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Brightness Preserving Bi-Histogram Equalization for Preprocessing in Counterfeit Indian Currency Notes Detection

Fathima Hibath Sudheer[1], Dr. Priya S[2], Mr. Sreekumar K[3]

[1]Mtech Student in Image Processing, Model Engineering College, Thrikkakara, Kochi, India
[2]Professor, Dept. of Computer Engineering, Model Engineering College, Thrikkakara, Kochi, India
[3]Assistant Professor, Department of Computer Engineering, Model Engineering College, Thrikkakara, Kochi, India

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Abstract – *The rise of color printing technology has increased the rate of fake currency note printing of identical notes on a very large scale. Few years back, Indian government has announced the demonetization of all Rs 500 and Rs 1000, in reserve bank notes of Mahatma Gandhi series. Indian government has introduced a new Rs 500 and Rs 2000, to reduce illegitimate activity in India. Even then the new notes of counterfeit or bogus currency are distributed in the society. The main purpose of this work is to identify counterfeit currencies among the real. From the currency, the strip lines or continuous lines are detected from real and counterfeit note by using edge detection techniques. LAB techniques are used to saturate the value of an input image. This proposed system focuses on pre-processing stage of the Counterfeit Indian Currency Notes Detection which includes image adjustment, image filtering using bilateral filter, image smoothening using Brightness Preserving Bi-Histogram Equalization (BBHE) and converting RGB image to LAB color space image.*

Key Words: **Counterfeit Banknote Detection Methods, Digital Image Processing Method, Image adjustment, Image filtering, Smoothening and RGB to LAB conversion.**

1. INTRODUCTION

Research areas for currency are banknote recognition, counterfeit banknote detection, serial number recognition, and fitness classification shown in Figure: 1.

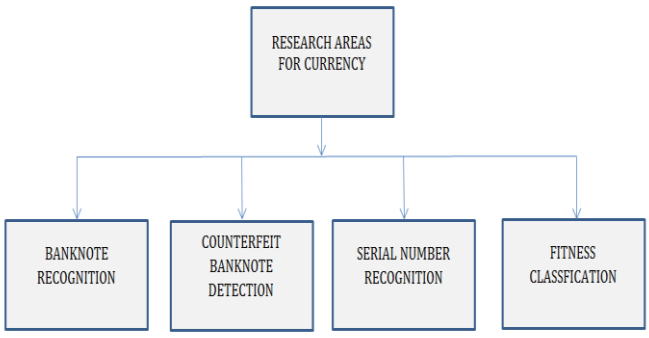

Figure 1: Research areas for currency.

Banknote recognition generally concerns with the classification of banknotes by denomination, i.e., the currency amount of a note of a specific country. This classification can also enable recognition of the year of printing and input direction of the classified denomination. In some studies, the scope of recognition is extended to the simultaneous recognition of two or more Indian currencies.

Counterfeit banknote detection generally concerns with the methods for distinguishing between genuine and fake notes.

Banknote serial number is the unique alphanumerical identifier engraved on each banknote in the banknote production process. It contains the name of the issuing bank and the serial information of each denomination. All banknotes have its own idiomatic serial number and it can be used to outline its source and circulation route and can thus be efficiently used to identify counterfeit banknotes.

Fitness classification of the banknotes generally concerns the methods for classifying banknotes according to their physical conditions, such as soiling. Banknotes of same denomination may exhibit fit or unfit conditions, which include soiling and creases, depending on circulation intensity and climate conditions. In order to conserve the robustness of banknotes in circulation, automated self-service terminals, such as ATMs, need to be equipped with a fitness classification function to sort out and retrieve unfit banknotes. Retrieving the unfit banknotes is also necessary for preventing banknote classification errors.

Within research areas, this work concentrates on Counterfeit banknote detection. For the last few years, as a result of the great technological advancement in color printing, duplicating and scanning, counterfeiting problems have become more serious. In the past, only the printing house has the ability to make a counterfeit note, but today it is possible for any person to print counterfeit bank notes simply by using a computer and a laser printer at the home. Therefore the issue of efficiently verifying counterfeit banknotes from real ones via automatic machines has become more important. Counterfeit notes are the problem of almost every country but India has been hit really hard and has become a very acute problem. There is a need to design the system that will helpful for

the recognition of paper currency notes with fast speed and in less time.

The Indian government announced the new rules to eliminate the bogus currency. The Reserve Bank of India is the only one that has the full authority to issue banknotes. There is no proper way to deal with them for a common person; the common person is also prey to this currency. Some of the effects that the bogus money has on society include a reduction in the value of substantial money and inflation due to more artificial money getting circulated in the society or the economy, and which in turn dampen our economy and growth. Then the decrease in the acceptability of paper money occurs. These are several techniques used by Reserve Bank of India to identify artificial currency.

In every year, Reserve Bank of India faces the counterfeit currency notes or destroyed notes. Handling of the large volume of counterfeit notes imposes additional problems. Therefore, involving machines with the assistance to the human experts makes notes identification process simpler and efficient. For the detection of forged notes, it needs to identify the denomination every time they use the device which consists of ultraviolet light. The bank employees keep the fake paper currency note on the device and try to find whether the watermark identification, serial number and other characteristics of the notes are proper to check its authentication.

2. RELATED WORKS

B.Sai Prasanthi, D. Rajesh Setty "Indian Paper Currency Authentication System using Image processing"[1].In this article, the authentication of Indian paper currency is described by applying image processing techniques. Generally, six features are extracted including identification mark, security thread, watermark, numeral, floral design, micro lettering from the image of the currency. The process begins with image acquisition and ends at a comparison of features. The system designed is a low-cost system. The system extracts the features even the note has scribblings on it. Also, the system will extracts features even the test image sizes are different when compared to the reference image.

Rubeena Mirza, Vinti Nanda"Design and Implementation of Indian Paper Currency Authentication System Based on Feature Extraction by Edge Based Segmentation Using Sobel Operator"[2].In this paper, the authentication of Indian paper currency is described by applying various image processing techniques. Generally, three features are extracted including identification mark, security thread, and watermark from the image of the currency. The process begins with image acquisition and ends at a comparison of features. The features are extracted using edge-based segmentation by Sobel operator and work well in the whole process with less computation time. The complete methodology works for the Indian denomination 100, 500 and 1000. The method is very simple and easy to implement. If the hardware part of image acquisition is designed then it surely helps us to minimize the problem of counterfeiting currency.

Sandeep Kaur, Seema Baghla, Sunil Kumar"Enhancement of Sift algorithm to check the authenticity of Indian Currency"[3]. SIFT algorithm has been used to analyze the external features of an image by various researchers in the past. The currency detection is the application of image analysis, in which the SIFT algorithm along with the nearest neighbor classifier has been applied to analyze external features of the checking the originality of currency notes. In the present work, a method using the SIFT algorithm with Bayesian classifier and DWT has been proposed for checking the originality of currency notes. The value of Peak signal to noise ratio (PSNR), root mean square error (RMSE), fault detection rate (FDR) and accuracy values of the proposed and existing algorithm (SIFT algorithm with nearest neighbor classifier) are compared to validate the proposed system. The results confirmed that the proposed technique is better as compared to the existing technique for checking the originality of the currency notes.

Deepak M. P, Prajwala N. B "Identification of Fake Notes and Denomination Recognition"[4]. The Indian currency system has different denominations that are unique in one feature or the other. These features are color, size or some identification marks, etc. This system recognizes and transforms the framework in order to diminish human energy, and to consequently perceive the measure of the money esteem and to change over it to different monetary forms without human supervision. Our proposed work differentiates white paper and the currency, by detecting colors of different currencies. We have used a feature extraction mechanism to identify various identification patterns and also the denominations in the currency. As our intention to achieve a simple however productive calculation that would be helpful for the most extreme number of monetary standards, using MatLab, we have developed an efficient system for the monetary standards 10,20,50,100,500 and 2000 which produces 98.8 accuracies.

Prashant Dhar, Md. Burhan Uddin Chowdhury, Tonoy Biswas "Paper Currency Detection System Based on Combined SURF and LBP Features"[5].Proposed a new paper currency detection system for Bangladeshi paper currency using combined SURF and LBP features. The prediction is made by SVM classifier. SVM performs very well in this case. Paper currency detection is a vital application for surveillance systems. Very few works have been done on this application. Here we proposed a new method to detect paper currency. We considered only paper currencies of Bangladesh. It is quite a challenging task to detect currency in different positions from

different environments. This proposed system can detect currency in rotated positions also. This proposed system can also calculate the total amount of currency that exists in an image. We achieved an overall accuracy of 92.6we will try to improve the performance for the rotated position of currency. We will focus on folding notes and overlapped notes. We will try to consider all possible sorts of notes. Moreover, we should investigate with other local or global features so as to improve performance better.

Navya Krishna G, Sai Pooja G, Naga Sri Ram B, Yamini Radha V, Rajarajeswari P "Recognition of Fake Currency Note using Convolutional Neural Networks"[6].In this paper, proposed a model which demonstrates the feasibility of using CNN with the VGG 16 architecture. Although the generated data set was small and did not represent the real-world scenario of counterfeit currency data-set, it was very helpful throughout the experiment. The process of detection of fake notes is quick and easy under the trained model. By this, we can also assure that under real and large data set, the model AFCRS can be well-trained and also provides accurate results, which can help the people in recognizing the currency note whether it is counterfeit or original. Future research may include the deployment of the model in smartphones as an application and make society and people more comfortable in recognizing counterfeit currency. This model can also be compared with various architectures of CNN which may have a low error rate than the present model and can be combined by applying image pre-processing techniques like and edge-detection to crop the currency note out of an image which will present better results.

Fumiaki Takeda and Sigeru Omatu" High Speed Paper Currency Recognition by Neural Networks"[7]. In this paper, we have applied NN to paper currency recognition and showed the effectiveness compared with a conventional manual method. Furthermore, we have proposed a structure reduction method of the NN using random masks and showed its effectiveness for time series data and its Fourier power spectra. Finally, we also introduced a new evaluation method for reliability and showed its effectiveness using real data. We expect that the present method will promote compactness, high-speed transaction, and low cost of paper currency recognition machines.

Gouri Sanjay Tele, Akshay Prakash Kathalkar, Sneha Mahakalkar, Bharat Sahoo, Vaishnavi Dhamane "Detection of Fake Indian Currency"[8].In this paper, a technique for verifying Indian paper currency. The approach gives an efficient method for fake currency detection based on physical appearance. The work will surely be very useful for minimizing the counterfeit currency. Through this application, we are able to see the missing parameters which the fake note doesn't have as compared to the original notes. Original Currency is being detected using the Image Processing Technique.

3. COUNTERFEIT BANKNOTE DETECTION

3.1 Counterfeit Banknote Detection Methods:

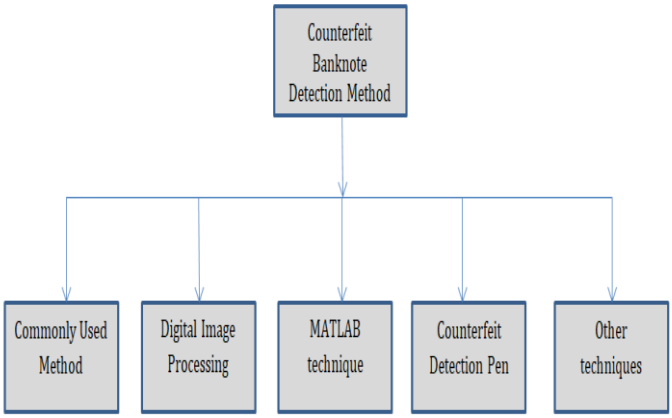

Figure 2: Counterfeit banknote detection methods

A. Commonly Used Method for Detecting Fake Currency

1. See-through Register

The small floral design printed on both front (hollow) and back (filled up) of the note in the middle of the vertical band next to the Watermark has an accurate back to back registration. The design will appear as the floral design when seen against the light.

2. Watermarking

The Mahatma Gandhi Series of the banknotes include the Mahatma Gandhi watermark with a light and shade effect and multi-directional lines in the watermark window.

3. Fluorescence

Number panels of the notes are printed in the fluorescent ink. The notes also have optical fibers. Both can be seen when the notes are exposed to the ultra-violet lamp.

4. Security Thread

The Rs.500 and Rs.100 notes have a security thread with the similar visible features and inscription "Bharat" (in Hindi), and "RBI". When held against the light, the security thread on Rs.2000, Rs.500 and Rs.100 can be seen as one continuous line. The Rs.5, Rs.10, Rs.20, and Rs.50 notes contain a readable, fully embedded windowed security thread with inscription "Bharat" (in Hindi), and "RBI". The security thread appears on the left of the Mahatma's portrait.

5. Intaglio Printing

The portrait of Mahatma Gandhi, the Reserve Bank seal, guarantee and promise clause, Ashoka Pillar Emblem on the left, RBI Governor's signature is printed on intaglio i.e. in raised prints, which can feel by touch, in Rs. 20, Rs. 50, Rs. 100, Rs.500 and Rs.2000 notes.

6. Latent image

On the opposite side of Rs.2000, Rs.500, Rs.100, Rs.50 and Rs.20 notes, a vertical band on the right side of the Mahatma Gandhi's portrait contains a latent image showing the respective denominational value in the numeral. The latent image is apparent only when the note is held horizontally at eye level.

7. Micro lettering

This feature sees between the vertical band and Mahatma Gandhi portrait. It always contains the word "RBI" in Rs.5 and Rs.10. The notes of Rs.20 and above also hold the denominational value of the notes in micro letters. This feature can see well under a magnifying glass.

8. Identification Mark

Each note has a unique mark. A special feature in intaglio has been presented on the left of the watermark window on all notes except Rs.10/- note. This feature is in different shapes for different denominations (Rs.20-Vertical Rectangle, Rs.50- Square, Rs.100-Triangle, Rs.500-Circle, and Rs.1000- Diamond) and helps the visually impaired to identify the denomination.

9. Optically Variable Ink

This is a new feature included in the Rs.2000 and Rs.500 notes with revised color scheme. The numeral 2000 and 500 on the opposite of Rs.2000 and Rs.500 notes respectively are printed in optically variable ink viz., a color-shifting ink. The color of the numeral 2000/500 appears green when the note is held flat but would change to blue when the note is held at an angle.

B. Digital Image Processing Method for Detecting counterfeit Currency.

Design flow of the counterfeit currency detection system includes eight stages: Image acquisition, pre-processing, gray scale conversion, edge detection, image segmentation, feature extraction, comparison and output [9]. This system works on two images, one is testing currency image on which authentication is to performed and the other is the original currency image.

1. Image Acquisition

There are various ways to acquire images such as with the help of a camera or scanner. The acquired image should retain all the features [9].

2. Pre-Processing

Pre-processing of the image is those operations that are normally required prior to the main data analysis and extraction of information. The aim of image pre-processing is to suppress undesired distortions or to enhance some image features that are important for further processing or to analysis. It includes:

2.1 Image Adjusting

When we get the image from a scanner, the size of the image is too big. In order to reduce the calculation, we decrease the size of the image. Image Adjusting is done by using image interpolation. Interpolation is the technique mostly used for tasks such as zooming, rotating, shrinking, and geometric corrections.

2.2 Image smoothening

While using a camera or a scanner and perform image transfers, some noise will appear on the image. Image noise is the random variation of the brightness in images. Removing the noise is a major step when image processing is being performed. Although, noise may affect segmentation and pattern matching. When performing the smoothing process on a pixel, the neighbor of the pixel is used to do some transforming. After that, the new value of the pixel is created. The neighbor of the pixel is consisting of some other pixels and they build up a matrix, the size of the matrix is an odd number, the target pixel is located on the middle of the matrix. Convolution is used to perform image smoothing. Image smoothening can also be done with the help of a median filter which gives more effective than convolution when the goal is to simultaneously reduce the noise preserving edges. The median filter replaces a pixel via the median pixel of all the neighborhoods [9].

3. Gray-scale conversion

The image acquired is in RGB color. It 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) [1].

4. Edge detection

Edge detection is an essential technique in image processing and computer vision, particularly in the areas of feature detection and feature extraction, which aims at identifying points in a digital image at which the image brightness alters sharply or, more formally, has

discontinuities. Edge detection is one of the major steps in image processing, image analysis, image pattern recognition, and computer vision techniques [8].

5. Image segmentation

Image segmentation sub divides the image into its component regions or objects. A level to which sub division is carried depends on problem being solved. Segmentation algorithm for monochrome images generally based on one of the two basic properties of image intensity values:

- Discontinuity
- Similarity.

The approach in the first category 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 according to a set of predefined criteria [8].

6. Feature Extraction

In pattern recognition and in image processing, feature extraction is the special form of dimensionality reduction method. This method captures the visual content of images for indexing and retrieval. If input data to an algorithm is too large to be processed and it is assumed to be notoriously redundant (much data but not much information) then the input data will be converted into a reduced representation set of features (also named feature vector). If attributes are extracted are chosen carefully, it is expected that the attributes set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of using the full-size input. Feature extraction involves simplifying the number of resources required to describe the large set of data.

Visual attributes of images are of two types:

- Domain-specific attributes include fingerprints, human faces.
- General attributes include color, texture, and shape.

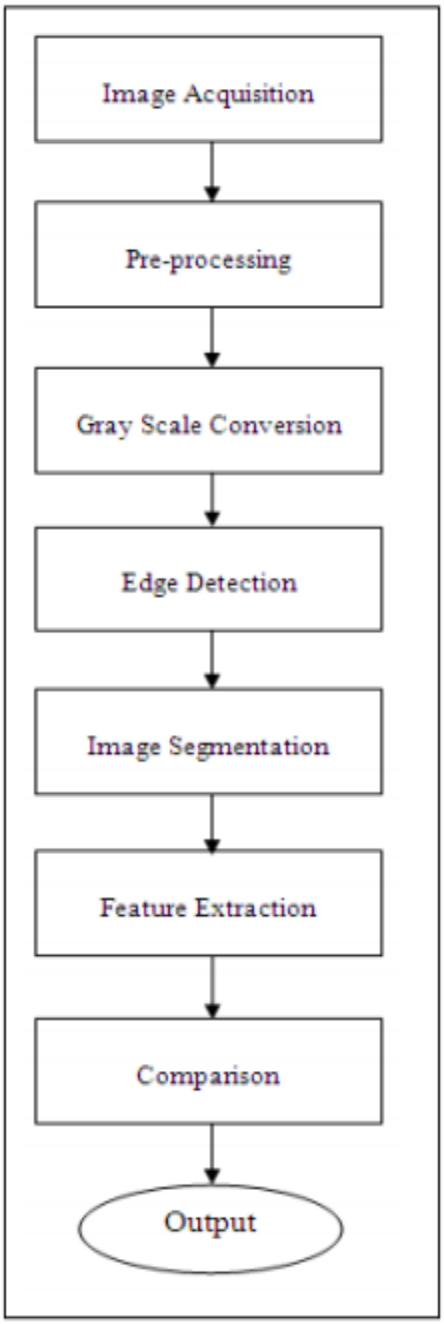

Figure 2: Flow Chart of Digital Image Processing Method to Detect Fake Notes.

There are two types of attributes distinguish under the shape attribute extraction:

- Global attributes include moment invariant, aspect ratio and circularity.
- Local attributes include boundary segments [1].

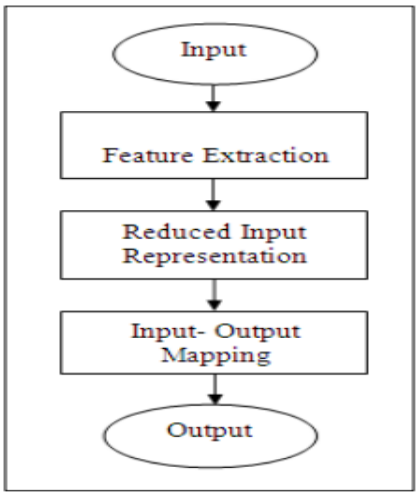

Figure 3: Feature Extraction Approach

7. Comparison

Finally, the extracted features of test currency image are compared with the extracted features of the original currency image, if it matches then the currency is original otherwise fake [1].

C. MATLAB technique:

In this technique, one can split red, blue, green components of a picture and name them as r1, g1, b1 which correspond to image i.e. original currency note. Consider the second image that is noted to be tested. Split this image to components r2, b2, g2. Construct a new image with components as r1, g2, b1 or r2, g1, b1 or b2, g1, b1. But r1,g2,b1 combination is most preferred because the human eye is sensitive to green component and most of our images contain maximum green component so that our output image will be much easier to identify counterfeit note more effectively. After that compare newly constructed images with image1. Calculate the threshold value of equivalence by calculating the standard deviation. If equivalence is above 40% then one can consider it as an original note. Here consider 40% of the value because note may be damaged. Parameters for a measure of comparing images are Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR in dB), and structural Content (SC). When combining two various components of two images then if a note to be tested is original then only at the place of a number we get variation. But in case of fake note after applying the same code, one can observe that the image overlapping is not done correctly. One can also see that the resultant image is blurred indicating fake note. So one can confirm that it is a fake note [12].

D. Counterfeit Detection Pen:

A counterfeit pen is simply an inexpensive device that is designed to determine if a currency note is original or fake. The pen includes a tincture of iodine as ink which, when drawn over a note, will remain amber or brown. According to the manufacturer, the ink will turn black if the note is fake.

1. Working of counterfeit pen:

The iodine in the pen respond with starch, which is the primary component that makes a white paper look brighter. Most corporate paper, made from wood pulp, is brown unless bleached and starched. If there is no presence of starch in the paper then the pen will indicate - by remaining amber- that the note is original.

2. How counterfeiters defeat this pen:

The iodine in the pen respond with starch that makes white paper look brighter. Most unless bleached and starched. If there is no starch present in the paper then the pen will indicate – by remaining amber - that the note is original [12].

E. Other techniques:

Another anti-counterfeit device for the money is an Ultraviolet counterfeit detection scanner. Best used in the highly lit point of sale locations, the UV detector identifies ultraviolet security features present in most currencies. By simply placing the note in the detector, counterfeit currency is immediately identified, without the need for an employee to closely examine the note [12].

These are the different techniques for counterfeit banknote detection. The most efficient technique is digital image processing method.

4. PROPOSED SYSTEM

The steps involved in Image Enhancement for Fake Indian Currency Notes Detection are shown in figure 4.

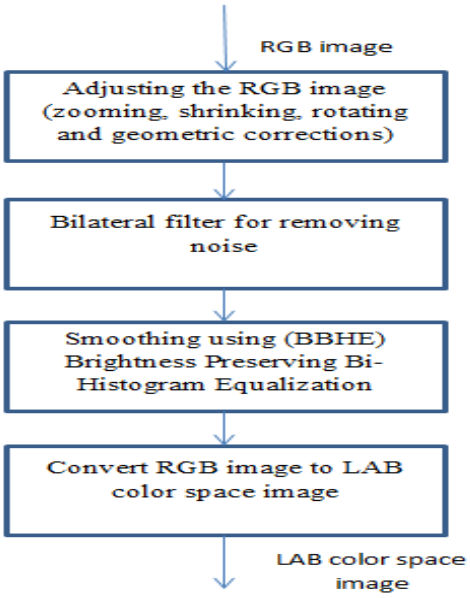

Figure 4: Block diagram for proposed system.

4.1 Input Image:

In this first stage of any vision system is the input image stage. After the image has been obtained, the various methods of processing can be applied to the image to perform many different tasks. Performing input images in image processing is always the first step in the workflow sequence because, without an image, no processing is possible. There are various techniques to acquire images such as with the help of a camera or scanner. The input image should retain all the features. Here input image is the RGB image of currency taken under the UV light.

4.2 Image Adjustment:

Image Adjusting is one of the most pre-processing techniques, which is done with the help of image interpolation. Interpolation is the technique widely used for tasks such as zooming, rotating, shrinking, and geometric corrections. Removing the noise is a major step when image processing is being performed. However, the noise may affect segmentation and pattern matching. When performing the smoothing process on a pixel, the neighbor of the pixel is used to do some transforming. After that, a new value of the pixel is created [13].

4.3 Image Filtering:

In this system, filtering is done for removing noise. Here the bilateral filter is used for noise removal. It is a non-linear, edge-preserving and noise-reducing smoothing filter for images. It substitutes the intensity of each pixel with the weighted average of intensity values from the nearby pixels. This weight can be based on Gaussian distribution. Crucially, the weights depend not only on Euclidean distance of the pixels but also on the radiometric differences (e.g., range differences, such as color intensity, depth distance, etc.). This preserves the sharp edges.

4.4 Image Smoothening:

Smoothening is done using Brightness Preserving Bi-Histogram Equalization (BBHE). BBHE firstly decomposes an image into two sub-images based on the mean of the input images. One of the sub-images is the set of samples less than or equal to the mean whereas the other one is the set of samples greater than the mean. Then the BBHE equalizes the sub-images independently based on their respective histograms with the constraint that the samples in the formal set are mapped into the ranges from the minimum gray level to the input mean and the samples in the latter set are mapped into the ranges from the mean to the maximum gray level. In other words, one of the sub-images is equalized over the range up to the mean, based on the respective histogram. Thus, resulting equalized sub-images are bounded by each other around the input mean, which has an effect of preserving mean brightness.

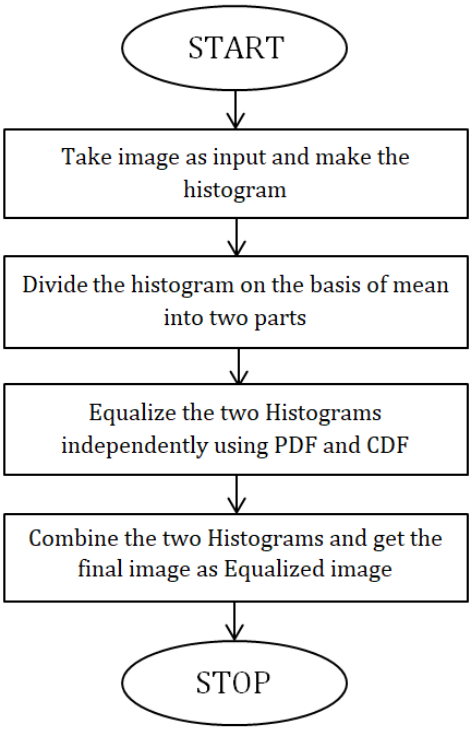

Figure 5: BBHE algorithm

4.5 RGB to LAB Color Space Conversion:

The next implementation in the proposed method is to convert the RGB color space to L*a*b* color space. For this proposed work L*a*b* color space is selected which is a homogeneous space for visual perception. The difference between the two points in the L*a*b* color space is the same as the human visual system. Since the L*a*b* model is a three-dimensional model, it can only be represented properly in three-dimensional space [14] - [2]. The solution to convert digital images from the RGB space to the L*a*b* color space is given by the following formula [14].

$$\begin{bmatrix} L^* = 116\, f(Y/Y_n) - 16 \\ a^* = 500[f(X/X_n) - f(Y/Y_n)] \\ b^* = 200[f(Y/Y_n) - f(Z/Z_n)] \end{bmatrix}$$

X, Y, Z, Xn, Yn, and Zn are coordinates of CIEXYZ Color space. The solution to convert the digital images from the RGB space to the CIEXYZ color space is the following formula.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.608 & 0.174 & 0.201 \\ 0.299 & 0.587 & 0.114 \\ 0.000 & 0.066 & 1.117 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Xn, Yn, and Zn respectively correspond to the white value of the parameter.

$$F(x) = \begin{cases} X^{1/3} & x>0.008856 \\ 7.787x+16/116 & x<= 0.008856 \end{cases}$$

Color space conversion is translation of the representation of a color from one basis to another. This typically occurs in context of converting an image that is represented in one color space to another color space.

5. EXPERIMENTAL RESULTS

In this project, the RGB image of currency note is given as input image and various preprocessing methods has been applied such as Bilateral filtering , Brightness Preserving Bi-Histogram Equalization (BBHE) and then converted equalized image to LAB color space.

Figure 6: Noise removal using bilateral filtering

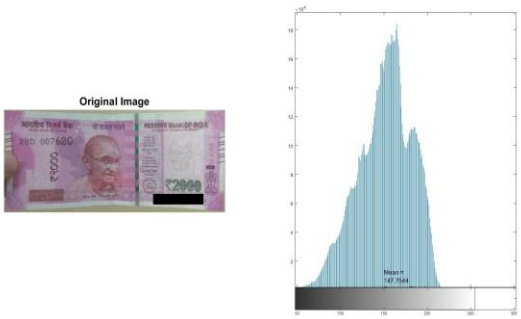

Figure 7: Histogram Equalization.

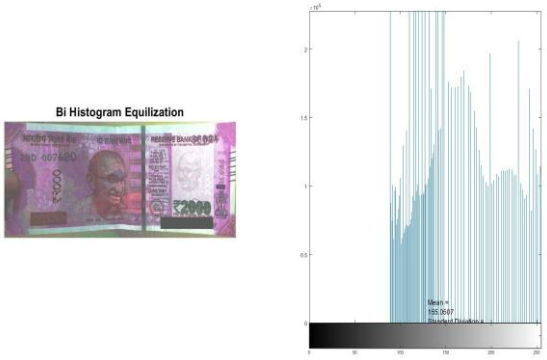

Figure 8: Brightness Preserving Bi-Histogram Equalization

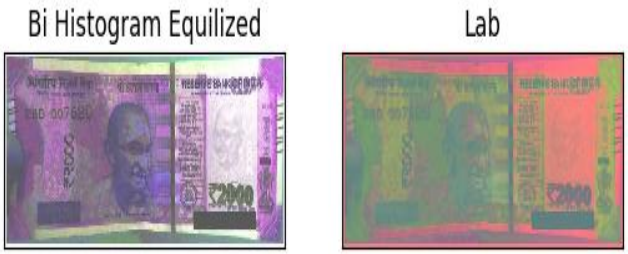

Figure 9: Converting equalized RGB image to LAB color space.

6. CONCLUSION

Pre-processing is a necessary step in any computer vision system, which includes extraction of information from the RGB image taken under UV light. According to the requirement, various different pre-processing techniques are used and developed. In this proposed work, we use different pre-processing methods such as image adjustment, image filtering using the bilateral filter, image smoothening using Brightness Preserving Bi-Histogram Equalization (BBHE) and converting RGB image to LAB color space image. This system provides better performance for processing than the existing method.

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