Indian Paper Currency Authentication System using Image processing

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ABSTRACT

Over the past few years, as a result of the great technological advances in color printing, duplicating and scanning, counterfeiting problems have become more and more serious. In the past, only the printing house has the ability to make counterfeit paper currency, but today it is possible for any person to print counterfeit bank notes simply by using a computer and a laser printer at house. Therefore the issue of efficiently distinguishing counterfeit banknotes from genuine ones via automatic machines has become more and more important. Counterfeit notes are a 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 a system that is helpful in recognition of paper currency notes with fast speed and in less time. This proposed system describes an approach for verification of Indian currency banknotes. The currency will be verified by using image processing techniques. In this article, six characteristic features are extracted. The approach consists of a number of components including image processing, edge detection, image segmentation, characteristic extraction, comparing images. The characteristics extraction is performed on the image of the currency and it is compared with the characteristics of the genuine currency. The Sobel operator with gradient magnitude is used for characteristic extraction. Paper currency recognition with good accuracy and high processing speed has great importance for banking system. MATLAB is used to extract the characteristic features of paper currency. The proposed method has advantages of simplicity and high speed. The result will be whether currency is genuine or counterfeit.

Key words

Characteristic Feature Extraction, Image Processing, Sobel operator, Decision making, Serial number extraction.

1. INTRODUCTION

With development of modern banking services, automatic methods for paper currency recognition become important in many applications such as in automated teller machines and automatic goods seller machines. The needs for automatic banknote recognition systems encouraged many researchers to develop corresponding robust and reliable techniques. Processing speed and recognition accuracy are generally two important targets in such systems. Modernization of the financial system is a milestone in protecting the economic prosperity, and maintaining social harmony. Automatic machines capable of recognizing banknotes are massively used in automatic dispensers of a number of different products, ranging from cigarettes to bus tickets, as well as in many automatic banking operations. The needs for automatic banknote recognition systems encouraged many researchers to develop corresponding robust and reliable techniques [1-5]. Processing speed and recognition accuracy are generally two important targets in such systems. The technology of currency recognition aims to search and extract the visible and hidden marks on paper currency for efficient classification. Until now, there are many methods proposed for paper currency recognition. The simplest way is to make use of the visible features of the paper currency, for example, the size and color of the paper currency [1]. However, this kind of methods has great limitations as banknotes are getting worn and torn with the passing of time and they are even dirtier when holding by dirty hands or in dirt. If any banknote is dirty or it may be changed into any other color then the color content of banknote may change largely.

The edge information on paper currency have extracted [2] and then used a three-layer BP NN for recognition. Although the NN technology has the ability of self-organization, generalization and parallel processing, and has a good fit for pattern recognition, it also has some weakness. First, it needs a large number of training samples, which are used to avoid over fitting and poor generalization. Second, if the distribution of training sample is not uniform, the result will probably converge to a local optimal or will even diverge unreasonably. Therefore, the selection of the training set is a crucial issue for the NN. In currency circulation, the original information on paper currency may have a loss because paper currency may be worn, blurry, or even damaged. Furthermore the complex designs of different kinds of paper currencies make automatic currency recognition difficult to work well. So it is important how to extract the characteristic information from currency image and select proper recognition algorithms to improve the accuracy of currency recognition. The method we present here is simple, less complex and efficient and can meet the high speed requirements in practical applications.

Digital image processing is an area characterized by the need for extensive experimental work to establish the validity of proposed solutions to the given problem. It has become economical in many fields of research and in industrial and military applications. Digital image processing encompasses processes whose inputs and outputs are images and encompasses processes that extract attributes from images up to and including the recognition of individual objects. The method we proposed in this paper is inspired by the analysis of hidden marks on the image of the paper currency. How to extract the hidden attributes of paper currency is a challenging task in image processing.

The algorithm we apply here is very simple and works properly. The image of the paper currency is acquired through camera by applying white backlighting to the paper currency so that the hidden marks of currency is appeared on the image. Now the image is further processed by applying the image processing techniques like image pre-processing, edge detection, image segmentation, characteristics extraction.

A Digital Image processing is an area characterized by the need for extensive experimental work to establish the validity of proposed solutions to a given problem. It encompasses processes whose inputs and outputs are images and encompasses processes that extract attributes from images up to and including the recognition of individual objects. MATLAB is the computational tool of choice for research, development and analysis. Characteristic extraction of images is challenging work in digital image processing. It involves extraction of visible and some invisible features of Indian currency notes. A good characteristic extraction scheme should maintain and enhance those characteristics of the input data which make distinct pattern classes separate from each other. The approach consists of a number of steps including image acquisition, gray scale conversion, edge detection, feature extraction, image segmentation and comparison of images.

Image acquisition is the creation of digital images, typically from a physical scene. In the proposed work, the image will be acquired by using simple digital camera by providing some backlighting so that all the features of the currency can appear on the image properly. The image is then stored in the computer for further processing. Edge detection and image segmentation are the most important tasks performed on the images.

A. Edge detection

Edge detection is a fundamental tool in image processing and computer vision, particularly in the areas of feature detection and feature extraction, which aim at identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities. Edge detection is one of the fundamental steps in image processing, image analysis, image pattern recognition, and computer vision techniques.

B. Image segmentation

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

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 according to a set of predefined criteria.

2. FEATURE EXTRACTION

In pattern recognition and in image processing, feature extraction is the special form of dimensionality reduction. It is the method of capturing the visual content of images for indexing and retrieval. When the input data to an algorithm is too large to be processed and it is suspected to be notoriously redundant (much data but not much information) then the input data will be transformed into a reduced representation set of features (also named feature vector). If the attributes extracted are carefully chosen, 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 the full size input. Feature extraction involves simplifying the amount of resources required to describe the large set of data.

Visual attributes of images are of two types-

A. Domain specific attributes which include fingerprints, human faces.

B. General attributes which include color, texture, and shape.

There are two types of attributes categorized under the shape attribute extraction-

A. Global attributes include moment invariant, aspect ratio and circularity.

B. Local attributes include boundary segments.

In this approach we extract the general attributes of the paper currency that is shape including identification mark, security thread and watermark etc.. These features are extracted by detecting the edges and estimating the gradient of the image at every point to generate a gradient image and thresholding the gradient image to accomplish image segmentation.

3. IMPLEMENTATION

The proposed system will work on two images, one is original image of the paper currency and other is the test image on which verification is to be performed. The proposed algorithm for the discussed paper currency verification system is presented as follows-

A. Image of paper currency will be acquired by simple scanner or digital camera.

B. The image acquired is RGB image and then it will be converted into gray scale.

C. Edge detection of the whole gray scale image will be performed.

D. After detecting edges, the six characteristic features of the paper currency will be cropped and segmented.

E. After segmentation, the characteristics of the paper currency will be extracted.

F. The characteristics of test image are compared with the original pre-stored image in the system.

G. If the conditions are satisfied , then the currency is said to be genuine otherwise counterfeit.

In the proposed method characteristics of paper currencies are employed that are used by people for differentiating different banknote denominations. Basically, at first instance, people may not pay attention to the details and exact characteristics of banknotes for their recognition, rather they consider the common characteristics of banknotes such as the size, the background color (the basic color), and texture present on the banknotes. In this method, these characteristics will be used to differentiate between different banknote denominations-

A. Security thread

It is a 3.00 mm wide strip with inscriptions ―.art― and ―RBI‖ and color shift from green to blue when viewed

from different angles. The thread is visible as a continuous line from behind when held up against light.

B. Latent image

It is a vertical band on front side of denomination at right hand side. It contains latent image showing the numeral of the denomination when the banknote is held horizontally at eye level.

C. Watermark

The portrait of Mahatma Gandhi, the multidirectional lines and on electrolyte mark showing the denominational numeral appear in this section and these can be viewed better when the banknote is held against light.

D. Identification mark

A symbol with intaglio prints which can be felt by touch, helps the visually impaired to identify the denomination. In 500 denominations the identification mark is a *circle*. In 1000 denominations the identification mark is a *diamond*.

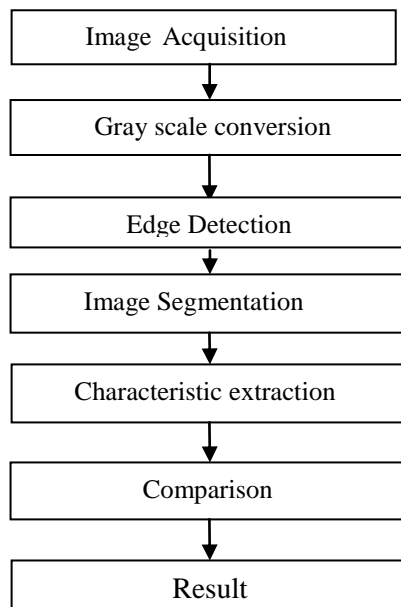The below diagram shows the step-by step process of this paper currency verification system-

Image Acquisition

↓

Gray scale conversion

↓

Edge Detection

↓

Image Segmentation

↓

Characteristic extraction

↓

Comparison

↓

Result

Fig. 1. Design Flow Of Indian Paper Currency Recognition System

OTHER CHARACTERISTIC FEATURES:

A. Intaglio Printing

This gives a more complex and reliable method, since it is the printing process itself that serves to vouch for the authenticity of the document. The note is subjected to a high-pressure printing process that strengthens and slightly raises the paper's surface structure. This method can also be used with optically-variable ink to produce interference which shows different spectral colors when viewed from different angles.

B. Micro lettering

The letters ―RBI‖ and the numeral ―500‖ can be viewed with the help of a magnifying glass in the zone between the Mahatma Gandhi portrait and the Security thread.

C. See Through Register

The floral design printed on both the front and reverse in the middle of the security thread and next to the watermark

window has the denominational numeral ―500‖. Half the numeral is printed on the obverse and half on the reverse. Both the printed portions have an accurate back to back registration so the numeral appears as one when viewed against light.

D. Ultraviolet Fluorescence

Embedded fluorescent fibers into the paper, or printed ultra-violet ink onto the paper, creates a form of optical verification easy. By exposing the note to ultra-violet light, the ink or fibers fluoresce, reveals a colored pattern not visible under natural light.

E. Optically Variable Ink

The color of the numeral 500 appears green when the note is held flat but would change to blue when the note is held at an angle. The font size is reduced.

F. Fibre-Based Certificates of Authenticity

Based on the characteristics of fibre-optic light transmission, this method makes use of unique configurations of fibres embedded in the paper. Using a scanner to illuminate one end of an embedded fibre, the other corresponding end of that fibre will become illuminated. By using the position of both illuminated ends, the certifier has a ―fibre signature‖. This string can then be converted into a bit string and combined with any extra data that is required (e.g. value, serial number, source, etc.). This is in turn combined with a cryptographic hash of itself and is signed using a private key, with the corresponding public key made available. The final result of these steps can then be encoded onto the banknote (this method is suitable for certifying a wide range of other documents too) in the form of a barcode or verification number of some kind.

11. Serial Numbers

Every banknote has its own serial number, so it is more important to check whether the number is wrong or repeated. The serial numbers are currency Issuance numbers, which are used as the identifiers (IDs) of the banknotes.

4. THE APPROACH

Our currency authentication system has four important parts-

1) Edge detection of currency image.

2) Segmentation after edge detection.

3) Feature Extraction.

4) Comparison of features.

The approach consists of the following steps-

1) Image acquisition: Image is acquired by digital camera by applying the white backlighting against the paper currency so that the hidden attributes are able to appear on the image of the currency. Here image acquisition of 500 denomination is shown below-

Fig. 2. Original Indian 500 denomination

2) Image pre-processing: pre-processing of image are those operations that are normally required prior to the main data analysis and extraction of information. Here image resizing is performed because the currency image is too large to process.

Fig.3. Indian 500 denomination after resizing the original image

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).

Fig.4 Gray Scale Image

4) Edge detection: edges are detected of the gray scale image of paper currency using Sobel operator. It smoothes the image and calculate the gradient of the image

Fig.5. Edge Detection (Gradient magnitude of the image)

5) Image segmentation: segmentation is the process of partitioning a digital image into multiple segments. It is typically used to distinguish objects from backgrounds. Here edge based segmentation is performed on the image.

6) Feature extraction: Now the features are extracted using edge based segmentation and objects and background are separated.

Fig.6: Edge based segmentation of Identification mark of 500 denomination
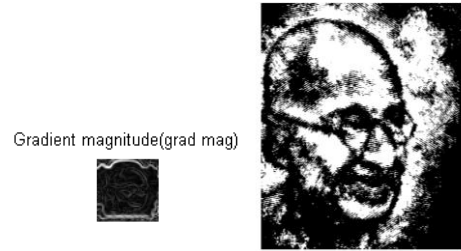

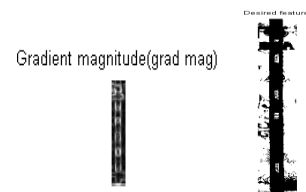Fig.7: Edge based segmentation of Watermark of 500 denomination.

Fig.8. Edge based segmentation of Security Thread of 500 denomination.

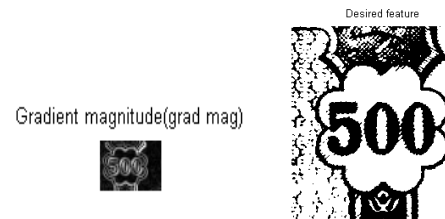Fig.9. Edge based segmentation of Numeral watermark of 500 denomination.

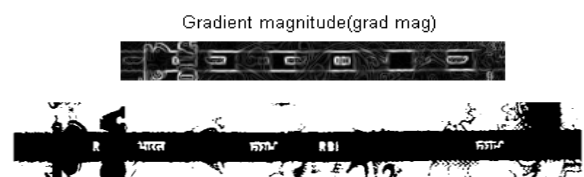Fig.10: Edge based segmentation of floral design of 500 denomination

Fig.11: Edge based segmentation of micro lettering of 500 denomination

7) Lastly the extracted features are compared with the extracted features of original currency by calculating the number of black pixels of segmented image. If the pixels of segmented image of test currency are approximately equal to the pixels of segmented image of original currency then the currency is found to be genuine otherwise counterfeit. The number of black pixels are tabulated for reference note and test currency.

8) Count: For authentication, we count black pixels for all six features. The error difference(e) is difference between number of black pixels in original currency and number of black pixels in test currency. The error difference(e) is calculated for each and every feature of the note. If the error difference is less than 500 pixels then the count(c) is

incremented by one or else previous value of c is retained. Initially the count(c) is assigned to zero. The count (c) tells us how many features have error difference (e) less than 500 pixels. The count loop is repeated six times because features extracted are six for any currency note.

9) Decision making: The final decision depends on the count (c).If the count is greater than or equal to 4,then the note is found to be Genuine which means out of six features, four features are found to have error difference less than 500 pixels. If the count(c) is less than 4, then the note is found to be Fake or Counterfeit.

After authentication, we extract the serial number of the particular note.

Serial Number Extraction:

The following steps are used to extract a serial number from a currency note:

1) Image acquisition: Image is acquired by digital camera by applying the white backlighting against the paper currency so that the hidden attributes are able to appear on the image of the currency. Here image acquisition of 100 denomination is shown below-

Fig:12. Original image

2) Image pre-processing: Pre-processing of image are those operations that are normally required prior to the main data analysis and extraction of information. Here image resizing is performed because the currency image is too large to process.

Fig:13: Resized image

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).

Fig:14: Gray scale image

4) Background subtraction: Background estimation is done using morphological opening and background is subtracted from the gray scale image to produce foreground image.

Fig:15: Back ground subtracted image

5)Binary image conversion: The back ground subtracted image is converted into binary image using the threshold.
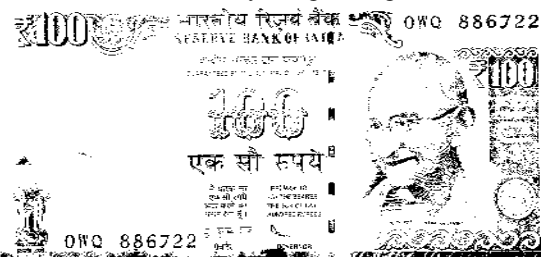

Fig.16: Binary image

6) Crop and complement: The serial number part is cropped from the binary image obtained. The cropped image is complemented.

Fig.17: Cropped image

Fig.18: Complemented image

7) Morphological dilation: The morphological dilation is performed on the complemented image to cover up the breaks in the serial number obtained.
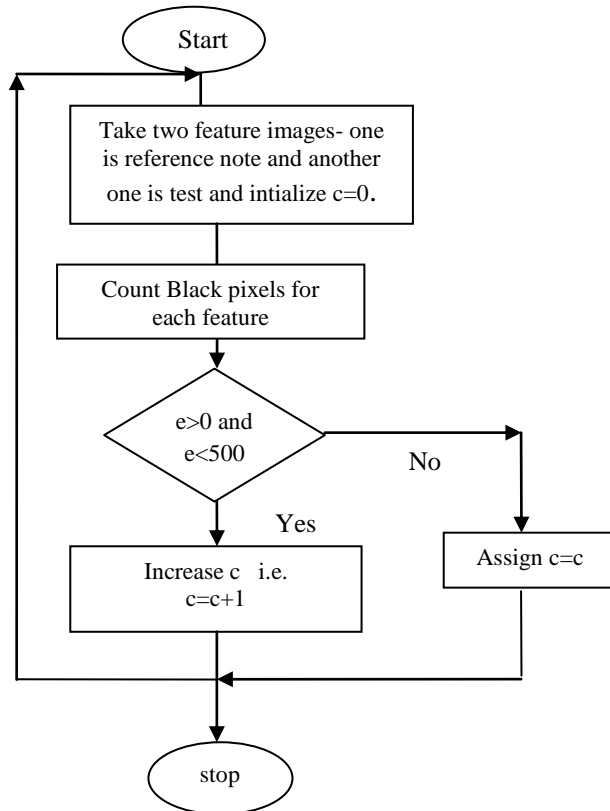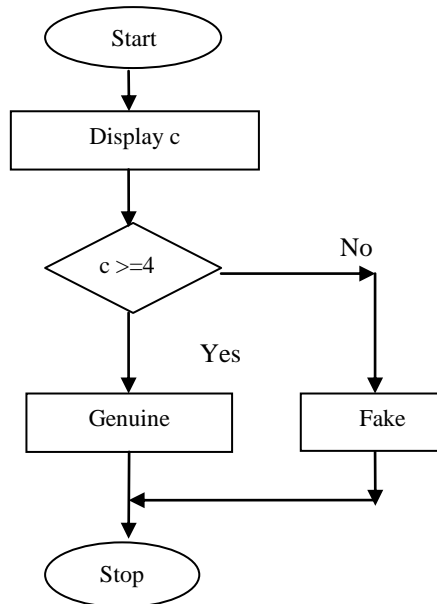

Fig.19: Dilated image

8)Removal of small objects: Sometimes due to uneven lighting conditions, unnecessary parts are highlighted so in order to remove those unnecessary parts, we perform morphological open binary image.

Fig.20: The serial number of the note

Flowchart for count:

Start

Take two feature images- one is reference note and another one is test and intialize c=0.

Count Black pixels for each feature

e>0 and e<500

No

Assign c=c

Yes

Increase c   i.e. c=c+1

stop

Flowchart for decision making:

Start

Display c

c >=4

No

Yes

Genuine

Fake

Stop

5. EXPERIMENTAL RESULTS

The experimental results shown in the form of graph after comparison of the features and calculating the number of black pixels in the segmented features of original currency and test currency.
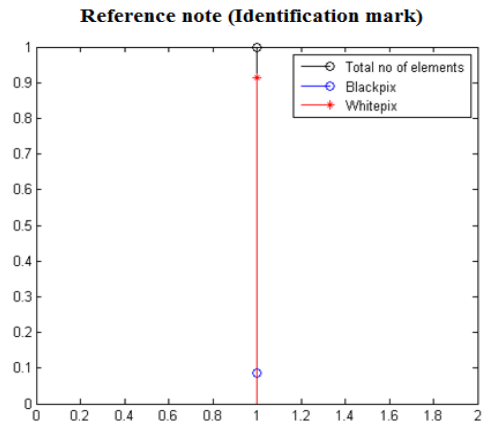

Fig. 21. Graph of number of black and white pixels in identification mark of original currency

Fig. 22. Graph of number of black and white pixels in identification mark in test currency.

From the graphs(Fig.21 and Fig.22),   we can observe that the black pixels of original currency and black pixels of test currency are almost equal.

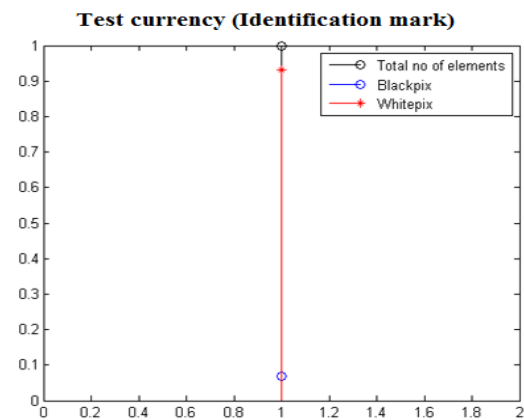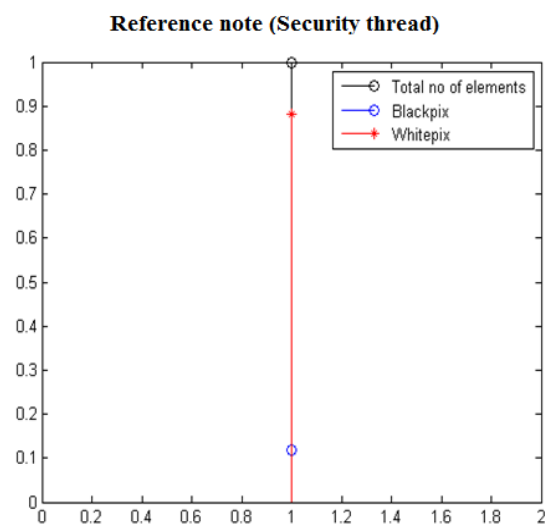Fig.23. Graph of number of black and white pixels in security thread of original currency
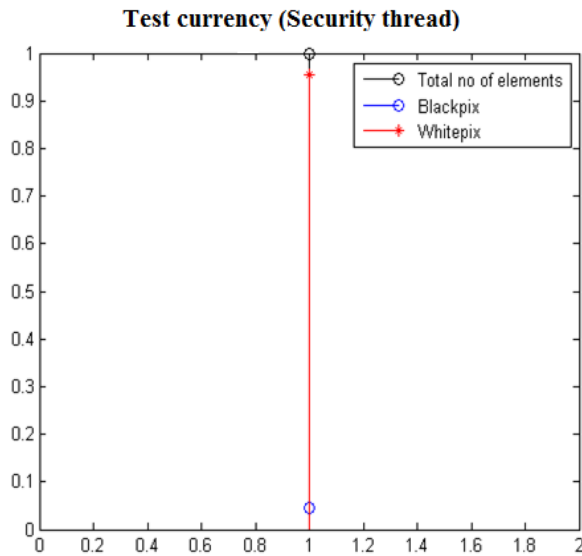
Fig.24. Graph of number of black and white pixels in identification mark in test currency.

From the graphs(Fig.23 and Fig.24), we can observe that the black pixels of original currency and black pixels of test currency are not equal.

(a) Reference image

(b) Test image

Note Feature	Reference image	Test image
Identification mark	Desired feature	Desired feature
Water mark		

	Security thread		
	Numeral		
	Floral design		
	Micro lettering		

Table 1: 500 note-1

Feature	Reference note	Test currency	Error (e)	Count (c)
Identification mark	45	43	2	1
Watermark	5240	2941	2299	
Security thread	440	426	14	2
Numeral	1938	1018	920	
Floral design	681	229	452	3
Micro lettering	1735	1615	120	4

From the above table, we can conclude that test image(b) that we considered is a genuine note because count (c) is equal to 4.

Table 2: 500 note-2

Feature	Reference note	Test currency	Error (e)	Count (c)
Identification mark	45	86	-41	
Watermark	5240	3137	2103	
Security thread	440	407	33	1
Numeral	1938	1857	81	2
Floral design	681	536	145	3
Micro lettering	1735	2683	-948	

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From the above table, we can conclude that test image that we considered is a fake note because count (c) is equal to 3.

Table 3: 100 note-1

Feature	Reference note	Test currency	Error (e)	Count (c)
Identification mark	60	53	7	1
Watermark	4675	1898	2777	
Security thread	589	528	61	2
Numeral	783	369	414	3
Floral design	1072	849	223	4
Micro lettering	2838	2344	494	5

From the above table, we can conclude that test image that we considered is a genuine note because count (c) is equal to 5.

Table 4: 100 note-2

Feature	Reference note	Test currency	Error (e)	Count (c)
Identification mark	60	156	-96	
Watermark	4675	2141	2534	
Security thread	589	214	375	1
Numeral	783	1970	-1187	
Floral design	1072	1101	-29	
Micro lettering	2838	1217	1621	

From the above table, we can conclude that test image that we considered is a fake note because count (c) is equal to 1.

Table 5: 1000 note

Feature	Reference note	Test currency	Error (e)	Count (c)
Identification mark	78	62	16	1
Watermark	4710	3091	1619	
Security thread	673	492	181	2
Numeral	954	923	31	3
Floral design	550	1057	-507	
Micro lettering	3051	2293	758	

From the above table, we can conclude that test image that we considered is a fake note because count (c) is equal to 3.

6. CONCLUSION

In this article, the authentication of Indian paper currency is described by applying image processing techniques. Basically six features are extracted including identification mark, security thread, watermark, numeral, floral design, micro lettering from the image of the currency. The process begins from image acquisition and end at comparison of features. After authentication, the serial number of the note is extracted. The use of serial number extraction is if any counterfeit note is encountered we can immediately send the report about that counterfeit note. The features are extracted using edge based segmentation by Sobel operator and works well in the whole process with less computation time. The complete methodology works for Indian denomination 20,50,100, 500 and 1000. The method is very simple and easy to implement. If the hardware part of image acquisition is designed then it is surely help us to minimize the problem of counterfeiting currency. This technique is used to extract six characteristics of paper currency including identification mark, security thread, floral design, numeral watermark, watermark, micro-lettering in security thread. The system may extract the hidden features i.e. latent image of the paper currency. The proposed work is an effort to suggest an approach for the characteristic extraction of Indian paper currency. Detailed approach is suggested from the beginning of image acquisition to converting it to gray scale image and up to characteristic features extraction. The decision making is done within 0.5 seconds. The system designed is a low cost system. The system is able to extract the features even the note has scribblings on it. The system can extract features even the test image sizes are different when compared to reference image.

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