



Image Processing Technique for Authentication of Indian Paper Currency

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Article History	Abstract
Received: 06 June 2023 Revised: 05 Sept 2023 Accepted: 30 Nov 2023	<p>As we all know day by day the technology is getting better and better, the production of counterfeit currency has been rapidly increasing. The counterfeit currency problem is faced by almost all countries. Since the real economy is affected, it has affected the economy of the country. Even when the drastic step of demonetization was taken in 2016 to overcome counterfeit currency, this problem did not end. The only one solution for this problem for a common man is to detect the fake currency, by using the fake currency detector machine. These machines are used in banks and large scale business, but for small scale businesses or for a common man these machines are not affordable. There are lot of researches taking place on this matter by using deep learning, image processing and machine learning techniques. This paper gives the complete methodology of fake note detector machine, which is affordable even for a common man. By implementing the applications of image processing techniques we can find out whether the currency notes are fake or not. Image processing technique consists of a number of operations that can be performed on an image, some of which include image segmentation, edge detection, gray scale conversion, pre-processing etc. The proposed system will detect the counterfeit currency of new denominations by distinguishing each denomination based on its size and depending on the features of each currency the comparison takes place. Based on the features matched, it detects whether the currency is counterfeit or not. The system have advantages like simplicity, reliability and cost effective. Which is affordable by a common man since the common man is the one who will be effected most, when the counterfeit currency are circulated in the market because he has to pay the real value of that currency.</p>
CC License CC-BY-NC-SA 4.0	Keywords: Segmentation, Edge Detection, Feature Extraction, Grayscale Conversion, Pre-Processing

1. Introduction

According to the statistics given by fraud monitoring report which was submitted by various banks they have lost Rs.16,789 crores by fraud. The growth of terrorism is influenced by the increase of fake currency. Now due to the advanced technology and use of laser printer, the fake currency are printed with very high accuracy. Few years ago print houses were used to print the currencies. According to the Crime Investigation Department (CID) even if the notes are printed with high accuracy they can be detected. There is a great need of an fake currency detector machine which is the solution for this problem. This machine will be helpful for common man to know whether currency is fake or not. They are reliable, cost effective and gives better accuracy. Considering the overall scenarios to preserve the value of the original currency, fake currency detector is required for the common man. This paper gives the view of how the image processing techniques are used to detect the fake currency. Complete methodology is described which contains different operations. In order to get the enhanced version of captured image, different operations are performed on the image which is called image processing technique. There are two ways to process the image one is by analog image processing and another is by digital image processing technique. To get the photographs, printouts and banner analog image processing technique is used i.e., to get the hard copy of image. Whereas in the digital image processing technique various algorithms are used to manipulate the image[1]. There are several stages of digital image processing which includes image acquisition, image enhancement, image

restoration, color image processing, wavelets and multiresolution processing, compression, morphological processing, object recognition, segmentation, description and representation[1]. The outcome of result depends on methodology considered, so it may be obtained in any of these steps. As complexity increases the total number of steps increases. In this project we are detecting and processing the image using software tool called OpenCV along with the python programming language. Along with the software tools some of the hardware tools are used which is 8MP raspberry Pi, camera, raspberry Pi 3 B+, box setup and lights. The methodology we have implemented is different from other image processing techniques used to detect fake currency, is we are calculating the white pixels from the features and based on that, the comparison is taken place. The white pixels value changes depending upon the amount of light present in the box, therefore we had to make sure the setup box should be fully covered.

Related Work

The working staffs in the bank are trained to detect the fake currency, but always these notes would not come to bank, instead they were circulated in the market from one person to another. The common man who doesn't even know the money he is carrying is original or fake, and then he just passes it on wherever he goes. In case if he goes to bank, he has to pay the huge loss. In order to solve these problem various machines are been implemented using different techniques. Here MATLAB is used for processing and detecting. The machine is implemented to which the camera is mounted on the top of it and note is scanned using it. Then based on the character recognition, the segmentation of image is carried out and result are obtained [2].

It is not possible to predict whether the currency is fake or not just by looking at it due to high level printing technologies and scanning. Manually trying to find out the difference in features is very difficult and it is time consuming. Automated process is required when it comes to detect large number of notes. Therefore the author here has implemented fake currency detector machine using MATLAB techniques and features are extracted by HSV color space [3]. If the counterfeit currency is distributed all over the market, and they are circulated in the hands of common man, and he goes to the bank unknowingly and money is detected to be fake then he has pay the value of real economy. He has to pay the loss. In this paper the author used MATLAB software to detect. The image to be processed is captured and then its red, green and blue components are split. The RGB components of testing image and original image is compared considering 40% liberality. [4].

The different countries have different currencies. Therefore it is difficult to distinguish between the fake and original. The software used is MATLAB. In this technique the first step is to identify the currency. Then the currency is converted to gray scale. Threshold considered here is 30%. Later the image is converted into binary image and total number of objects are counted for comparison. [5]. The counterfeit currency problem is the problem around world. The comparison of testing currency with original currency is done in order to detect whether currency is fake or not. The image is captured and sent for further processing, here smoothening is done using gaussian filter. Direction and magnitude gradient are measured. Non-maxima suppression is carried out and edges are detected by canny algorithm. The result is determined by comparing the characteristics of original and fake currency. [6]. Before analyzing the image the basic step is to capture the image. This step is called image acquisition which is dependent purely on hardware based device, which captures the light energy reflected back from the object. The light energy is converted into electrons in form of 2D array of cells in the internal sensor chip. These charges are converted into digital or analog based on the processing requirements [7].



Figure 1: Illustrates the Indian currency of Rs. 2000

A. Identification Mark

Identification mark is present above the Ashoka's pillar emblem only in denomination above 100, in different shapes in different currency as shown in Fig. 1 (d).

Features Considered

There are lots of security features in Indian currency if we consider them. But we have selected some features among them for further processing. To distinguish the original currency from the fake currency, the features are for benefit of public as well as general. The dimensions of each currency are different. The smallest currency is 1 rupee and the largest is 2000 rupees. As the dimensions increases the features also increases, therefore 2000 rupees have the highest number of features. Every currency differs in color also. Rupee one has pink and green color shades, rupee 10 is chocolate brown, rupee 20 is in fluorescent green,

rupee 50 is in fluorescent blue, rupee 100 is lavender in color, rupee 200 is in orange color, rupee 500 is in grey color and 2000 is in magenta color. Below shown are the figures based on 2000 rupees. The various features considered are Ashoka pillar, portrait of Mahatma Gandhi at the center, security thread, denominational numeral with rupees symbol, guarantee clause, denomination numeral in Devanagari, identification mark, bleed lines, latent image of denomination numeral, see through register, Omron feature and micro lettering.

A. Portrait of Mahatma Gandhi at the Center

The intaglio printing of portrait of Mahatma Gandhi portrait is at the center of the currency, as shown in Fig. 1 (a).

B. Ashoka Pillar

The Ashoka pillar image is present at the right corner of currency, as shown in Fig. 1 (b).

C. Security Thread

The security thread has "RBI" and "Bharat" written continuously on it and this is present on the right side of Mahatma Gandhi portrait, when it is held against light. It is shown in Fig. 1 (c).

D. Guarantee Clause

Guarantee clause consists of promise clause with governor's signature printed in intaglio, which is present to the right side of Mahatma Gandhi portrait, it is as shown in Fig. 1 (e).



A. Denominational Numeral with Rupees Symbol

Denomination numeral with rupees symbol will be printed in fluorescent ink. The color of numerals change when held in different angles. This feature is as shown in Fig. 1 (f).

B. Denomination Numeral in Devanagari

The denomination numeral is in Devanagari script, present on the left side of Mahatma Gandhi portrait. The denomination numeral is as shown in Fig. 1 (g).

H. Bleed Lines

Bleed lines are present on both the sides of currency and are present only in denomination above 100. The bleed lines are as shown in Fig. 2(a).

I. See Through Register

The denomination is indicated by see through register. This is present on the both sides i.e., back and front. On one side its hollow shaped and on other side it is filled up. It is written in horizontal way and when viewed against light, it is seen as single design along the micro lettering. The design of see through register is shown in Fig. 2(b).

J. Latent Image of Denomination Numeral

There is vertical band on the other side of the currency at the right side of Mahatma Gandhi's portrait. The vertical band contains the latent image which has the value of particular denomination. The value of denomination is in the form of number. This feature cannot be seen directly, it is visible when the currency is held horizontally at the eye level. It cannot be seen in case of fake currency. The latent feature is as shown in the Fig. 2(c).

K. Micro Lettering

Micro Lettering is present between the Mahatma Gandhi portrait and vertical band. It contains the denominational value and word 'RBI' in micro letters. Micro letters are not printed in fake currency. as shown in Fig. 2(d).

L. Omron Feature

Omron feature is present on the left side just above the latent image of the currency. They are circle-shaped as shown in Fig. 2(e).

This feature is available only in 1 rupee currency. The feature 'Government of India' is printed on the top of the currency. The reason for this feature to be available only in 1 rupee is that the currency is issued by Government of India and rest of the currency are issued by Reserve Bank of India. Therefore the signature of the Finance Secretary is only present and not of Governor. It is shown in Fig. 2(f).



Figure 2: Showing the Indian currency of Rs. 2000

2. Materials And Methods

The data flow around the different components in this project are shown in Fig. 3 (a). Inside the box setup testing currency is placed. Since the different currencies have different dimensions, based on dimension the machine will identify the denomination. Processing of image is carried out in rest of the steps. The overall algorithm of proposed methodology is shown in Fig.3 (b). The first step in methodology is image acquisition, this is achieved using 8MP raspberry pi camera. Using python as programming language, the image is acquired with the help of OpenCV. Once the image is captured, then the image is processed under image segmentation step. The part of the image required for processing is acquired by detecting the edges using canny detection algorithm. Next the edge detected image is sent for extracting the features, here the relevant features are extracted from the image to be tested. The comparison step is carried out where the features of previously recorded image are compared with the extracted features of testing currency. White pixels are calculated and threshold is set, based on the threshold the result is obtained whether currency is fake or not. The basic and important step in image processing is image acquisition. In order to accomplish this step hardware setup is required i.e., the box is prepared which has no light passing through it, raspberry camera is mounted on the top of the box. Raspberry Pi controls the working of raspberry pi camera using a ribbon cable attached to the Camera Serial interface(CSI). Since the box is covered completely, the source of light is mounted inside to get clear image. There is opening at one end of the box from where the currency is placed inside the box. That opening can be closed once the currency is placed. Along with light source, Raspberry Pi 8MP camera is mounted on the top of the box. In order the Raspberry Pi to be worked 5V 2A power is supplied. Below Fig.16 shows the hardware modules with box setup.

3. Results and Discussion

The data flow around the different components in this project are shown in Fig. 3 (a). Inside the box setup testing currency is placed. Since the different currencies have different dimensions, based on dimension the machine will identify the denomination. Processing of image is carried out in rest of the steps. The overall algorithm of proposed methodology is shown in Fig.3 (b). The first step in methodology is image acquisition, this is achieved using 8MP raspberry pi camera. Using python as programming language, the image is acquired with the help of OpenCV. Once the image is captured, then the image is processed under image segmentation step. The part of the image required for processing is acquired by detecting the edges using canny detection algorithm. Next the edge detected image is sent for extracting the features, here the relevant features are extracted from the image to be tested. The comparison step is carried out where the features of previously recorded image are compared with the extracted features of testing currency. White pixels are calculated and threshold is set, based on the threshold the result is obtained whether currency is fake or not. The basic and important step in image processing is image acquisition. In order to accomplish this step hardware setup is required i.e., the box is prepared which has no light passing through it, raspberry camera is mounted on the top of the box. Raspberry Pi controls the working of raspberry pi camera using a ribbon cable attached to the Camera Serial interface(CSI). Since the box is covered completely, the source of light is mounted inside to get clear image. There is opening at one end of the box from where the currency is placed inside the box. That opening can be closed once the currency is placed. Along with light source, Raspberry Pi 8MP camera is mounted on the top of the box. In order the Raspberry Pi to be worked 5V 2A power is supplied. Below Fig.16 shows the hardware modules with box setup.

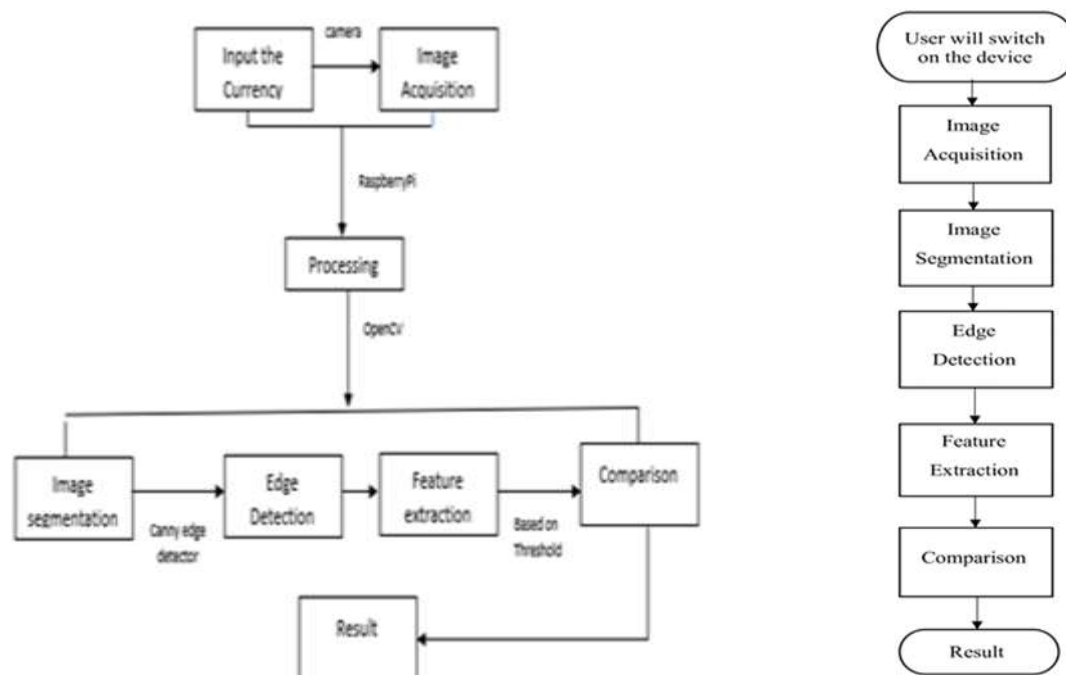


Figure 3: Illustrates the methodology

A. Image Acquisition

There are many means to acquire an image, such as scanners, sensors, cameras etc.[7]. Here we are using Raspberry Pi 8MP camera. The currency note in question is to be placed inside the box setup showed in Fig. 4(a). The image of the currency under the light is captured. This camera is controlled with the help of Raspberry Pi 3 B+ model that receives the commands from OpenCV. This is the basic and the most important step in image processing technique. Fig. 4(b) shows the result of image acquisition.



Figure 4: Illustrates the image acquisition and its result

B. Segmentation

In the image processing the most demanded and important process is image segmentation. The image is categorized based on same features into meaningful parts or pixels[8]. The pixels that are similar are grouped together with respect to some characteristics. The characteristics may include color, intensity or texture. To represent the image in more detailed and in more understandable way is the aim of image segmentation process.

Segmentation can be done in two ways: Global segmentation and local segmentation[8]. It can be categorized as similarity detection based approach and discontinuity detection based approach, grounded on the features of image. The contour of currency which is scanned is showed in Fig. 6. Below given are the four things that take place in image segmentation.

a) Detection of corner points

The captured image is loaded and then resized so that height is 500 pixels. Compared to larger image it is easy to process the smaller image. By using the shape function, original dimensions of the image that has to be tested is tracked. Then the image which is in the form of RGB is converted to greyscale. To remove high frequency noise, gaussian blurring is performed on greyscale image. Then operation of canny edge detection is carried out. Edge detected image is formed at the end of this step.

b) Finding the Contours

Since the Indian currency is in rectangular shape. we need to find out the four corners of the currency. Scanning is done by using simple heuristic. The rectangular region which is formed by four points

is the region that is required for further processing. After detecting the edges the region is formed. There are different functions like `cv.findContours()` (binary, `cv2.RETR_TREE`, `cv2.CHAIN_APPROX_SIMPLE`) function as showed in Fig.5 used in OpenCV for finding the contours. The points that are detected are based on the area in which smaller pixels are removed by keeping only the largest pixels. After looping and finding the pixels the largest area of rectangle is formed. This means the image of currency is found. To draw the contours of image, `cv.drawContours(img, contours, -1, (0,255,0), 3)`.

```
void cv::findContours ( InputOutputArray_<
                        OutputArrayOfArrays_<
                        OutputArray_<
                        int_<
                        int_<
                        Point_<
                        )
```

Figure 5: Illustrates different functions like `cv.findContours`

c) Draw the Edges

The width and height of the image is determined using the four corner pixels of the image. The width is calculated considering the largest distance from the right of bottom to left of the bottom(or top left to top right) which gives x coordinates. y coordinates are calculated considering the largest distance from right of top to the left of bottom(or from top left to bottom right). The corner four points of image are joined using the wrapping transform. The result of drawing the edge is shown in Fig. 6. Unfolding the edges $e=(v, w)$, weight is computed by using $\frac{\langle c, v-w \rangle}{|v-w|}$. Where v(vertices) and w are end points of e and $\langle \dots \rangle$ indicates inner products and c is the cut.

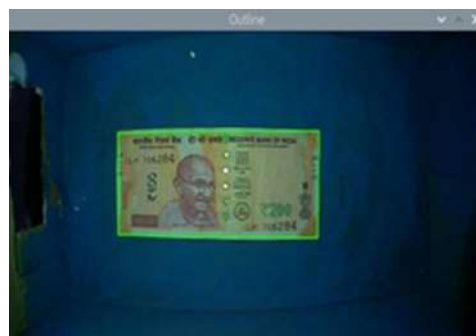


Figure 6: The contour (outline) representing the paper currency being scanned

d) Cropping

In the image segmentation the last step is cropping. The portion of image that is required for further processing is foreground image, which is separated from background image. In order to get the to-down view of image which was segmented perspective transform is applied.

Syntax: `image[start_x:end_x, start_y:end_y]`

The result of image segmentation is showed in Fig.7.



Figure 7: Segmented image of paper currency

C. Edge Detection

One among the image processing technique is edge detection. The boundaries within the image of object are determined by edge detection. Sobel operator, canny and prewitts are the several methods used for edge detection. We have used canny edge detection technique because the Indian currency is very detailed. The

comparative study of sobel, canny and prewitts operator are shown in Fig. 8 [9]. The canny edge detector consumes less time for execution, as in Table. I. Canny operator detects the edges by detaching the noise. Therefore we have come up with the conclusion of using canny edge detection for our methodology.

The one among powerful edge detection technique is considered as canny edge detection technique. There are many sub steps which comes under canny algorithm such as finding intensity gradient, noise reduction, hysteresis thresholding [9] and non-maximum suppression. Consider below the main 5 steps under canny algorithm:

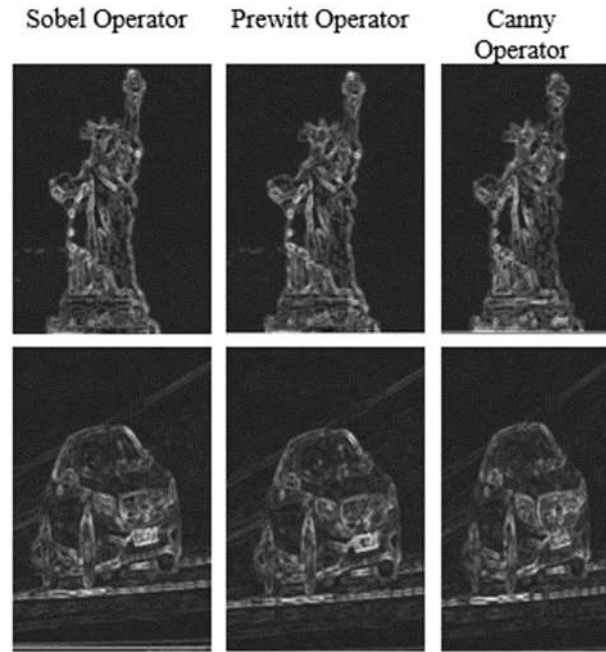


Figure 8: Results of comparison of canny, prewitt and sobel operator

Table 1: Time Taken For Execution

Algorithms	Time(in sec)
Sobel	34.90
Prewitt	34.85
Canny	34.30

1. 5x5 Gaussian filter as shown in Fig.9 is applied to get the smoothened image and also to reduce the noise.

The Gaussian filter equation $H_{ij} = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{(i-(k+1))^2 + (j-(k-1))^2}{2\sigma^2}\right); 1 \leq i, j \leq (2k+1)$. The intensity gradients of image are calculated using Sobel kernel which is applied in both vertical and horizontal directions. The equations $G = \sqrt{G_x^2 + G_y^2}$ and $\theta = \text{atan2}(G_y, G_x)$ for finding the intensity gradients. Application of non-maximum suppression is applied to dispose the spurious response to the edge detection.

$$B = \frac{1}{159} \begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix} * A$$

Figure 9: 5x5 Gaussian Filter

2. In the negative and positive gradient direction the pixels, edge strength is compared.

3.If the current pixels edge strength is largest compared to that of mask of other pixels in the same direction(for e.g., if pixel is considered in x-direction then that pixel will be compared with the pixels in the right and left direction in the horizontal axis), the value that is calculated is preserved. If the value is not calculated then the value is suppressed.

4. In order to find the potential edges of image Double Threshold is applied.

5. The final step is tracking the edges by hysteresis. The weak edges are suppressed by using this method. The condition must be seen that weak edges must not be connected to strong edges. Function used in OpenCV is cv2.Canny() to detect the edges. Fig. 10 shows the result of edge detection.



Figure 10: Result of canny edge detection

D. Feature Extraction

Based on the features of different currencies for the comparison purpose each features are extracted [10]. We consider total of 5 features for rupee 1, 7 features for rupees 10 and 20, 8 features for rupee 50, 11 features for rupees 100 and 200 and 12 features for rupees 500 and 2000 where at least the minimum number of features should match in order for that currency to be considered as original currency [11]. The minimum number of features that needs to be matched correctly are 3 for rupee 1, 5 for rupees 10,20 and 50, and 8 for rupees 100, 200, 500 and 2000 as tabulated in Table.II. The intensity of each feature is measured by counting the number of white pixels [12]. This is the important step because the detection of currency is completely grounded on it. countNonZero() function is used to count the pixel value.

Table 1: Features Considered For Each Currency

Features	1 Rupee	10 Rupee	20 Rupee	50 Rupee
Portrait of Mahatma Gandhi		✓	✓	✓
Ashoka Pillar		✓	✓	✓
Security thread		✓	✓	✓
Identification Mark				
Guarantee Clause	✓	✓	✓	✓
Denominational Numeral with Rupees Symbol	✓	✓	✓	✓
Denominational Numeral in Devanagari	✓	✓	✓	✓
Bleed Lines				
See through Register		✓	✓	✓
Latent Image of Denomination Numeral				
Micro lettering				
Omron Feature				✓
Government of India	✓			
Rupees in words	✓			

Table 2: Features Considered For Each Currency

Features	100 Rupee	200 Rupee	500 Rupee	2000 Rupee
Portrait of Mahatma Gandhi	✓	✓	✓	✓
Ashoka Pillar	✓	✓	✓	✓
Security thread	✓	✓	✓	✓
Identification Mark	✓	✓	✓	✓
Guarantee Clause	✓	✓	✓	✓
Denominational Numeral with Rupees Symbol	✓	✓	✓	✓
Denominational Numeral in Devanagari	✓	✓	✓	✓
Bleed Lines	✓	✓	✓	✓
See through Register	✓	✓	✓	✓
Latent Image of Denomination Numeral	✓	✓	✓	✓

Micro lettering	✓	✓	✓	✓
Omron Feature	✓	✓	✓	✓
Government of India				

E. Comparison

Comparison is the last step of this methodology, where the features of the original currency tested are compared with the testing currency [13]. The number of white pixels are calculated from the features and the count of white pixels are compared. White pixels are calculated using the function `countNonZero(InputArray src)`. Based on the white pixels threshold is calculated considering several currencies and the average is set [14]. Depending upon the threshold value, if the some features based on currency value matches then it concludes whether the currency is fake or not [15]. There are different number of features that we have considered for different currency.

$\sum_{i:src(i) \neq 0} 1$ For example if 10 notes of 200 rupees are considered the different values of white pixels are noted down as shown in Table.III. If the currency has 5 features then, even if 3 features out of 5 are matched it results in original currency. There will be a chance that currency is torn or it is dirty, in that case some 18% of liberty is given. Fig. 11(a) and Fig. 11(b) shows the flow diagram of comparison step.

Table 3: Threshold Value For Each Features Of 200 Rupees

Features	White pixel value(threshold)
Devanagari script	4600-7199
Security thread	11100-20128
Portrait of Mahatma Gandhi	34013-48862
See through register	313-1561
Guarantee clause	23216-37990
Rupees in symbol	7900-9580
Ashoka pillar	3802-7898
Omron feature	2900-4999
Latent image	990-2677
Bleed lines	510-1396
Identification mark	2000-3592

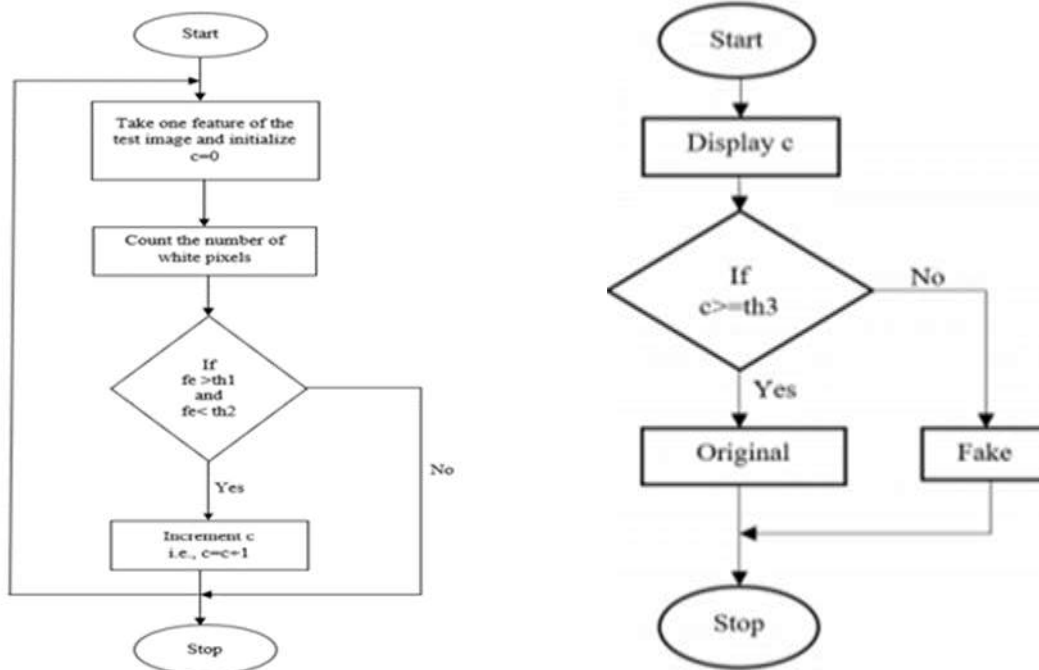


Figure 11: Showing the flow diagram of comparison step

The features are compared based on the intensities of the features (pixel count) [16-22]. The number of features are compared and based on the matched features, the result is obtained whether the currency is fake or not. We used 20 toy currencies (fake currency) and 25 original currencies, from the results we found that it gave 100% accuracy for fake currency and 92% accuracy with original currency, therefore the overall accuracy is 96%. Fig. 12, shows the results for the detection of currency. Accuracy rate = (No. of correct readings/Total No. of readings)*100 Accuracy rate = 96%.



```

pi@raspberrypi:~$ python test1.py
('count:: ', 163299)
('height ', 650)
('width ', 1442)
Fake two hundred rupee note
pi@raspberrypi:~$

```



```

pi@raspberrypi:~$ python test1.py
('count:: ', 158374)
('height ', 650)
('width ', 1446)
Rupees 200 detected
Checking for validity.....
original two hundred rupee note
pi@raspberrypi:~$
pi@raspberrypi:~$

```

Figure 12: Showing result saying whether the note is fake or original**4. Conclusion**

By using various image processing and other techniques like deep learning, machine learning we can verify whether the currency is fake or not. But we have come up with the image processing technique because the accuracy compared to other methods is good i.e., almost more than 90%. Whereas the accuracy of deep learning and machine learning has been up to 60-70%. Those who have used image processing techniques they have used MATLAB but we used OpenCV along with the python programming language. Based on the set of features that we considered for comparison the results of experiments are decided. The features included are see through register, identification marks, optical variable ink, security threads, currency color code, watermarks, micro lettering, latent image, Ashoka pillar and many more.

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