density of such pixels in the selected mask is calculated. The assessment carried out, is represented by the colour composition ratio (CCRatio) [7] feature as:

$$f_i^{1} = \frac{\#\, ON\ pixel\ in\ mask}{Pixels\ in\ the\ mask}$$

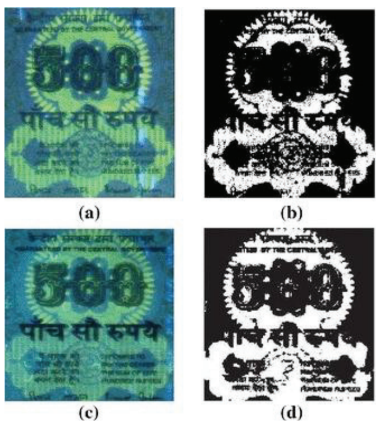

Fig. 1 :Colour composition assessment: a) & c) are fake and original image scanned using UV, b) & d) are obtained after filtration of their respective left-hand sides. [7]

Micro Letters:(f_i^2) Micro letters are seen between the vertical band and Mahatma Gandhi portrait. The RGB values are first transformed to a specific absolute colour space. The adjustment makes the data independent of device. The masked image was changed from RGB to L∗a∗b∗ colour space. Using a variation of yellow hue, the micro-letters are printed on a yellow background. To check if the variance is within the limits, the difference of the yellow colour variation against the expected value is calculated. Figure 2 shows the difference between the real and fake note:

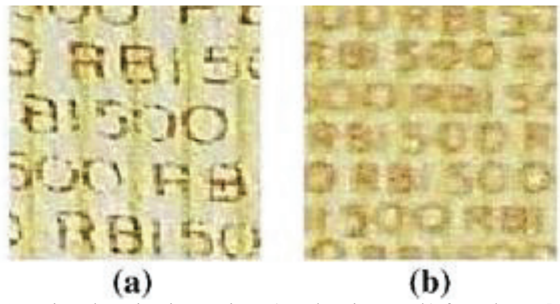

Fig. 2 : Micro-lettering inspection: a) authentic note, b) forged note [7]

Ink Fluidity :

The genuine notes printing blot are more than the fake notes, so to produce this effect of blotting, the makers of fake notes also try to spread the ink a little bit but the pattern in which the ink spread is different. To check the authenticity of ink, intensity profile was plotted by extracting the edges of the note. (Figure 3) (f_i^3).

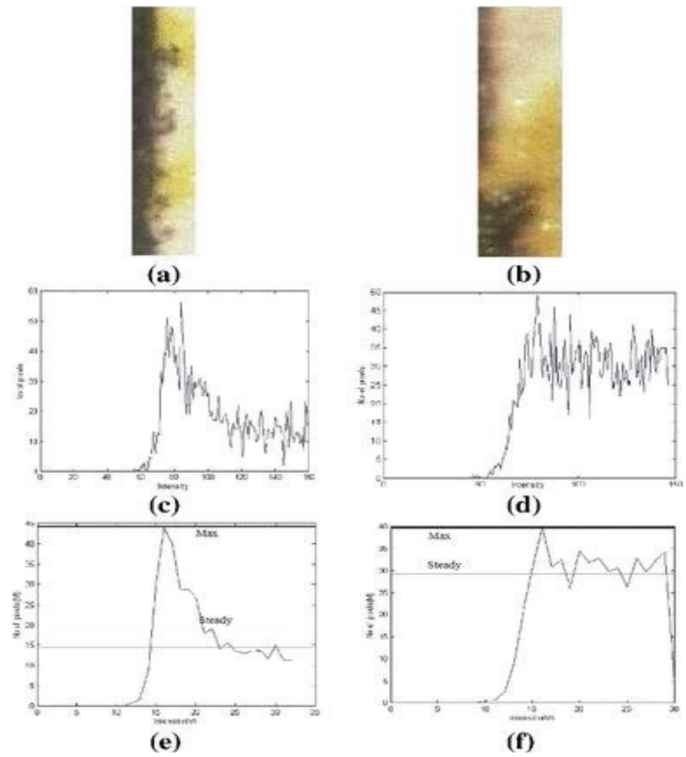

Fig. 3 : a) Ink spread of a genuine note, b) Ink spread of fake note, c) & d) Edge intensities plotted on histogram of genuine and fake note respectively, e) & f) Normalized histogram graph of the same.[7]

3) Thread:

The registration of the currency notes and the text in the security strip are two important security thread-related features.

Registration (f_t^1):

The key distinguishing factor to check the registration of security thread in notes is the appearance of the thread in a single line. In the two set of thick blobs: (see Fig. 4): One representing the thread parts on the front, while the other, representing the thread parts on the back of the note. Two lines are drawn that pass through the centroid of these blobs. If the two lines coincide to form a single line, then the note is genuine. However if the two lines fail to coincide at any point then the note is fake.

Text in the thread (f_t^2):

This is a binary feature which checks whether thread text "RBI" and "Bharat" (Hindi for India) written on original notes, appearing alternatively, exists.The textual content is extracted and compared using conventional pattern matching.There are only four text patterns as shown in Fig. 5 to compare for pattern matching, so the templates extracted from the original image were used as ground truth data. Since a majority of the false notes did not have the text(Fig. 5), they showed negligible pattern matching.

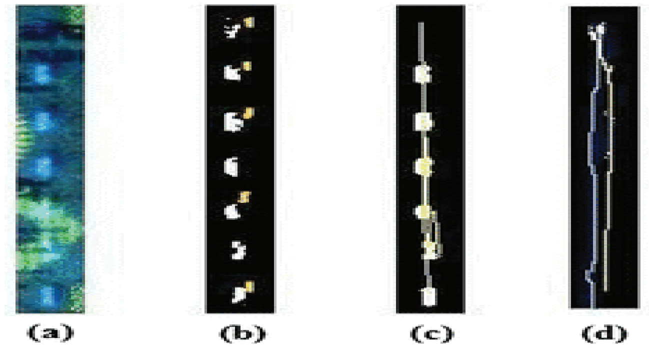

Fig. 4: a) false note, b) thick blobs on the front, c) line in front, d) two non-overlapping lines.

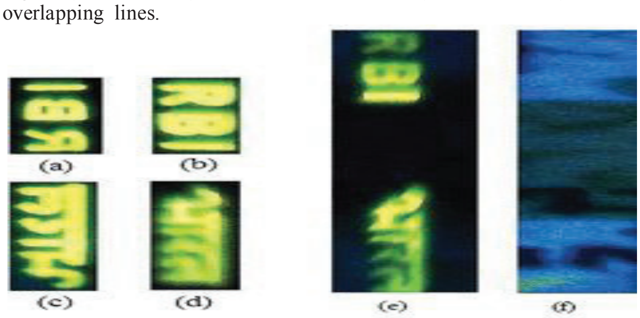

Fig. 5: a)–d) four occurring patterns, e) original note, f) fake note [7]

4)Artwork:

This section deals with printing patterns in the note design. Initially, to remove impulsive noise the image is passed through a median filter and mapping of each centroid is carried out as shown in Fig 6 and following features are extracted.

Dot Distribution:

It is observed that fake notes have less distribution of the dot centroids when compared to genuine notes. Thus we can say that there is a disruption in uniformity of fake notes. The measure of this randomness is provided by entropy count [7].

Cluster Distribution and Dot Density features:

We also compute the number of clusters found at the character strokes of the letters. To calculate the number of clusters, an unsupervised agglomerative hierarchical clustering scheme is used with a Euclidean distance. This process continues iteratively until the separation of the clusters exceeds a threshold which is indicated by a Euclidean distance. An observation that the original notes consist of a more even ditribution and that it has considerable dot count in the character strokes is an important distinguishing factor.

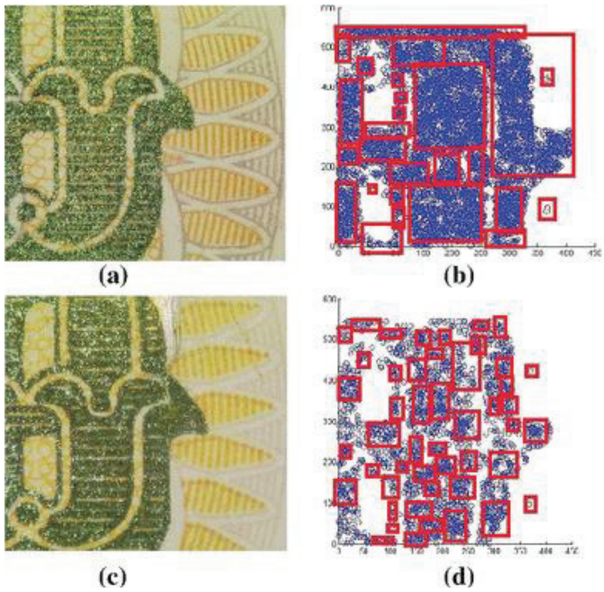

Fig. 6: a) genuine note, b) dots centroids distribution for the genuine note, c) fake note and d) dot centroids distribution for the fake note. [7]

5) Identification Mark: [2]

Special Intaglio marks are used to categorize different notes based on a particular shape. For detection and categorization, the said part is isolated and shape recognition algorithms are used to recognize the shape of the identification mark and validate.

6) RBI Logo: [1]

The binary image of the logo is transformed into a gray scale image. This image is complimented and wiener filter is applied. A wiener filter recovers a blurred image while trying to minimize the additive noise that inverse filtering usually adds.

Figure 7 shows the input image and the output of the wiener filter.

7) Watermark: [3]

A white backlight in the scanning system is used to detect watermark. The validity of a currency note helps in differentiating fake from real. The mean pixel intensity and standard deviation of the ROI are the two parameters considered for this feature.

Fig. 7: RBI logo feature.[1]

8) See-through register:

On the obverse and reverse, the floral design printed, is seen as one complete design when it is held against the light. The number of objects on each side are detected which are expected to be equal and different notes will have different number of objects. The input image is converted to binary by applying appropriate threshold value to isolate the desired region and to get count of the objects.(Fig. 8) Then OCR is conducted against a white backlight.

Fig. 8: Input images(Rs. 1000 and Rs 500 notes) and their binary counterparts for finding the number of isolated objects.

SECTION II

1) Using MSE [1]

Mean square error is the average of the squares of all the errors and this is calculated between two images. With the reference database that was created of different denominations, the values for different features was calculated based on the extraction methods that were used. These values now became reference values and the extracted images of the features were would be used as the reference image. The sample input notes were compared with these values and it was found out that the fake notes had a greater variance and mean square error. The permissible value of error for a note to be genuine was kept at 1%.

The mean square error can be calculated as follows:

$$MSE = \frac{1}{MN} \sum_{y=1}^{M} \sum_{x=1}^{N} [I(x.y) - I'(x,y)]^2$$

Where, M and N are the dimensions of the images. I(x,y) denotes the reference image and I'(x,y) is the sample input image.

2) Using SVM [6]

The very first step is to calculate the Histogram of Oriented Gradient (HOG) Descriptor. It is a feature descriptor used for object detection. It describes the shape of the object in an image by the distribution of intensity gradients/edge detectors. It divides the image into small connected regions called cells and calculates the hog value by the compilation of each pixels in the cell. The 4x4 HOG Descriptor is used to encode patterns and then the features are fed to the SVM Model. SVM model is trained in a way that it creates a hyperplane to minimize the classification error and maximise the distance between the values. Each set is classified as either fake or genuine. The function for SVM model is given as follow:

$$f(x) = \sum_{i=1}^{M} y_i \, . \, a_i \, . \, k(x, x_i) + b$$

where k denotes the kernel function and the sign of x is determined by f(x). Values of yi={1,-1}.

3)Using C4.5 Decision Tree [4]

A cascade of classifiers is used in a such manner that the output of one classifier acts as an input for another classifier. This process helps in filtering the currency notes belonging to a particular class. Each classifier classifies the input set on the basis of some security features. These classifiers are trained individually and then connected in a cascade. Percentage of histogram bins is calculated as a pre-processing step. The value of each bin is divided by the total number of pixels and multiplied by 100 to express as a percentage of pixels with particular intensity.

4) Using HSV [5]

Dimensions of the currency and its aspect ratio is calculated. Aspect ratio remains the same in all lighting conditions. Thus it becomes an important feature recognition of an image. H,S,V value of each blocks of the currency is evaluated. An average is obtained and compared with the database value. Euclidean distance is used to find out the average of the differences between the ideal values and the observed values. Formula used is:

$$d(p,q) = \sqrt{(H2 - H1)^2 + (S2 - S1)^2 + (V2 - V1)^2}$$

Where,
(H1, S1, V1) = Target image feature set
(H2, S2, V2) = Ideal feature set

Hue determines pure colour, Saturation is radius in the circle while Value is pure white to any fully saturated colour.

5) Using ANN [7]

For each feature group, three different sets of neural network classifiers are used. Each neural network consists of of three layers viz. input (layer 1), hidden layer with multiple nodes and output (layer 3). The input layer consists of input nodes depending on the number of features in the respective feature group viz ink work, printing ,artwork. Since the accuracy obtained is maximum in one hidden layer, multi-perceptron model is not used. For training with sigmoid activation function given by:

$$f(x) = \frac{e^x}{1+e^x}$$

The normal back propagation algorithm [7] has been used. The aim is to arrange the feature groups on the basis of their performance and impact on the classification process. This reduces the machine load if at various stages the checked notes could be reduced without affecting the accuracy. This process is done using Linear Discrimination Analysis.

The system operates fastest when thread feature group is placed at the beginning and all other features, being independent of each other, are implemented simultaneously. Using an AND gate on the decision vectors gotten from various classifiers, a clear majority for genuine note or a single negation produced for a fake note can be deduced.

III. Inference

In the following table, the resulting accuracies of different algorithms have been tabulated to compare them against each other.

Algorithm	Accuracy
Mean Square Error[1]	100% accuracy with permissible error of 1%
Support Vector Machine	100% accuracy with limited testing
C 4.5 Decision Tree	93.94% accuracy with 90% training set data and 10% testing set data
Artificial Neural Network (Accuracies of individual features are)	Ink- 98.5% Artwork- 99.3% Print based- 99.8%

The MSE and SVM methods give the highest accuracy followed by ANN and the least accuracy is given by C 4.5 decision tree. The HSV method is usually followed by a Neural Network and Pattern Recognition Technique. Hence, its accuracy is algorithm dependent.

IV. Conclusion

The methods of extraction of features remain more or less constant for different algorithms used for detection of counterfeit notes. Different combinations of features can be used to determine which is the fastest and the most accurate way of detecting counterfeit notes. The above methods take a huge amount of time to compute the result and it would be difficult to implement these in real time because at any given time in banks there will be thousands of notes that will require checking. Hence, despite the accuracies of some of the methods being as high as 100%, they cannot be implemented in real life due to time constraint.

V. Proposed Future Work

The above techniques of detection have all been performed on the older notes of Rs. 500 and Rs. 1000. We need to expand the database to other denominations and include the newer notes. Instead of Intaglio printing, the new notes use ink that has imported from a Swiss company SICPA. The characteristics of this ink need to be studied in order to perform detection based on Printing techniques. An algorithm that gives maximum accuracy in minimum amount of time needs to be developed as opposed to the existing algorithms that have a very high time complexity. For the same, we would need to figure the smallest number of key features that will be enough for counterfeit currency detection. And to be able to deploy this on a huge scale, the method of detection needs to be inexpensive.

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