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Authentication of Indian paper currency using digital image processing

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Abstract

Counterfeit currency notes create serious threat to the economy as it reduces the value of genuine currency and hampers the financial system due to inflation. Hence to limit the circulation of fake currency notes a system needs to be designed which can authenticate a banknote more efficiently. The aim of this present investigation is to differentiate between real and fake currency notes by considering various elements of digital image processing (IP). This methodology when applied on MATLAB software gives a striking contrast between the real and fake Indian currency notes. The advantage of this technique is that the currency image can be captured by any type of simple scanner or digital camera in any lighting condition as well as can recognize the currency note from any direction and angle. From the output of the MATLAB programming the clear disparities obtained between genuine and counterfeit banknotes helps to detect a fake currency note very efficiently. The proposed approach for processing Indian currencies using IP seems to be a very simple and novel method and also open up entirely new application area for comparison of genuine and fake notes that have not previously been feasible or cost effective.

Keywords: Indian currency notes, counterfeit, compare, MATLAB programming

1. Introduction

In every country an automatic system is required to detect counterfeit currency notes in order to eliminate the circulation of black money and fake currency notes used for funding illicit activities. Therefore, a system should be introduced which is convenient, user-friendly, cost effective, fast and reliable approach for the identification of genuine and fake Indian currency notes. Hence the need for an automatic banknote recognition system has offered many researchers to make up robust and dependable techniques. Speed and accuracy of processing are the key factors in such detection systems. Digital image processing (IP) involves changing the character of an image to boost its visual information for human interpretation. The proposed methodology consists of various steps that are performed when genuine and fake currency notes undergo in the stage of image acquisition. After some preprocessing methods applied to the currency images it then gets converted from red, green, and blue (RGB) to hue saturation value (HSV) form. Several other IP techniques such as image enhancement, edge detection using Canny, Sobel and Prewitt filter, image segmentation, histogram of an image and number of objects detection are used in the present investigation. The clear disparities between the genuine and fake banknotes can be ultimately compared with each other.

Some works in the domain of IP had been done by various researchers. Chakraborty, et al. (2013) proposed a paper that presented an extensive survey of research on various developments in identification of currency denomination in recent years. This paper primarily focused on currency detection system including various steps involved in it like image acquisition, feature extraction and classification system by using various algorithms of IP. Yadav, et al. (2014) proposed a fake currency note detection technique using MATLAB and feature extraction with HSV color space and other applications of IP. Ismail and Makone (2014) investigated an automated recognition of currency notes that was introduced with the help of feature extraction and classification based on IP. Ballado, et al. (2015) investigated the Phillipine currency paper bill counterfeit detection techniques through image processing using Canny edge technology. Edge detection is the most important process in IP, and the detection results directly influences the image. Semary, et al. (2015) presented a paper where a currency recognition system was applied to Egyptian banknotes. The basic techniques utilized in their proposed system included image foreground segmentation, histogram enhancement, region of interest extraction and finally template matching. Zeggeye and Assabie (2016) presented a paper on automatic recognition and counterfeit detection of Ethiopian paper currency. Suresh and Narwade (2016) mentioned the approach which consisted of a number of components of IP including edge detection, image segmentation, characteristic extraction and comparison of images to check the validity of fake or genuineness of currency notes. Sawant and More (2016) introduced a paper based on recognition and detection method for Indian currency using IP based on a set of unique non-discriminating security features. Agasti, et al. (2017) suggested the design of a system that detected fake currency notes in less time and in a more efficient manner with the help of IP. Barman, Saha and Bandyopadhyay (2018) proposed a method for identification of different objects present in the Indian currency note using IP. Alnowaini, Alabsi and Ali investigated an approach based on Yemeni counterfeit paper currency detection system. This study provides a solution for every Yemeni denomination with the help of IP and machine learning techniques. Sharan and Kaur (2019) proposed a system to differentiate between a real and fake note which was based on the IP technique and was implemented on MATLAB. Mangayarkarasi, et al. (2020) proposed an approach that consisted of multiple element transactions like image acquisition, feature extraction and comparison, texture features, and voice output. In the present investigation a new framework has been designed on the basis of various digital IP techniques for the detection and authentication of Indian currency notes by obtaining several MATLAB programming outputs and analyzing the clear disparities among the genuine and counterfeit notes.

2. Overview of digital image processing-based currency recognition

For multidimensional systems having two or multiple dimensions of an image, digital IP plays an important role. It permits extensive range of algorithms to take part at the input side along with avoiding complexities of noise and distortion during the processing. The IP takes into consideration the initial step of image acquisition tools where the images are imported. The second step focuses on images being examined and manipulated. The final step is based on scrutinizing an image the output is generated in which altered results for the images are displayed.

The various IP techniques (Gonzalez and Woods, 2002) that are used in the present study are discussed below for ready reference and easy convenience.

Image pre-processing: The goal of image pre-processing is to enhance the image data that restricts distortions present in an image or improves image characteristics for further examining and processing task (Agasti, et al., 2017). The operations which are included during pre-processing helps to decrease the information content from an image only if entropy is the measurement of information. Image pre-processing uses the set of operations that generalizes an image at its lowest level. Four different kinds of image pre-processing techniques are segmentation and image filtering technique, image restoration and Fourier transform technique, brightness correction or pixel brightness transformation technique and geometric transformation technique.

Image enhancement: The process of eliminating any unwanted or unnecessary information from an image according to particular needs is done by image enhancement (Iwasokun and Akinyokun, 2014). It also highlights the required parts of an image. For instance, to highlight features of an image it adjusts the levels, eliminates unwanted noise and displays the blurred details of an image. Image enhancement techniques are divided into spatial domain and frequency domain. The operations executed by spatial domain procedures are directly applied on the pixels of an image. It separates an image on the basis of uniform pixels with a definite resolution with respect to its spatial domain coordinates. However, the operations executed by frequency domain procedures are indirectly applied on the pixels of an image. The improved quality of an image is acquired by using Fourier transform to the spatial domain.

Edge detection: The groups of pixels that are connected to each other and create a boundary between two disconnected regions are determined as edges. In a digital image the considerable changes of intensity are represented by edges. The three types of edges that are present in an image are: diagonal edges, horizontal edges and vertical edges. Edge detection always decreases the number of data present in an image as well as maintains the structural attributes of an image. It is a technique of segregating an image into the regions of discontinuity. Edge detection permits the users to examine the characteristics of an image by creating a noticeable transition in the gray level (Sonka, Hlavac and Boyle, 2014).

Sobel operator: The Sobel operator is also known as Sobel filter or the Sobel-Feldman operator. In the domain of computer vision and IP, Sobel operators take into account the edge detection algorithms in order to highlight the edges present in an image (Kanopoulos, Vasanthavada and Baker, 1988). At each point in the image, the result of the Sobel operator is either the corresponding gradient vector or the norm of this vector. It is formulated on rotating the image with a distinguishable integer valued filter horizontal as well as vertical directions. Therefore, in terms of calculations it is comparatively low-cost and reasonable.

Prewitt operator: Prewitt operators detect edges with the help of a mask whenever there is an abrupt transition in the pixel intensities (Dong and Shisheng, 2008). By applying the method of differentiation, the edges present in an image can be clearly interpreted. In the graphical illustration of Prewitt mask's result, the edges are described by the local maxima or minima where the mask is a first order derivative type. Prewitt operators detect two types of edges and they are horizontal edges and vertical edges.

Canny operator: These types of operators use Canny edge detection which is a method to lessen the quantity of data that needs to be processed and only select the necessary information from different objects (Ballado, et al., 2015). The applications of Canny edge detection are extensively used in computer vision system where in a wide range of situations the detection method can be executed.

Image segmentation: This technique changes as well as simplifies the characterization of an image into something that is simple to understand and analyze (Suresh and Narwade, 2016). Image segmentation as the name suggests separates a digital image into its numerous segments which are referred as image objects or image regions. It is normally used in an image in order to trace boundaries such as curves, lines, etc. and objects. This technique is widely used in IP and computer vision where the image pixels that have common characteristics between them and share certain attributes are allotted a particular characterization in case of every pixel.

Image histogram: Histogram of an image corresponds to a function that is discrete in nature having gray levels in the range [0, L−1]. The relative frequency of occurrence of different gray levels can be depicted by the histogram of an image. The required information of an image acquired by the histogram is always wide-ranging in nature. Usually, histogram provides an overview of the overall appearance of an image. The horizontal axis of a histogram determines the variation of tonal ranges of an image whereas the vertical axis determines the aggregate number of pixels present in a specific tone. Histograms have diverse applications in the field of IP as it helps to scrutinize an image by just viewing at its histogram. For modifying the contrast of an image histograms are used along with brightness purposes as required. Equalization of an image is also done by the application of histograms (Thomas, Flores-Tapia and Pistorius, 2011).

Object detection: In digital videos and images this technique is associated to digital IP and computer vision that allows recognition of occurrence between objects connected with a certain class like such as buildings, cars or humans. Classification of objects is based on its unique characteristics, for example all rectangles are quadrilateral with adjacent equal sides. Therefore, when searching for rectangles, objects that are having four adjacent equal sides are looked for. Again, in case of triangles, objects that are having three edges and three vertices are detected. A similar perspective is applied in case of identifying the features of a face in which facial features can be pointed out along with color of the skin as well as distance between eyes. These are the special characteristics that object class recognition uses (Hussin, et al., 2012).

3. Proposed methodology

The methods that are used in this study are presented on MATLAB software with the help of MATLAB programming. Dummy or fake currency notes taken here are generally used for playing monopoly, business games and other board games for kids and all.

The IP algorithm which is applied for the detection of counterfeit Indian currency notes is depicted in Figure 1 representing the flowchart of proposed methodology. The algorithm consists of various elements of IP.

Images of genuine and fake currency notes are acquired by a HP Ink Tank Wireless 419 scanner having optical scanning resolution 1200 × 1200 spi. All the scanned images of the currency notes are in jpg extension. Image acquisitions have been done for both the genuine and fake banknotes simultaneously. Preprocessing is applied to both the images and then it transforms the RGB images into its corresponding HSV form. Image enhancement has been performed in order to improve the quality of the image for better inspection by enhancing the intensity and improving the contrast. It also eliminates noise from the image for better visibility. The edge detection technique is also performed by considering various operators such as Canny, Sobel and Prewitt operators. The process of image segmentation has been executed to create a subdivision of numerous image segments to convert the representation of the image. The outcome of an image segmentation operation is a group of segments that identifies boundaries such as lines, curves, etc. as well as certain objects that share the same characteristics.

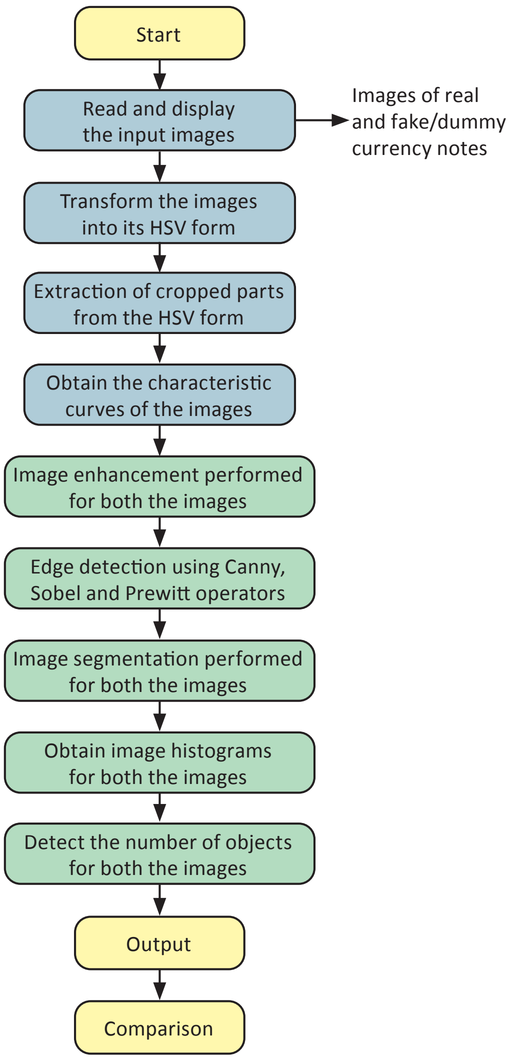


Figure 1: Flowchart of present methodology

Histograms of the images determine the brightness measure by representing the tonal values on a bar chart. The horizontal axis ranges from black on left hand side having 0 % brightness to white on the right-hand side having 100 % brightness. The frequency of each tone present in the image is represented with the vertical axis. Finally, the last technique which has been applied is known as the object detection where the number of objects obtained from the images are calculated and shown in the numerical form. Thus, after the application of various elements of IP, the processed images of the genuine and fake banknotes are then compared where the difference can be perfectly identified. In order to test the efficiency and validity of the proposed system, MATLAB programming is implemented using a Lenovo G50-70 laptop which has the following features: Intel (R) Core (TM) i3 4030U CPU @ 1.90GHz, and 4.00GB of RAM, 64-bit Windows 7 and the MATLAB version of R2009a. Based on the flowchart as illustrated the various techniques of IP used in this investigation are presented by developing corresponding algorithm of various elements of IP which is given in detail in Figure 2.

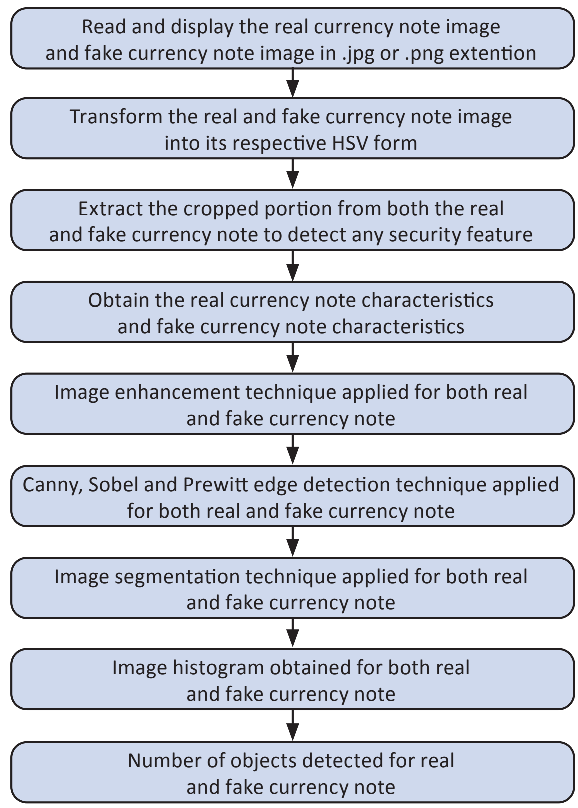


Figure 2: Algorithm of present methodology

Several outputs have been generated with the help of MATLAB programming. The programming codes have been developed in such a way that it can detect the currency note from any direction and from any angle. Also, the images can be read in both .jpg and .png extension.

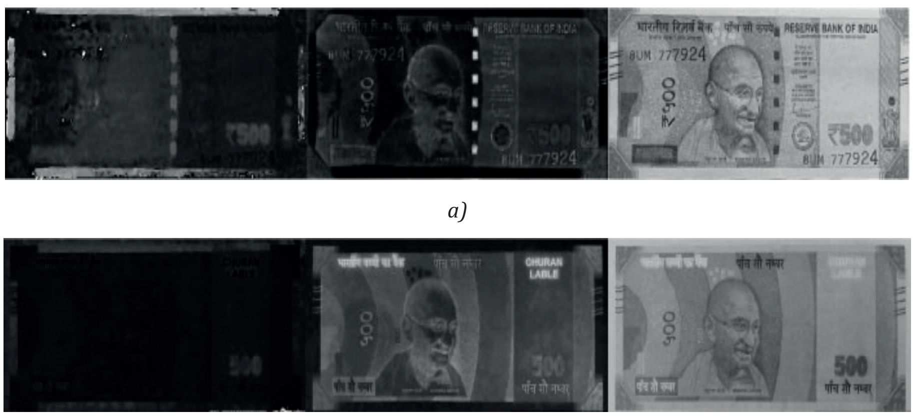
4. Experimental results and analysis

Ten genuine and two fake/dummy currency notes in values of 10, 20, 50, 100, and 500 Indian rupees were used in this study. The size and aspect ratio of the genuine currency paper notes are found to be constant for each denomination i.e, standardized values set by Reserve Bank of India, Government of India. On the other hand, in case of dummy paper notes the size and aspect ratio are not standardized.

Figure 3 shows the output of the real currency note and fake/dummy currency note when the images have been acquired. In Figure 4 the RGB to HSV conversion has been depicted for a real currency note and a dummy currency note. A difference can be seen between the images obtained after the RGB to HSV transformation.

a) b)

Figure 3: Images of currency notes: (a) real, and (b) dummy



a)

b)

Figure 4: RGB to HSV form of real and dummy currency note: (a) real, and (b) dummy

The left side of the images for both real and dummy notes represent the Hue part, the right side of the images represent Value part whereas the middle portion of the images designate the Saturation part as shown in Figure 4. The security thread illuminates in case of real currency note but no such case in case of fake currency note.

a) b)

Figure 5: Cropped part from the HSV form of real and dummy currency note: (a) real, and (b) dummy

The cropped images of HSV form of real currency note and dummy currency note have been illustrated in Figure 5. The cropping is generally done to remove unwanted object or irrelevant noise of an image. When the cropped image for a real currency note has been extracted, in case of a genuine currency note it portrays the security thread feature whereas the cropped image for a dummy note is completely black, no security feature obtained. It indicates that the most common security features like security thread cannot be extracted in case of a dummy note.

a) b)

Figure 6: Rotated 90 degrees solid line image for real currency note and broken line image for dummy currency note: (a) real, and (b) dummy

The solid line image and the broken line image have been portrayed in Figure 6 for real and dummy currency note, respectively. Here the images for both the notes have been rotated by 90 degrees so that the significant changes between a genuine and dummy note can be analyzed from any angle in any direction by the use of any lighting condition. As the aspect ratio of the dummy notes does not follow any standardization, the size of the real currency notes differs with that of dummy notes. The solid line image for genuine currency note is much more bright and enhanced compared to the fake currency note which remains dull and blackish.

Figure 7 represents the characteristics of a real currency note and the characteristics of a fake/dummy currency note. Here the pixel values of the region of interest (ROI) of the image are normalized between 0 and 1. In order to develop the characteristics of the images of both real and fake/dummy currency, the peak-to-peak normalized pixel intensities of the images along the scanned distance have been obtained and illustrated in Figure 7. The normalized pixel intensity distributions along the distance of the images generated at the output for a genuine currency note and a dummy currency note give a clear distinction between the two currency notes by considering the threshold values of a currency note.

Figure 8 depicts the enhanced images for a real currency note and a dummy currency note, respectively. In case of image enhancement, the genuine currency note gives an enhanced image in the dark background whereas there is no such enhanced image in case of dummy note.

Figure 9 represents Canny edge detection when applied on a real currency note and a fake currency note. The Canny edge detection gives detailed edges for a genuine currency note whereas the edge detection in case of dummy note is blurred.

Figure 10 illustrates the Sobel edge detection when used on a real currency note and dummy currency note, respectively. A sharp contrast arises in case of Sobel edge detection for the genuine currency note where the edges are sharp and clear, however, in fake/dummy note the edges still remain unclear.

Prewitt edge detection has been portrayed in Figure 11 for a real currency note and for a fake currency note. The Prewitt edge detection shows the perfect edges in case of real currency note but fails to detect proper edges for a dummy note.

Figure 12 shows image segmentation for a real currency note and dummy currency note. With respect to a dark background the clear segmented parts of a real

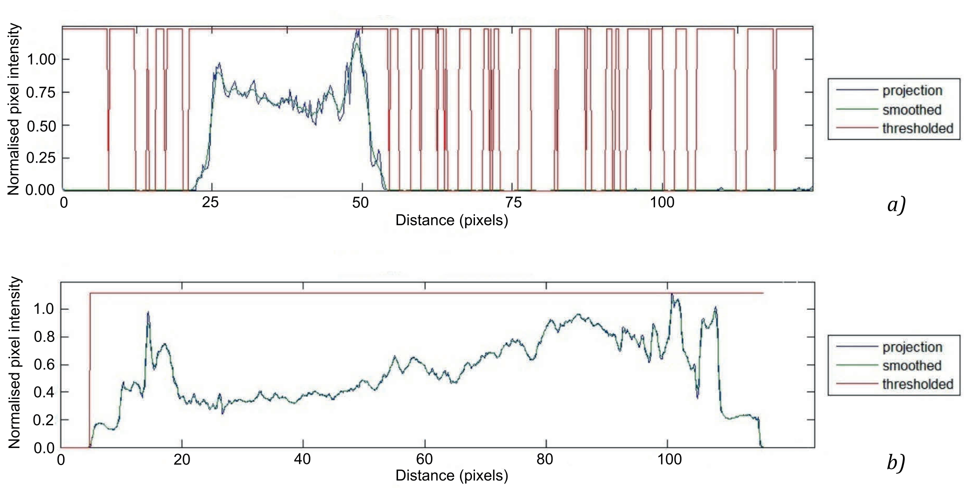
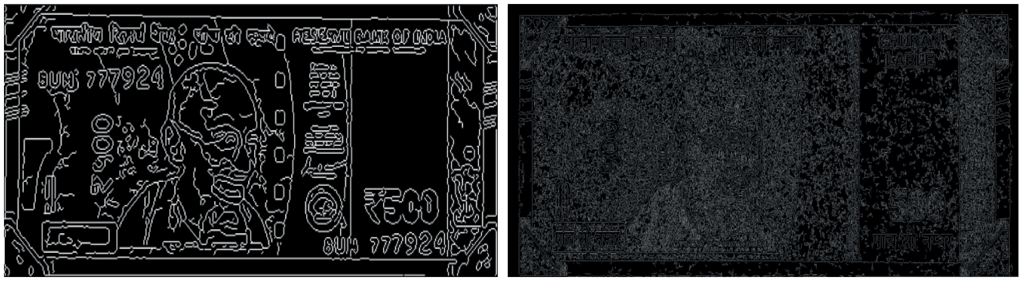


Figure 7: Characteristic curves of real and fake/dummy currency note: (a) real, and (b) dummy

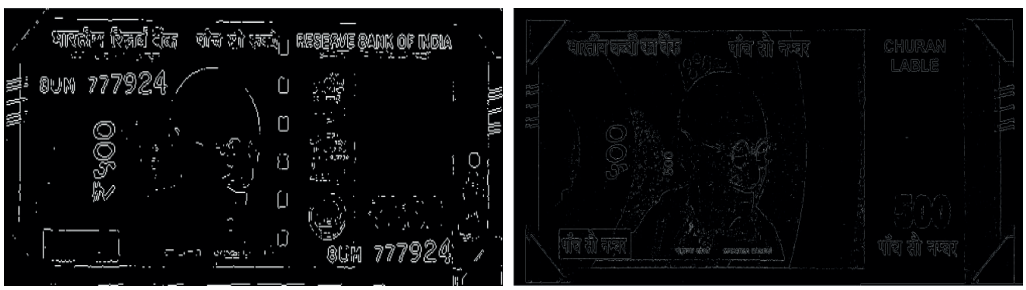
a) *b)*

Figure 8: Enhanced image of real and dummy currency note: (a) real, and (b) dummy



a) b)

Figure 9: Canny edge detection of real and dummy currency note: (a) real, and (b) dummy

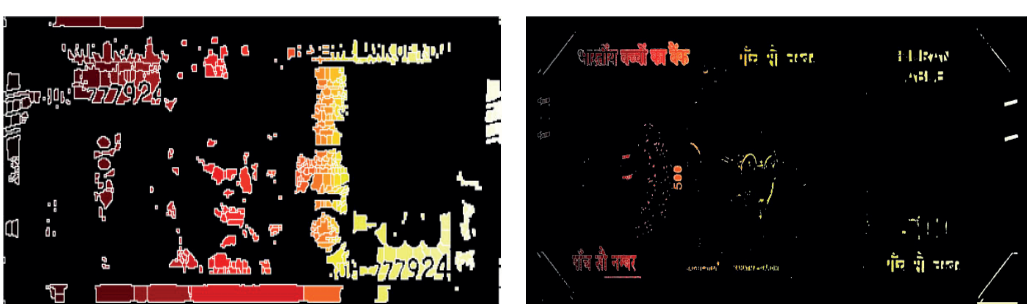


a) b)

Figure 10: Sobel edge detection of real and dummy currency note: (a) real, and (b) dummy

a) b)

Figure 11: Prewitt edge detection of real and dummy currency note: (a) real, and (b) dummy



a) b)

Figure 12: Image segmentation (dark background) of real and dummy currency note: (a) real, and (b) dummy

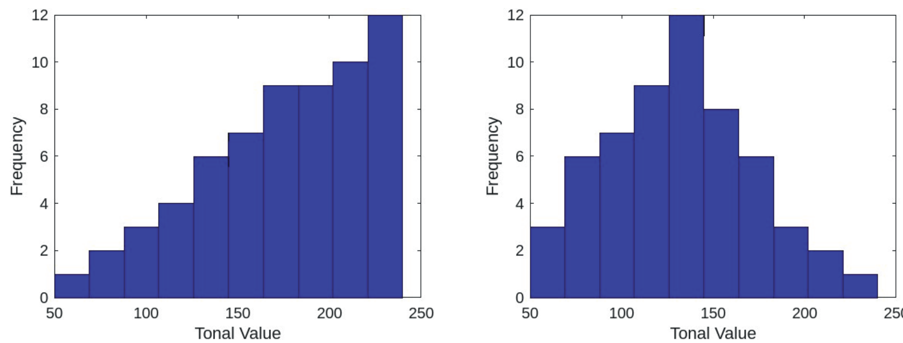
currency note can be noticed but no such proper segmentation takes place in case of dummy currency note.

The final segmented image for a real currency note and a dummy currency note has been in Figure 13. In image segmentation the blue lines that are present on the genuine note determine the segmented portions of a genuine currency note, however, it cannot segment any such portions in the case of a dummy note.

Image histograms for a real currency note and a dummy currency note has been illustrated in Figure 14.

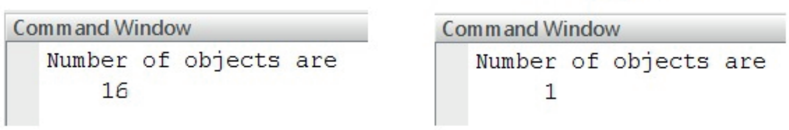
a) *b)*

Figure 13: Image segmentation (light background) of real and dummy currency note: (a) real, and (b) dummy



a) *b)*

Figure 14: Image histogram of real and dummy currency note: (a) real, and (b) dummy



a) *b)*

Figure 15: Number of objects detected in real and dummy currency note: (a) real, and (b) dummy

Here the *x*-axis represents the tonal gradation of the image and the *y*-axis represents the frequency of pixels present in a particular tone. It is observed that in the case of real currency note the number of pixels or tonal values is more in the high-key region than in the case of the low-key region. On the other hand, the fake/dummy note portrays a maximum number of pixels or the tonal values in the mid-key region of the histogram.

Figure 15 shows the number of objects detected in a real currency note and the number of objects detected in a dummy currency note. The number of objects detected for the genuine currency note is 16 whereas it is 1 in case of dummy currency note.

The results shown from Figure 3 to Figure 15 have been obtained for the Indian paper currency (both genuine and dummy) note of value 500. Similar kinds of observations have been noticed for other values of Indian currency notes.

5. Conclusion

Developed MATLAB programming codes have been applied to both genuine and fake currency notes. It is observed that the results obtained from IP analysis on the real Indian paper currency notes are distinct from that of the dummy notes. A clear contrast between a genuine currency note and a fake currency note has been obtained by considering several IP techniques such as image enhancement, edge detection using Canny, Sobel, and Prewitt operators, image segmentation, histogram of an image, and a number of objects detection. The results give accurate disparities between both images that are obtained from the output.

This proposed system focuses on the approach for authentication of Indian banknotes. Since the framework is based upon a generalized concept therefore it is not limited only to Indian currency notes but it can also authenticate any currency notes across the world.

This research work may be expanded to an application-based system to detect the characteristics of a genuine currency note by just capturing the image of a banknote. Moreover, for better authentication functionality image processing can be used with machine learning as an attempt to automate the image analysis process. On the basis of published research results available in references and authors' previous and the present research, the authors assume this methodology can also be adapted to detect fake notes which are close to the original. The advantage of this method is that the image of the currency can be captured by a simple scanner or digital camera in any lighting conditions which can recognize the currency note from any angle in any direction. Moreover, a smartphone-based application system can also be developed to detect the characteristics of genuine currency notes which may be useful for the common people.

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