www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume – 4 Issue - 12 December, 2015 Page No. 15317-15327

Fake Currency Verification Using Blue Pixel Region Analysis And Image Difference

Rajarshi Paul[1], Dr. Sanjib Kalita[2]
[1] P.G Scholar, Institute of Science and Technology,Gauhati University, Guwahati-781014, India
rajarshi.paul7@gmail.com
[2]Assistant Professor, Department of Computer Science,Gauhati University, Guwahati-781014, India
sanjib959@gmail.com

Abstract: Indian paper currencies are now a days feign in various tricky techniques by the counterfeiters and is very difficult to detect. A regular bearer may easily be mislead with the note and can consider it to be a genuine one for transaction purpose. It is a very challenging job to verify an Indian currency by image processing techniques. This paper demonstrates a comparison method of colors of RGB color model on the variable color shifting property region of a genuine with that of a fake note and produces a differential comparison on abstracted regions and subsequent analysis for the validation of the procedure**.**

Keywords: Color Shift Dominancy; PSNR; Average Intensity Shift; Blue Segmented region;

1. Introduction

Although sometimes high resolution scanners and printers used for duplicating paper currencies they sometimes cannot integrate some or all the security features embodied in an original currency. Sometimes due to the poor scanning and printing techniques used compared to the standards maintained by the Govt. Press machines, tools, secret systems and printing procedures for duplicating the original note, some borders and lines of textures copied are either fade or nearly missing in the currency. Sometimes low quality paper is used for printing and blotting effect of ink can be observed on the numbers and textures[1]. It can also be observed that some white dots (like salt and pepper noise) also appear in the continuous color regions of the printed duplicate currency. Fake currency detection is a challenging work in digital image processing. In any currency recognition system, feature extraction and representation is one of the most challenging tasks because the notes of current generation contain various complex textures and some regions content is irregular enough to describe. In feature extraction technique the aim is to analyze and identify the unique and distinguishing features of each denomination under various challenging conditions such as old notes, dusty note, worn out notes and also under illumination of different types of light and background conditions. Some general security features such as "number panels", "optical fibers embedded" on the currencies as defined by the Reserve Bank of India can be verified under the ultraviolet lighting condition. Some low level image processing techniques such as edge detection, segmentation and feature extraction is sometimes effective in detecting fake notes. But these not always prove to be effective always for all aspects.

2. Literature Survey

2.1 Standards set by government bodies in India as identification marks for an original note

Reserve Bank of India has set some design criteria to prevent counterfeiting of Indian bank notes which are the security features used to verify whether a note is an original or a duplicated one. Although all these features of a bank note are not available on a single note, these features vary depending upon the denomination of the currency concerned as described below,
See through Register:- A filled and unfilled sectored five hundred or one thousand numeral depending

upon the denomination printed on the left side of the watermarked Mahatma Gandhi's face. When seen vertically the full numeral can be sensed and when seen transversely sectored filling of the numeral is seen.[12]

Water marking:- A Mahatma Gandhi watermark is printed having a defined shape and structure and which can be seen as a light and shade effect and many multi-directional lines in the watermark can also be observed. [12].In a duplicated currency the shape properties can differ.

Optically Variable Ink: The numeral 1000 and 500 on the Rs.1000 and Rs.500 denomination is printed with optically variable ink viz., a color-shifting ink. The color of the numeral 1000/500 appears green when the note is observed vertically but when seen with an angle less than 90^0 is seen as blue colored.[12]

Fluorescence:- Number panels of the notes are printed in fluorescent ink and the notes have optical fibers. These can be marked when these features are exposed to ultra-violet light.[12]

Security Thread:- The Rs.500 and Rs.100 notes have a greenish security thread marked with the words 'Bharat' (in Hindi script), and 'RBI'(in English alphabets). This thread posses one feature that: when held on a light, the security thread and also the texts can be seen in one continuous line. The Rs.5, Rs.10, Rs.20 and Rs.50 notes also have this feature. The thread appears to the left of the Mahatma Gandhi's color visible.[12]

Intaglio Printing:- The portrait of Mahatma Gandhi, the Reserve Bank seal, guarantee text by Government of India, the lions of Ashoka Pillar on the bottom left, RBI Governor's signature are printed in intaglio i.e. raised with ink, which can be felt by touch, in Rs.20, Rs.50, Rs.100, Rs.500 and Rs.1000 notes.[12]

Latent image:- The Rs.1000, Rs.500, Rs.100, Rs.50 and Rs.20 notes facing or turned towards the observer one can observe a vertical band with green texture design on the right side of the Mahatma Gandhi's which contains a hidden image showing the respective denomination value in numeral. It can only be seen when the note is held horizontally towards the observer.[12]

Micro lettering:- It is a micro feature and appears between the green designed vertical band and Mahatma Gandhi portrait. For Rs.5 and Rs.10 note the word 'RBI' is printed in very small letters. In Rs.20 notes and above the denomination value of the notes is written after the word 'RBI' in micro letters. This feature can be inspected by using a magnifying glass or by a digital zooming procedure.[12]

Identification Mark:- A special feature for visually impaired persons has been introduced in intaglio technique on the left of the Mahatma Gandhi's watermark window. A mark having various shapes for various denominations are introduced like for Rs100 a triangle, Rs.500 a Circle, and Rs.1000 a diamond shape which helps the visually impaired to identify the denomination.[12]

The security features as listed above give a computer scientist a base for designing and making a model for a particular method or an algorithm suitable for a computing device to check and verify a currency to be fake or original. All the features are not still fully modeled for a computing device for all possible type of duplications. These still remains by and large a manual verification method.

2.2 Existing and recent trend for fake note detection

Ultraviolet light scanner is used now a days in financial workplaces as an handy way for detection of fake notes. UV light projection devices can project UV light precisely on the UV security features of a particular denomination. The UV sensors present in those devices can grab the returned light carrying information from the note's security regions and can analyze the light spectrum data. Magnetic ink characters can also be verified by testing the magnetic properties of the ink, fluorescent light is used for watermarks present on the notes, micro letters are verified by subsequent magnification OCR methods.

2.3 Earlier mathematical and statistical proposals

Some earlier mathematical and statistical proposals were put depending upon the physical characteristics of Indian paper currency. Segmentation algorithm for monochrome images generally are based on one of the two basic properties of image intensity values[7],

1) *Discontinuity*
2) *Similarity*

In the first category, the approach is to partition an image based on abrupt changes in intensity such as edges in an image.

The approach in the second category is based on partitioning an image into regions that are similar or dissimilar according to a set of predefined criteria.

Feature Extraction Methodology is most commonly used to experiment the printing techniques used for original and fake note[3]. Edges of original currency are used to be rough compared to fake one. One issue that is noticed between a original and a fake note is the Edge Roughness depending on the printing technique used(in fake vs original)[3]. Based on printing technique various statistical measures like- dominant intensity calculation, hole count, average hue, root mean square contrast, key tone value, average colour, edge roughness, area difference, correlation coefficient were proposed[3]. Vila *et. al.*[6] proposed a method is to analyze several areas of the banknotes using Fourier transformed infrared spectrometer using a microscope and analyzing the attenuated total reflectance. The study considered four different regions of a note and showed that the infrared spectra from the regions can nicely distinguish and describe the genuine notes. However, the study did not propose any automated way for decision-making.

2.4 Earlier attempt of verification by channel interchanging idea of images

One experiment was performed by D.Alekhya, G. Devi Surya Prava, G. Venkata Durga Rao in which they intermixed the tested currency's green channel with the red and blue channel of the original currency as they considered green channel to be sensitive to human eyes and most of the images contains maximum green components [2]. The newly formed image is compared with the original one. This is a global comparison of the two currency samples without localizing the method to a particular area or feature of an image. They calculated threshold value of equivalence by calculating standard deviation. If it is above 40% they considered it to be original[2].

3. Theories related to the work

3.1 Image Difference Operation in Set Theoretic notation

Difference between two binary images f(x,y) and f′(x,y) is defined[4] in set theoretic operation,
$f(x,y) - f'(x,y)=\{w|w \text{ is a pixel}, w\in f(x,y) \text{ and } w\notin f'(x,y)\}$.

Similarly difference between two intensity or gray scale images I(x,y,i) and I′(x,y,i), where (x,y) is the coordinate of I and I′, i is the intensity at (x,y) can be assumed as below[4],
$I(x,y) - I'(x,y)=\{w(x,y,k)|\ w \text{ is an intensity pixel}, k=I(x,y,i)-I'(x,y,i)\}$. If both intensity are same then black will result, i.e. one will complement the other. For grayscale images the difference is simply a numerical difference between the two grayscale intensity values.

For 2 RGB color images c(x,y,v) , c′(x,y,v), where x, y is the coordinate and v is the set v={R,G,B}, where R is the red intensity, G is the green intensity and B is the blue intensity at (x,y) then,
c(x,y) - c′(x,y) consists of 3 operations,
$R(x,y) - R'(x,y)=\{w(x,y,k_R)|$ w is the red intensity pixel, $k_R=I(x,y,i)-I'(x,y,i)$ if both intensity is same then black will result for the resultant red intensity}
$G(x,y) - G'(x,y)=\{w(x,y,k_G)|$ w is the green intensity pixel, $k_G=I(x,y,i)-I'(x,y,i)$ if both intensity is same then black will result for the resultant green intensity}
$B(x,y) - B'(x,y)=\{w(x,y,k_B)|$ w is the blue intensity pixel, $k_B=I(x,y,i)-I'(x,y,i)$ if both intensity is same then black will result for the resultant blue intensity}
The shift of red, green and blue intensities can be described by a vector $[k_R,k_G,k_B]$.
So, average intensity shift for a pixel at a point(x,y) is given by,

$$AIS_{(x,y)} = \frac{k_R + k_G + k_B}{3} \quad (1)$$

Similarly minimum saturation shift can be derived from saturation definition of HSV model as,

$$MSS_{(x,y)} = 1 - \frac{3}{(k_R + k_G + k_B)}[\min(k_R, k_G, k_B)] \quad (2)$$

If a sampled rectangular region sampled under consideration in the differenced image is given by the dimension w×h, then the overall amount of shift is,

$$MSS_{avg} = \frac{\sum_{w,h} MSS_{(x,y)}}{w \times h} \quad (3)$$

Resultant color image is given by,
$c(x,y) - c'(x,y)=\{x,y,[k_R,k_G,k_B]\}$

3.2 Region creating using 8-pixel connectivity

A pixel p at position (x,y) is connected with another pixel q at (x´,y´) which shares some common criteria in 8-connectivity procedure if they either share a side or a corner position in the image.

Using 8-connectivity procedure we can construct many disjoint regions and can count their numbers and analyze some statistical properties like dispersion of the clusters etc.

3.3 Distance measure of pixels

The simple of the distance measure between two pixels (x_1,y_1) and (x_2,y_2) is the Euclidian distance d given as[4],

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (4)$$

Distance measure between two pixel in RGB color model are,

$$d_{CM} = \sqrt{(R(x,y) - R_O(x,y))^2 + (G(x,y) - G_O(x,y))^2 + (B(x,y) - B_O(x,y))^2} \quad (5)$$

Where, R(), G() and B() are considered red, green and blue pixel color intensities of the paper currency to be tested and R_O, G_O() and B_O() are the corresponding color intensities of the original currency.

For an intensity image standard deviation is calculated along row wise or column wise by using the following formula,

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad (6)$$

Where, x_i is the intensity of the i^{th} pixel and $\bar{x}$ is the mean intensity along the row or the column.

3.4 Error Metrics used for image comparison

Two of the error metrics commonly used to compare the various image compression techniques are the Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR).

SNR or signal to noise ratio is defined as the ratio of average signal power to average noise power. For an MxN image[10].

$$SNR_{DB} = 10\log_{10}\left(\frac{\sum_{i,j} I(x,y)^2}{\sum_{i,j}(I(x,y) - I'(x,y))^2}\right) \quad (7)$$

For, $0 \le i \le M-1$ and $0 \le j \le N-1$

where, I(x,y) denotes a pixel of the original currency image and I'(x,y) denotes the pixel of the noisy image(changed color component image).

The MSE is the cumulative squared error between the changed color component image and the original image. The mathematical formulae for the two are[10],

$$MSE = \frac{1}{MN}\sum_{y}^{M-1}\sum_{x}^{N-1}[I(x,y) - I'(x,y)]^2 \quad (8)$$

PSNR or peak signal to noise ratio is a measure of the peak error[10],

$$PSNR_{DB} = 20\log\left(\frac{MAX_1}{\sqrt{MSE}}\right) \quad (9)$$

Where, MAX_1 is the maximum possible pixel value of the image. When the pixels are represented using 8 bits per sample, this is MAX_1= 255.

More generally, when samples are represented using linear PCM with *B* bits per sample, MAX_1 is 2^{B-1}. For color images with three RGB values per pixel, the definition of PSNR is the same except the MSE is the sum over all squared value differences divided by image size and by three[8].

Now, if I(x,y) is the original image, I'(x,y) is the changed color image and M,N are the dimensions of the images which are converted to the same dimension by image preprocessing techniques like image transformation. A lower value for MSE means lesser error, and as seen from the inverse relation between the MSE and PSNR, this translates to a high value of PSNR. Logically, a higher value of PSNR is good because it means that the ratio of signal to noise is higher. Here, the 'signal' is the original image, and the 'noise' is the amount of blue intensity that is introduced in resultant changed color image from the sample image. If the sample note is genuine then more blue pixels will be introduced i.e. more error in our case and if the sample note is fake then lesser blue pixel will be introduced so lesser error. So, if we find a result with lower MSE (and a high PSNR) we can take the sample currency image as fake.

3.5 Purpose of using PSNR for testing by quality assessment

PSNR is generally used to measure the quality of reconstruction of lossy and lossless compression (e.g., for image compression). The signal in our case is the original data, and the noise is the error introduced by interchanging the color channel of the fake note. When comparing compression codecs, PSNR is an approximation to human perception of reconstruction quality[8]. Here in our case we consider the amount of adulteration by the blue channel of the fake note in the following method to be discussed. If the sample note is genuine we can say that reconstruction quality is good. Although a higher PSNR generally indicates that the reconstruction is of higher quality, in some cases it may not. And PSNR is most easily defined and calculated by the mean squared error.

3.6 Structural Content analysis

If there is inter relation among pixels and they form a close special distribution in an image then they can describe some structural information. These dependencies convey important information regarding the structure of the objects in the human visual perception[9].

MSE and PSNR estimate errors which are perceived by human eye, on the other hand structural similarity index, SSIM also considers image degradation i.e. the original image g(x,y) is degraded by a noisy substance η(x,y) [extra erroneous information which we can consider here the noisy pixels carried by the fake note] giving a noisy or degraded image f(x,y). i.e we can get the original image g(x,y) by the following operation[4],

$$g(x,y) = f(x,y) - \eta(x,y)$$

Thus, structural similarity measurement considers image degradation as the perceived visual change with respect to the original currency.

The SSIM is a measure to find the visual similarity between two images. SSIM is a better method to measure the human visual observation of an object and it is a better measure over peak signal-to-noise ratio (PSNR) and mean squared error (MSE) which were traditionally used, and are not found much efficient for human eye perception [9].

The measure of SSIM between two image of x and y of same size(M by N) is defined as[9]

$$SSIM_{(x,y)} = \frac{(2\mu_x\mu_y + c_2)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (10)$$

Where,

μ_x= average in image x,

μ_y= average in image y,

σ^2_x=variance of x,

σ^2_y=variance of y,

σ_{xy}=covariance between x and y and is given as,

σ_{xy}=E[(x-E[x]])(y-E[y])]

where, E[x] and E[y] are mean intensity value of x and y.

and $c_1=(k_1L)^2$, $c_2=(k_2L)^2$

c_1 and c_2 are used as stabilizing variables when the division contains with weak denominator,

L=Number of intensity levels in the image

By default $k_1=0.01$ and $k_2=0.03$

The SSIM index is a decimal value and lies between -1 and 1, and value 1 is only possible if the two images are perfectly identical.

Similarly structural dissimilarity index, DSSIM is derived from SSIM and is a improved pixel distance measure for computer vision,

$$DSSIM_{(x,y)} = \frac{(1 - SSIM_{(x,y)})}{2} \quad (11)$$

4. Observations

We can observe that exact color values in the fake and a original currency vary if these are printed using low quality techniques. i.e. The visual perception of an original and fake note depends upon whether the techniques like intaglio printing, offset printing, dry offset printing, letter press, serigraphy etc are used or not and also the usage of the materials like paper, ink, dryer chemical, rubber pad etc.

The Mahatma Gandhi series of notes are currently printed with the numeral of the denomination in variable color ink or colour shifting ink in the middle. If the note is original and tilted and it is seen at an angle less than 90^o then the number appears to be blue rich. And when seen at an 90^o angle i.e. perpendicularly appears green. In case of counterfeited currency when seen at an angle $<90^o$ the numerals will appear green.

5. Proposed approach

Interchanging of color components of two different images is adopted and the resultant image is analyzed and compared with the original currency image taken as known base. The methodology adopted is a image verification technique depending upon the blue pixel characteristics. We will replace the blue channel of the original currency with the sample currency and it will be verified with the

DOI: 10.18535/Ijecs/v4i12.38

original currency. A differential comparison particularly on blue channel is adopted.

The strategy adopted for image verification is simple, we will check the number of 8-connected blue intensity pixels in the processed resultant image and compare it with the number of 8-connected blue regions(blue intensity pixel cluster) in the original. We will also use other conventional measures like MSE and PSNR for comparison.

Besides the conventional measures like MSE, PSNR etc other measures can be proposed regarding the average size of the blue pixel clusters or regions. Since the fake note has less blue dense regions, so adding it to the original note's red and green components and subtracting it from the original note will give a resultant image of more blue dense regions compared to the fake note. We are getting a relatively blue rich regions after subtraction,

$Blue_{Rich}=\{Blue_{More(in\ original\ image)}-Blue_{Less(in\ interchanged\ image)}\}$

Infect the image obtained from the difference operation of the interchanged blue component image from the original image will contain no Red and Green components. It will only contain blue intensities. If the blue intensity is more in the original currency's image compared to the interchanged image then a blue shift will result. Hue and saturation of the fake note may also vary from the original one if the printing techniques, methods, materials and ink properties used to print the fake note differ from the genuine one. But we are not considering hue(pure color) or saturation(with white color) into consideration in our analysis. So, simply by counting the number of regions we can compute the average cluster size of the connected blue pixels. The average cluster sizes of connected blue pixel regions can be given by,

$$CS_{avg} = \sum_{i=1}^{n} \frac{S(C_i)}{n}$$

(12)

Where, n is the number of blue pixel regions. $S(C_i)$ is the size of the n-th connected region and CS_{avg} is the average cluster size. Average value should be more from a threshold value if the note is fake or counterfeited.

Standard deviation of cluster sizes can also be a good measure of structural content of the result and can be defined as,

$$\sigma_{cluster} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(S(C_i)-\mu_c)^2}$$

(13)

Where, μ_c is the mean of blue region's cluster size, and $S(C_i)$ is the size of the nth cluster. Dispersion will be less if the note is genuine according to our methodology which explained in our next discussion.

Since the variable color ink region for the denomination numeral does not form any significant structure and are dispersed randomly so SSIM index and DSSIM index verification is not very suitable approach for us. It is better to use simple co-variance measurement, mean square error and pick signal to noise ratio between blue pixels of the processed result and the original note.

5.1 Assumption and Terminology

Dominant channel is considered as the color in the RGB model which cannot be duplicated in the fake currency on some security feature or some other regions of the currency. e.g. the blue channel on the variable color ink region of the denomination numeral. When it is seen perpendicularly (i.e. at an angle 90^o) it appears green but when tilted and seen at an angle $<90^o$ it is seen blue. This blue behaviour cannot be duplicated in the fake currency.

5.2 Flow diagram of the proposed methodology

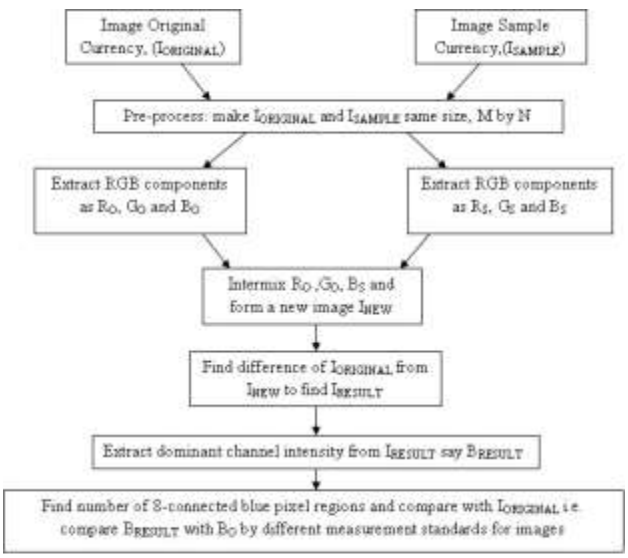

Fig 1: Overall description of the procedure for analysis

5.3 Proposed Algorithm

Description: Our new proposed interchanging color verification algorithm using dominant color (taken as blue for analysis) of the original currency's color shift numeral with neighborhood processing and other standard measurement.

Step 1: Capture images $I_{ORIGINAL}$ and I_{FAKE}, $I_{ORIGINAL}$=Original currency, I_{SAMPLE}=Currency to be tested.
Step2: Choose the dominant color from a RGB image of an original currency provided the currencies are in ideal conditions of lighting, illumination, positional and orientation constraints.
Step 3: Pre-process the images, remove noise, scale to the same size M by N.
Step 4: R_O=Red($I_{ORIGINAL}$)
G_O=Green($I_{ORIGINAL}$)
B_O=Blue($I_{ORIGINAL}$)
R_S=Red(I_{SAMPLE})
G_S=Green(I_{SAMPLE})
B_S=Blue(I_{SAMPLE})
Where the functions Blue(), Red(), Green() are the operations to extract Blue, Red and Green channels of an image. R_O, G_O, B_O, R_S, G_S, B_S are intensity matrices of red, green and blue channels of original and sample notes.
Step 5: Pick the channel found to be dominant or cannot be counterfeited (in the original note) from the fake note (e.g. the blue channel in the variable ink numeral) to interchange with the blue channel of the original note. Say we pick blue from the fake note which is non-counterfeit-able in the color shifting ink portion of a 500,1000 rupees denomination when seen at an angle<90^o. So,
I_{NEW}=Concatenation(R_O,G_O,B_S)
/*Concatenation() operation simply reconstructs the new image with given R,G and B channels*/
Step 6: Find the difference between the new image and the original note.
I_{RESULT}=Diff($I_{ORIGINAL}$,I_{NEW})
Step 7: Extract the blue component from the resultant image subtraction.
B_{RESULT}=Blue(I_{RESULT})
Step 8: Use a suitable error metric for comparison.

5.4 Time complexity analysis

It can be observed that the whole operation can be summarized as,

T(n)=(Time required to Extract the Red Channel of Original Note) + (Time required to Extract the Blue Channel of Fake Note) + (Time required to Extract the Green Channel of Original Note) + (Time for concatenation operation) + $2\times$(8-neighborhood processing for each pixel)

Taking time to extract a channel(R or G or B) from a 3 dimensional RGB image matrix as constant operation,
each point f(x,y) in the G_{RESULT} requires 8 comparisons
(2 horizontal+2 vertical+4 diagonal). So for the entire image and for all pixels of the image it requires $n\times n=n^2$ operations. So it stands out to O(n^2). Image difference is a linear operation of comparison. So it is 'n' operations i.e. O(n).

So, our result stands out to be,

$$T(n)=c+c+c+n+2\times n^2$$

Therefore the overall time complexity will be O(n^2) for best, average and worst cases.

6. Results and Experiment

After adding the blue less channel of the fake note to the original note and difference is calculated we are getting a relatively blue rich image, since the fake note contains relatively less blue pixel.

We next find the co-variance between blue channels by the co-variance formula. We have calculated the MSE and PSNR between the blue channels B_O and B_{RESULT}. We have calculated number of connected 8-Neighbourhood components of B_{RESULT} and compare with 8-neighbourhood components of B_O. If the number of 8-connected components or regions is less than an accepted level then the second note tested is fake. This algorithm is based on the density of the pixels having blue component rich in RGB color space so the 8-connected regions found will be more.

6.1 Suitable condition for better output

This procedure can be useful by observing the region of the green/blue variable color ink numeral region of Gandhi series currency when the images of the original and fake note are captured at an angle <90^o.

6.2 Checking variable color ink

The Mahatma Gandhi series notes currently printed with the numeral of the denomination in variable color ink. If the note is original and tilted and seen at an angle less than 90^o then the number appear to be blue rich. And when seen at a 90^o angle i.e. perpendicularly it appears green. But in case of counterfeited currency when seen at an angle <90^o

the numerals will appear green. So we can compute the average green value.

Test1: Tested currency is a fake one

Fig 2: Oblique view of the variable link numeral of the original currency

Fig 3: Oblique view of the variable link numeral of the tested currency

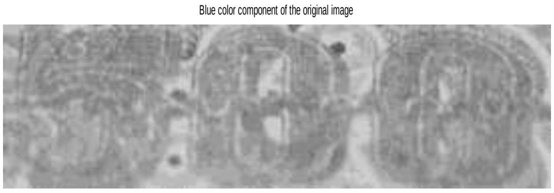

Fig 4: Blue color component of the original image(intensity image)

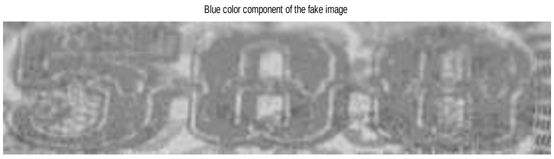

Fig 5: Blue color component of the fake image(intensity image)

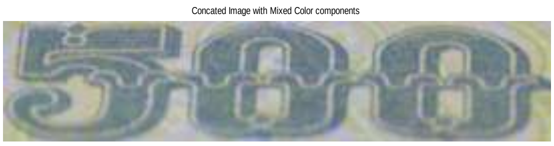

Fig 6: Concatenated image with changed blue color component

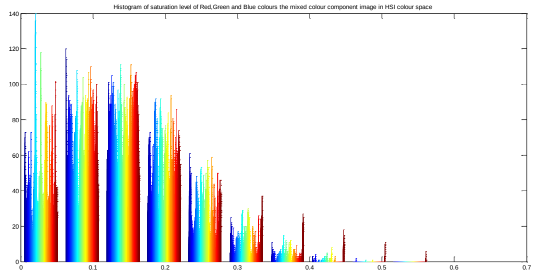

Fig 7: Histogram of saturation level of Red, Green and Blue colours the changed color component image in HSI color space

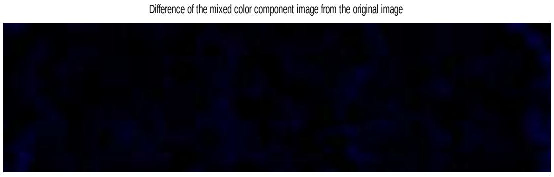

Fig 8: Difference of the changed color component image from the original image

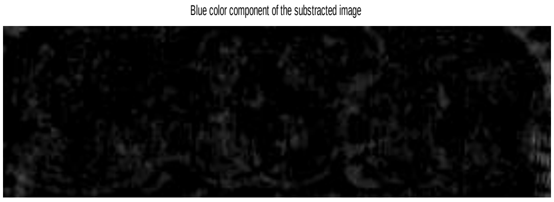

Fig 9: Blue color component of the subtracted image(intensity image)

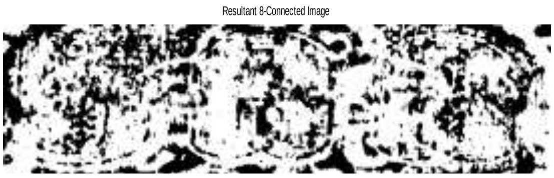

Fig 10: Resultant 8-neighbourhood connected image of blue pixels

Fig 11: Resultant 8-connected component region centroids with fake note

Test2: Tested currency is an original one

Fig 12: Oblique view of the variable link numeral of the original currency

Fig 13: Oblique view of the variable link numeral of the tested currency

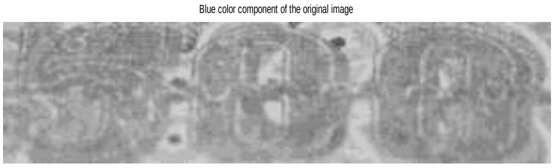

Fig 14: Blue color component of the original note image(intensity image)

Fig 15: Blue color component of the fake note image(intensity image)

Fig 16: Concatenated image with changed blue color component

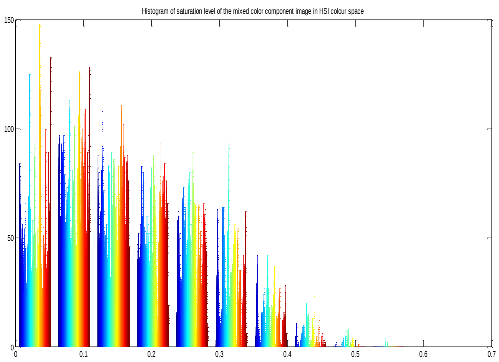

Fig 17: Histogram of saturation level of Red, Green and Blue colours of the changed color component image in HSI color space

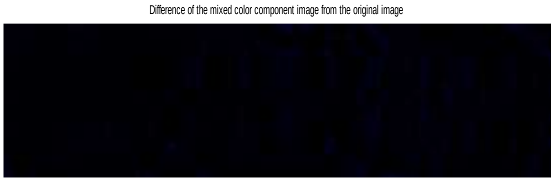

Fig 18: Difference of the changed color component image from the original image

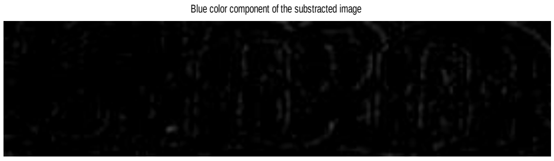

Fig 19: Blue color component of the subtracted image(intensity image)

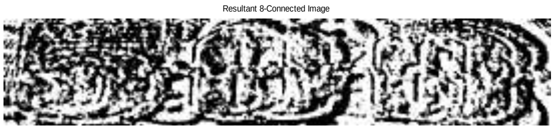

Fig 20: Resultant 8-neighbourhood connected image of blue pixels

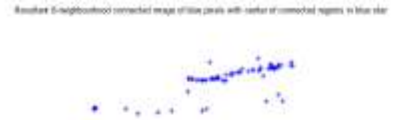

Fig 21: Resultant 8-connected component region centroids with original note

6.3 Result obtained from fake currency

It can be noticed that the pixel density clusters spreads from left to right since the notes tested is a fake one and dispersion is more i.e. noise is present.

Fig 22: Result :- Number of 8-connected components found 304.

Co-variance matrix result between the original and the fake notes is found to be,

$$\begin{bmatrix} 334.6368 & 99.4388 \\ 99.4388 & 172.9050 \end{bmatrix}$$

MSE value found=21623.3
PSNR value found=4.78158
Average area of 8-connected blue regions=378.335172 pixel^2.
Standard Deviation of 8-connected blue region areas=7463.486435

6.4 Result obtained from original currency

It can be noticed that the pixel density clusters tends to be at the center since the two currencies verified are original so dispersion is less.

Fig 23: Result:- Number of 8-connected components found 725.

Co-variance matrix result between two original notes is found to be,

$$\begin{bmatrix} 334.6368 & 77.4056 \\ 77.4056 & 75.2745 \end{bmatrix}$$

This value is much less than that found in the fake note.

MSE value found=23193.6
PSNR value found=4.47712
Average area of 8-connected blue regions= 221.823448 pixel^2.
Standard Deviation of 8-connected blue region areas= 2788.244555

6.5 Discussion

We have found greater MSE value and lesser PSNR in test2 then in test1. Which means more blue pixels from the genuine note contributed the result. We have not tested the resultant image containing irregular structural features on neural network and have not determined any threshold value for acceptance. We have placed only a comparative measure.

References

[1] Machine Assisted Authentication of Paper Currency: an Experiment on Indian Banknotes, Ankush Roy, Biswajit Halder,Utpal Garain,David S. Doermann.

[2] Fake Currency Detection Using Image Processing and Other Standard Methods: D.Alekhya , G.DeviSuryaPrabha , G.VenkataDurgaRao (International Journal of Research in Computer and Communication Technology, Vol 3, Issue 1, January- 2014.

[3] Authentication of Currency Notes through Printing Technique Verification: Ankush Roy, Biswajit Halder, Utpal Garain

[4] Gonzalez, R. C. , and Woods, R. E. 2002. Digital image processing (2nd edition). Prentice Hall

[5] S Jayaraman, S Esakkirajan, T, Veerakumar, Third Reprint 2010, Digital Image Processing.

[6] INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY A Study on Diverse Recognition Techniques for Indian Currency Note, Ms.Rumi Ghosh, Mr Rakesh Khare

[7] Digital Image Processing by Sanjay Sharma.

[8] https://en.wikipedia.org/wiki/Peak_signal-to-noise_ratio

[9] Image Quality Assessment: From Error Visibility to Structural Similarity, Zhou Wang, *Member, IEEE*, Alan Conrad Bovik, *Fellow, IEEE*, Hamid Rahim Sheikh, *Student Member, IEEE*, and Eero P. Simoncelli, *Senior Member, IEEE*

[10] Image Quality Assessment Based on a Degradation Model Niranjan Damera-Venkata, *Student Member, IEEE*, Thomas D. Kite, Wilson S. Geisler, Brian L. Evans, *Senior Member, IEEE*, and Alan C. Bovik, *Fellow, IEEE*

[11] C.H. Lampert, L. Mei, and T.M. Breuel, "Printing Technique Classification for Document Counterfeit Detection," in Proc. of

Int. Conf. on Computational Intelligence and Security, pp. 639-644, China, 2006.
[12]http://www.rbi.org.in/currency/Security Features.html

Author Profile

Mr. Rajarshi Paul received Degree of Master of Computer Application in 2008 from North Eastern Regional Institute of Management, Guwahati, Assam, India.
Currently a final year student of Master of Technology(Information Technology) in the Institute of Science and Technology, Gauhati University. He has worked on web applications having security features for private companies earlier.

Dr. Sanjib Kr. Kalita is an Assistant Professor in the Department of Computer Science, Gauhati University, Assam, India. Dr. Kalita has previously worked at various Government Colleges and Universities. He was the head of the dept. of Computer Science, Handique Girls' College, Guwahati(2002-09). He headed the dept. of Computer Science, Gauhati University, Kokrajhar campus (presently Bodoland University) (2009-12). He has earned his PhD degree from Gauhati University in speech processing. He has authored over thirty peer-reviewed articles, and one book.