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Counterfeit Recognition of Pakistani Currency

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Abstract

The forgery of currency is one of the major problems with money transactions all over the world. This is intended to exacerbate corruption and hindered the development and growth of the economy. As the resources for development are increasing in the present times, similarly, the sources of fraud are also increasing. Thus, making counterfeit notes has become even easier with the use of modern technology. Detecting and recognizing fake notes physically becomes a tedious and muddled practice, hence there is a requirement for automatic techniques which perform the desired task more effectively. Therefore, simple solutions are proposed for a novel application. The proposed methods are based on the automated environment framed in MATLAB which reduces human efforts and the probability of error as a result, the efficiency of identifying the falsification in the Pakistani currency is optimized. In these methods, the generalized parameters are used for identification which is recommended by the governed financial body of Pakistan. This work is achieved through image processing techniques that perform acquisition and characteristic extraction, followed by some straightforward algorithms that perform verification checks on banknotes to authenticate serial numbers, security threads, and picture watermarks. The simplicity of these algorithms allows for the processing to be done swiftly and efficiently. The idea of the paper is to develop a system that can not only recognize Pakistani notes but is also capable of detecting fake notes, separating the fake notes from the stack of money into its compartments, and displaying the number of fake notes.

Keywords: Automation, Counterfeit, Currency, Detection, Fake notes, Image Processing, MATLAB, Recognition, Sorting, and Template Matching.

1. Introduction

The document safeguard of finance has been an age-old necessity since the inception of coinage itself. With the first coin came the first counterfeit coin; with the first bill came the first counterfeit bill, and so on. Throughout the ages, man has attempted to damage

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control by trying to overcome the issue through numerous manual methods of detection and recognition. But, with the ever-evolution of technology and advancements in printing, making it more difficult to verify the security characteristics of impressively produced dupes, manual methods have begun to seem obsolete. The currency circulation in Pakistan was put over at the end of the British Raj in 1947. However, Pakistani currency has different notes of denomination, such as 10, 20, 50, 100, 500, 1000, and 5000 rupees containing different colors and sizes. All notes feature a watermark of Muhammad Ali Jinnah (founder of Pakistan) and it has a crescent and star and a security thread that differentiates the fake banknotes. Since the state bank started a new series having more security features after the year 2005. Each denomination described above has unique features. These features may be color, size or some identification marks, etc. The State Bank of Pakistan, like every other developing country's central bank, is responsible for regulating the issuing of banknotes and the holding of reserves to ensure monetary stability in Pakistan. With the consent of the Federal Government, the State Bank of Pakistan prints a new series of notes from time to time and demonetizes the previous series. Issuing new series and demonetizes outdated design banknotes may help to detect counterfeiting. The State Bank of Pakistan goes to great lengths to prevent counterfeiting to minimize its influence on Pakistani banknotes and retain public faith in them. A couple of measures are taken to safeguard the banknote. The new generation of Pakistani banknotes has several security measures that are simple to use yet difficult to replicate or counterfeit. All real banknotes have many security characteristics that can be checked easily and rapidly to avoid counterfeiting. State Bank of Pakistan suggests a few security characteristics to verify the genuineness of banknote that are: raised circles and raised printing are those features that one can easily feel by touching the notes and picture watermark, value figure watermark, security thread, latent image, see-through numeral, color-changing flag are those characteristics when viewed from different angles [1].

With this being the era of technological advancement, everything is automated from appliances and medical equipment to office temperature sensors and mobile phones. Consequently, the banking industry is also evolving. For the longest time currency security has been done manually here in Pakistan. While many researchers from different countries have been urged to create a reliable and efficient automatic fake currency detector. Introducing an automatic counterfeit currency detecting technique that would be able to recognize fake currency in Pakistan would be a revolutionary step in bringing the country up to speed with the advancement of the rest of the globe. There has been minimal study on the identification of counterfeit currency in Pakistan based on image processing which is why this technology is introduced to benefit the country and add to its measures. The environment is designed to detect fake notes with the help of an image processing technique using MATLAB.

The proposed idea is mainly focusing on three different currency denominations, i.e., 500, 1000, and 5000 PKR. In this approach, the note is placed in front of the camera to recognize whether the currency is fake or genuine. The program that is installed in the system then begins its operations. The operations incorporate image acquisition in which an image is taken using the digital camera, image pre-processing includes resizing and orienting, greyscale conversion in which RGB values (24-bit) are converted into greyscale values (8-bit) and histogram equalization helps to enhance the contrast of an image, binarization converted the image into bi-level document image and then characteristics extraction. The added feature of this system is to detect fake notes in UV light after capturing the picture from the webcam. It also communicates with the controller to sort the note into its compartment.

2. Literature Review

Forging money is not a new problem, it's been there since the coinage was started by the Greeks in 600 B.C. During that period, to create fake coinage the edges of the coin were hacked off to get the significant metal. Paper cash came into existence in 700 A.D. in China and mulberry wood was utilized to make fake paper money. The security aspects of a currency are difficult in identifying the difference between a real and counterfeit form. The common security features are picture watermarks, security threads, latent images, value figure watermarks, etc. Manual examination of currency is not effective as in this advanced era of technology everything is automated. In this manner, automated solutions are necessary to identify the contrast between real and counterfeit notes. [2]

The study of differentiating the unique qualities of different countries' currencies to make them less vulnerable to fraud [3]. In doing so, a method to identify forged banknotes with low-resolution images was proposed and twenty various denominations of European, Asian, and American currencies were used to test the proposed algorithms [4]. Later, The Scale Invariant Feature Transform approach is used to create an android-based mobile application majorly for people with disabilities that find the nominal and the money's legitimacy of a piece of Singapore Dollar banknote [5]. Another android-based mobile application system was proposed using the Oriented Fast and Rotated BRIEF (ORB) method which introduced Singapore banknotes and determined their authenticity [6]. In such a manner, a method using unity 3D was proposed, a multiplatform mobile application development framework, to create a cellular application for identifying currency denominations and detecting counterfeit Nigerian Naira notes. It was based on Android and iOS devices respectively [7].

Many other approaches were applied based on machine learning algorithms in which banknote recognition and counterfeit detection can be performed. In addition, the proposed method extended the standard Grad-CAM approach and provide pixel-wise gradients for the explanation [8]. One more study suggested a bill acceptor/validator that uses image processing techniques to accept, identify, and validate bills using the MATLAB

computer vision abilities. Ultraviolet is used for the authentication of the bill [9]. However, a study suggested centered on Pakistani currency, a banknote verification system for mobile phones, especially for Android devices is proposed based on the banknote's numerical traits and surface roughness which represent several banknote qualities such as paper material, printing ink, and surface roughness. X-ray Diffraction and scanning electron microscopy analysis were used to examine the real and counterfeit banknotes [10]. The study focuses on the two important regions of the banknote, i.e., serial number and flag portion [11].

Another study used an image processing technique that presents a system that can be categorized and validate the Indian currency. It works by comparing the input banknote to compute reference values for various parameters of original banknotes in a comparable setting [12]. A system was designed that includes a categorization component that denominates the currency notes into their various denominations as well as verifies if the currency is legitimate or not. Software and hardware solutions were presented in this paper that use photographs of Ethiopian currency as input from a scanner and camera. Genuine and counterfeit Ethiopian currency and other nations' currencies were used to test this system [13]. To determine the authenticity of currency, an empirical technique for automated money recognition is formulated and a prototype is created. In this paper, color features and texture features are combined to form a two-part feature vector. A Feedforward Neural Network (FNN) is used to classify the banknote in question, and a measurement of the similarity between available samples and the suspect banknote is generated [14].

A study has been done, which offered the recognition approach for RMB word numbers based on character properties. Image processing, number region localization, feature extraction, and character recognition were among the recognition techniques. The findings suggested that with this strategy, an automatic recognition system may obtain a high identification rate and processing speed [15]. Another research involves an online application to detect counterfeiting [16]. Another study suggested an image processing technique that can quickly and correctly recognize the real Egyptian currency counterfeit. This paper has focused on two phases: the first compares two photos, and the second extracts and judges some currency security properties [17].

A work presented a deep-learning approach for identifying counterfeit BAM banknotes using CNN models [18]. A novel banknote validation approach based on the usage of an RFID chip and an NFC-enabled smartphone has been described. With the help of an Internet connection, the chip delivers a challenge and calculates an equal response. The smartphone is then delivered an approval or disapproval message [19]. Another study utilized a simple and effective method for eliminating black money and counterfeit currencies in India by utilizing advanced technology. RFID and NFC chips were employed, which are readily accessible nowadays, and combined RFID tags with the notes to make them more secure [20]. A study focused on the technique that allows visually challenged people to recognize Bangladeshi cash in real-time as the similarity

of the paper size and texture across various banknotes that a visually impaired person has while attempting to recognize paper currency. The suggested method makes use of image processing technologies to help visually challenged persons recognize banknotes more easily [21]. Similarly, a study suggested a new paper money identification based on the combination of SURF and LBP characteristics of Bangladeshi notes. This proposed system can detect cash at various locations in various environments and can also determine the total amount of money [22]. Further, six supervised machine-learning methods were utilized to identify the authenticity of money using data from the UCI machine-learning repository [23]. In [24] a holistic-based method such that a local binary pattern (LBP) is proposed use for the conversion of face features into texture features followed by wavelet decomposition. The informative image subbands were selected by using the proposed filter-based method.

In the review of literature, much work has been done for detecting cash such as color segmentation for cash detection and recognition based on the size of the note but all were tested and verified on different currencies [25],[26]. This paper represents an image processing method for recognizing only Pakistani currency with its fixed standard detection of forgery parameters. Cash recognition algorithms are generally divided into five categories such as note image capture, converting it to a grayscale image, comparison with the reference image, detecting whether the note is real or fake, and displaying and recognizing the note. In this method, Template Matching is used for recognition of the denomination whereas color recognition in UV light is used to detect real or fake notes.

3. Counterfeiting Recognition Process Through Image Processing

Image processing is used for different applications, for instance, image sharpening and restoration, medical field, recognition, color processing, etc. In this designed environment, an image processing technique is used to recognize the fake currency based on a few security features provided by the State Bank of Pakistan to avoid counterfeiting. The features include watermarks, security features, see-through numerals, latent images, color-changing flags, raised circles, and raised printing. Some of these features can easily be felt by touching the notes, i.e., raised circles and raised printing. Previously in Pakistan, a study based on the utilization of the devices X-Ray Diffraction and a special type of scanning electron microscopy was proposed to evaluate the genuine and counterfeit banknotes but both methods have high operating cost limitations and it is not easily understandable to operate [7]. The existing research focuses on two key aspects of the banknote: the serial number and the flag part. While the proposed research focuses on some of the security features suggested by the State Bank of Pakistan such as picture watermark, security thread, and serial number.

3.1 Picture Watermark:

The watermarks are recognizable designs and are employed on the banknote to prevent an individual from making fake currency and, therefore, to be confident that the banknote is authentic. When the note is held up to the light, the image of the founder of Pakistan appears on the right side of the note.

3.2 Security String:

When held up to the light, an embedded security thread in the paper almost in the middle of the note may be seen.

3.3 Serial Number:

The PKR currency of any value consists of a seven-digit serial number with a prefix at the right top and another number below the watermark at the left bottom. Magnetic ink has been used to print both numerals.

4. Methodology

In the proposed system, the mobile scanner application is used which allows the users to scan the documents using their Android and iPhone cameras. The mobile phone application has been used for this purpose because this technology is easily accessible to all users and there is no need to buy a separate device for that. As the growth of smartphone photography has resulted in various unexpected consequences and can do a variety of tasks. In today's technologically advanced world, all that functionality is now available at the touch of a button on a smartphone. To verify the results, the Cam-Scanner android application is used for scanning purposes and digitizing paper documents. The Cam-Scanner smartphone app enhances the usefulness of the particular device by mimicking a scanning machine. The scanning applications offer various features such as board identification, intelligent scanning, OCR, etc. The key features of this Cam-Scanner application for android are Automatic edge detection, when scanning a document, this application recognizes the edges automatically and captures just the primary region. Another main feature is magic color, this feature makes use of the color correction technique to improve the quality of the scanned image or document. Users may use the application's brightness, greyscale, and black-and-white filters to manually improve the quality of a scanned image or document [9].

In this process, the picture is firstly scanned through the Cam-scanner application using the mobile Camera. The scanning starts by clicking the camera icon in the app. Once the image is scanned, the application's cropping screen appeared which adjusts the cropping area's boundary to remove any unwanted background or to focus on a specific section of the document. Then, apply the different style filters to the scan. There are seven options available: Auto, Original, Lighten, Magic Color, Grey Mode, Black and White, and Black and White 2. The magic color filter is applied to the scanned image to improve the quality of the scanned picture. These filters are intended to make the work simpler to read. Contrast, Brightness, and Level of detection be adjusted manually if the filter is not sufficient. In Table 1. The level of attributes is represented in which the test sample has been adjusted for their visualization.

Table 1: Level of Attribute

Attribute	Intensity
Brightness	50
Contrast	50
Details	10

The procedure that will be followed in the proposed system is depicted in the flow diagram shown in Figure 1.

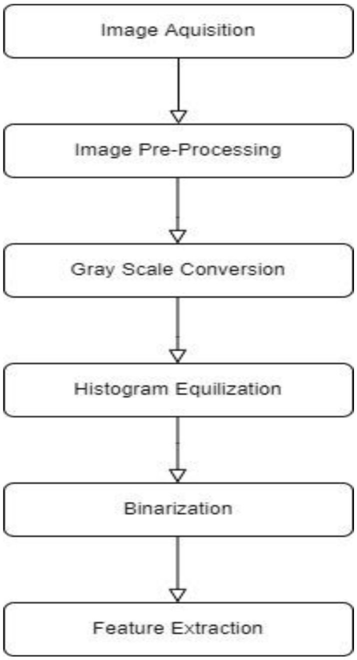


Figure 1: Process Flow

4.1 Image Acquisition:

Picture acquisition is always considered the opening step in image processing. In this step, a picture is taken from a source such as a camera and a scanner so that it can be utilized for the further process. In this proposed technique, the Cam-Scanner android application is used to acquire the image. Figure. 2. Shows the image acquisition of the test sample by a simple android phone.

Figure 2: Banknote acquisition and cropping

4.1.1 Image Pre-Processing:

The term pre-processing refers to the process of preparing an image for a specific task, such as recognition, feature extraction, etc. The pre-processing of an image includes resizing, orienting, and color adjustments.

4.1.2 Greyscale Conversion:

Greyscale images, often known as grey monochrome or black-and-white images, are made up entirely of greyscale shades. This tool eliminates all colors from JPG/JPEG images. The JPEG's output is a greyscale version. Converting RGB color components into grayscale can be done in different ways. The image is converted from RGB to greyscale by using the formula represented in equation (1)

$$Grayscale = [0.299 * red + 0.587 * green + 0.114 * blue] \quad (1)$$

4.1.3 Histogram Equalization:

It is used to adjust the contrast of an image. The mathematical representation of adjusting contrast is demonstrated in equation (2)

$$p\alpha(i) = p(\alpha = i) = \frac{n_i}{n} \; 0 \leq i < GL \qquad (2)$$

Whereas in equation (2),

pα(I)= probability mass function of the pixel,
GL = No. of grey levels in the image,
n = No. of pixels.

Equation (3) shows the mathematical calculation to obtain the cumulative distribution function corresponding to *I* as,

$$f_\alpha(i) = \sum_{j=0}^{i} p_\alpha(\alpha = j) \qquad (3)$$

To build a transformation of the type *z=T(α)*, to construct a new picture 'z' with a flat histogram. A linearized cumulative distribution function (CDF) would be present in an image throughout the range for some constant K, i.e.,

$$f_z(i) = (i+1)K \quad for\; 0 \leq i < GL \quad (4)$$

where in equations (4) and (5)
k = the range [0, GL-1],
T = range of [0, 1]

Since in the test sample the normalized histogram of {α} is used, therefore, the following basic transformation must be done with the result to translate the values back into their original range which represents in equation (6)

$$z' = z\,.(\max\{\alpha\} - \min\{\alpha\}) + \min\{\alpha\} = z\,.(GL-1) \qquad (6)$$

4.1.4 Binarization:

Binarization is one of the steps for image analysis and processing. Image binarization is the conversion of an image into a bi-level image. There are different methods to convert the image into binary form. In the test sample, the global thresholding method, i.e., the Otsu method is used which converts the greyscale image to a bi-level image. The pixels are divided into two groups using this technique: foreground and background. It selects the best threshold for separating the picture into two classes. The threshold value is set so that the within-class variance is kept to a minimum while the between-class variance is maximized. Mathematical representation is defined in equation (7),

$$\sigma_w^2 = p_0(t)\,\sigma_0^2(t) + p_1(t)\,\sigma_1^2(t) \qquad (7)$$

Whereas,

p_0 and p_1 = the probabilities of two classes

t= threshold

σ_0^2 and σ_1^2 = variances

And probabilities $p_{0,1}(t)$ is computed from the histogram as shown in equation (8)

$$p_{0,1}(t) = \sum_{i=0}^{t-1} p(i) \sum_{i=t}^{L-1} p(i) \qquad (8)$$

4.1.5 Feature Extraction:

It is a step in which it divides and reduces a large collection of initial unprocessed data into smaller pieces of information. As a result, processing will be simpler to get the best feature from the big data sets. The extracted features of the genuine are shown in Figure. 3

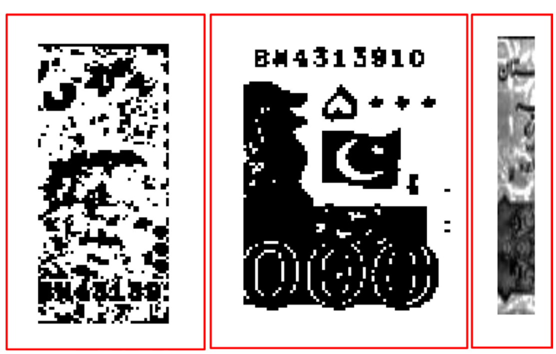


Figure 3: Left-most shows the extraction of the picture watermark, the central one shows the extraction of the serial number, and the right-most shows the security thread extraction of genuine note

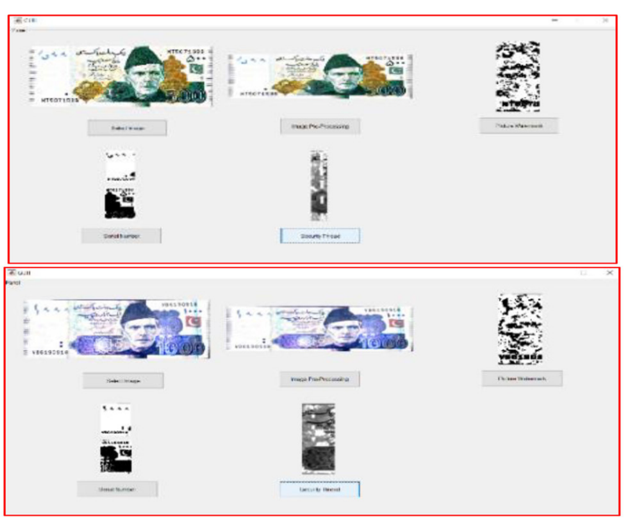
4.1.6 Analysis of Test Samples

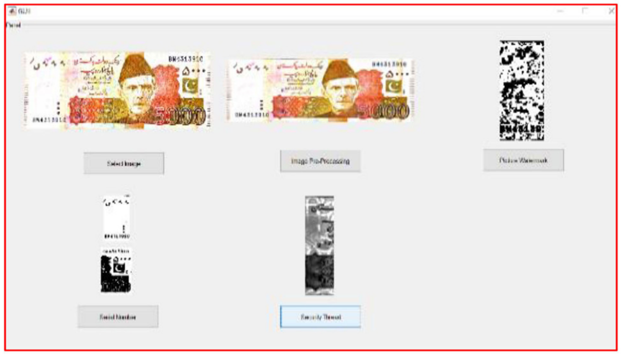
For this experiment, fake notes were first obtained through the inner circle, including friends and colleagues, as well as through the help of shopkeepers at local markets to collect fake notes. These were fake notes circulating in the market which were rejected by the shopkeepers. The notes collected from shopkeepers included Rs. 100 and Rs. 5,000, which were tested against security measures respectively.

Samples of the remaining banknotes of Rs. 10, Rs. 20, Rs. 50, Rs. 500, and Rs. 1,000 were prepared by scanning each original note through the high-quality resolution scanner and then printing them in color for each case. It also proved successful when tested against properties extracted from genuine banknotes.

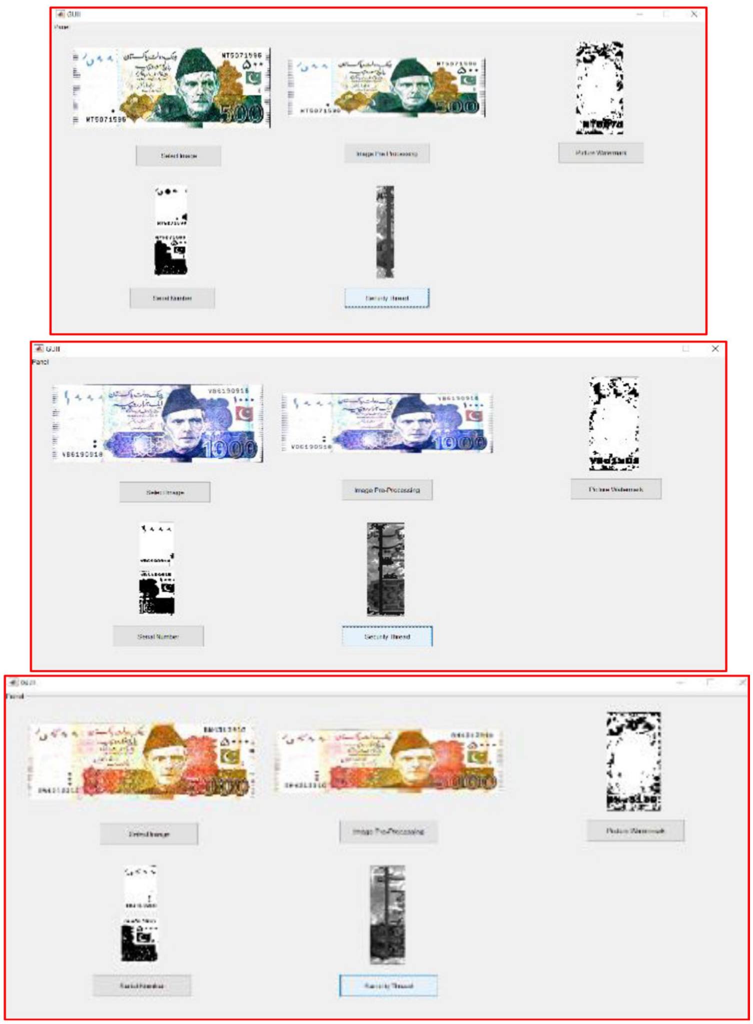
The aforementioned cases are however of fake bank notes generated through low complexity methods as the experiment is at the initial stage of a larger, broader impact solution to the issue at hand, making it not entirely capable of processing fake bank notes generated through any and every means of production. This is because, the higher the complexity of the production process, the higher the complexity and sophistication of the detection and decision-making algorithm.

The findings are shown in a MATLAB GUI in Figure. 4, which displays extracted information such as the picture watermark, security thread, and serial number, and based on only applying the simple and sophisticated feature extraction algorithm, the identification of the picture watermarks and the security thread can be achieved which helps in the counterfeiting detection. Moreover, the dots can also be traced for counterfeiting identification while extracting the serial number. Whereas serial numbers can further be utilized by using the template matching technique for recognition of the currency number which was later proposed in the second method of the counterfeiting and sorting mechanism. For testing and analysis, three denominations 500, 1000, and 5000 are used. The reason to choose these denominations is that these are the highest number of currencies available and their forgery causes more problems.





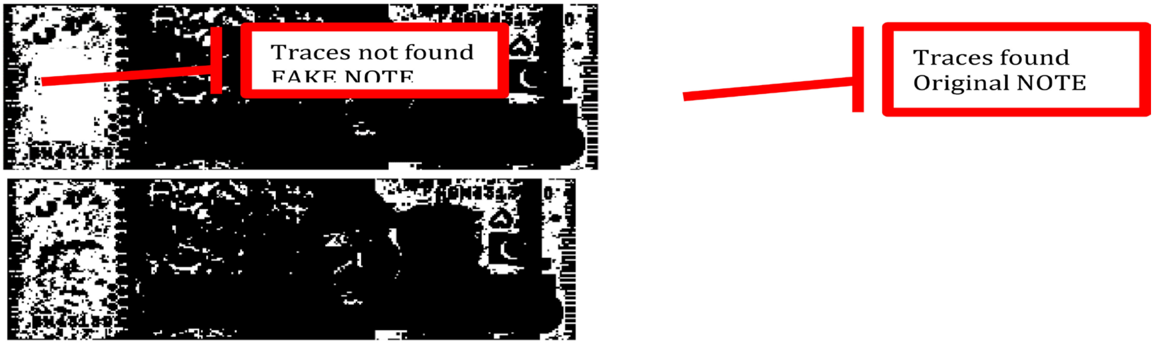
(a)



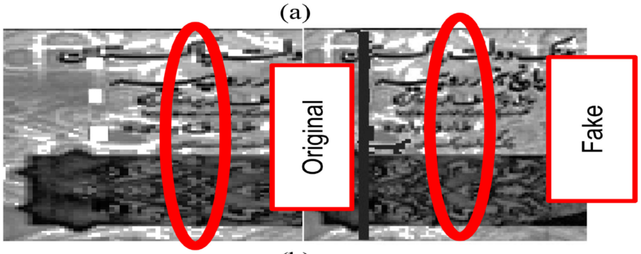
(b)

Figure 4: (a) Testing a 500,1000 and 5000 domination genuine note and (b) fake note

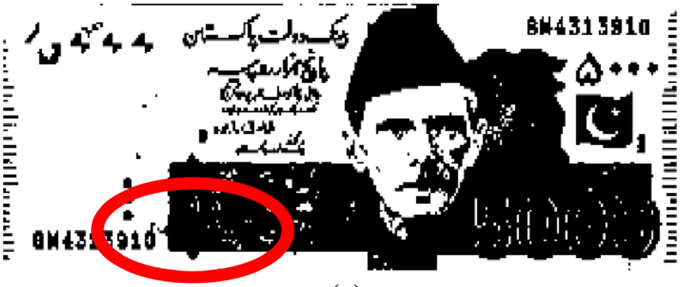
During the process of feature extraction for both the genuine and fake banknotes be it 500, 1000, or 5000 notes, the picture watermark out of the three security aspects played a crucial part in the detection but in completely contrasting ways. It was observed to show up with heavy traces on the real "genuine" notes, appearing more heavily in the form of splotches and large spots after passing the algorithm. Whereas in comparison, the fake one showed the traces appearing to be as more minimal flecks or almost nothing at all creating a visually clear indication of the false note. For the security thread, it was noted that the thread in a fake note has been tampered with and its color is grey or blackish completely, whereas, in contrast, the thread on a genuine note is visible in a straight line. Similarly, for the serial number, observation revealed the template of the numbers to have a stark difference. The serial number of the real notes matched with the template of the numbers previously gathered and stored in the database for the very purpose of detection. Whereas, the template of the serial number of the fake notes was found to be very off and inconsistent compared to the template of the monetized notes in circulation. Figure 5, represents the clear vision of the comparison between the fake and genuine feature extraction results.



(a)



(b)



(c)

Figure 5: Comparative analysis (a) Picture WaterMarks (b) Security thread (c) Serial Number

To estimate the efficiency of the proposed method, a demographic analysis has been conducted in which there were 100 test samples have been evaluated by the proposed method. Table II shows the complete demographic analysis performed on the fake and genuine or original currency. The analysis has taken place concerning the features of extraction such as picture watermarks, security thread, and serial number. The results were generated either by the data being extracted marked as “Y”, or not extracted or partially extracted which was marked as “N” for NO or “P” for partial detection. There were 19 fake notes utilized for this testing mechanism since it is difficult to find or collect fake notes therefore, test samples are restricted to only 19. Other than the 19 remaining 81 samples are the original or real currency, which has been tested for the proposed method. In this method net worth of 80,000 PKR currency is used for acquiring the sample. There are numbers 08, 05, and 06 samples used for 500, 1000, and 5000 denominations of fake notes respectively, while 41, 24, and 16 samples are used for the 500, 1000, and 5000 denominations of genuine notes respectively. The suggested approach was 93 % accurate in terms of currency verification. The accurateness of the proposed system is calculated mathematically by using the following equation (9) and the graphical representation is in Figure.6

$$Accuracy\ (\%) = \frac{Number\ of\ correctly\ verified\ notes}{Number\ of\ tested\ notes} \times 100 \tag{9}$$

Table 2: Demographic Analysis of Accuracy Estimation

Test Sample Number	Plotted Notes	Note denomination (PKR)	Feature Extraction		
			Picture Water marks	*Security thread*	*Serial #*
1-7	FAKE NOTE	500	Y	Y	Y
8			Y	Y	P
9-13,14		1000	Y	Y	Y
14,16,19		5000	Y	Y	Y
15			Y	P	Y
17			P	Y	Y
18			Y	Y	P
20-24,28-35,37-42,44-46, 48-60	ORIGINAL NOTES	500	Y	Y	Y
25-27			Y	N	Y
36			Y	P	Y
43			P	Y	Y
47			Y	Y	P
61,63-68,70-72,75,78-84		1000	Y	Y	Y
62			Y	P	Y
69,74,77			Y	Y	P
73			Y	N	Y
76			N	Y	Y
85-87,89-94,96-98,100		5000	Y	Y	Y
88			Y	Y	N
95			Y	Y	P
99			Y	P	Y

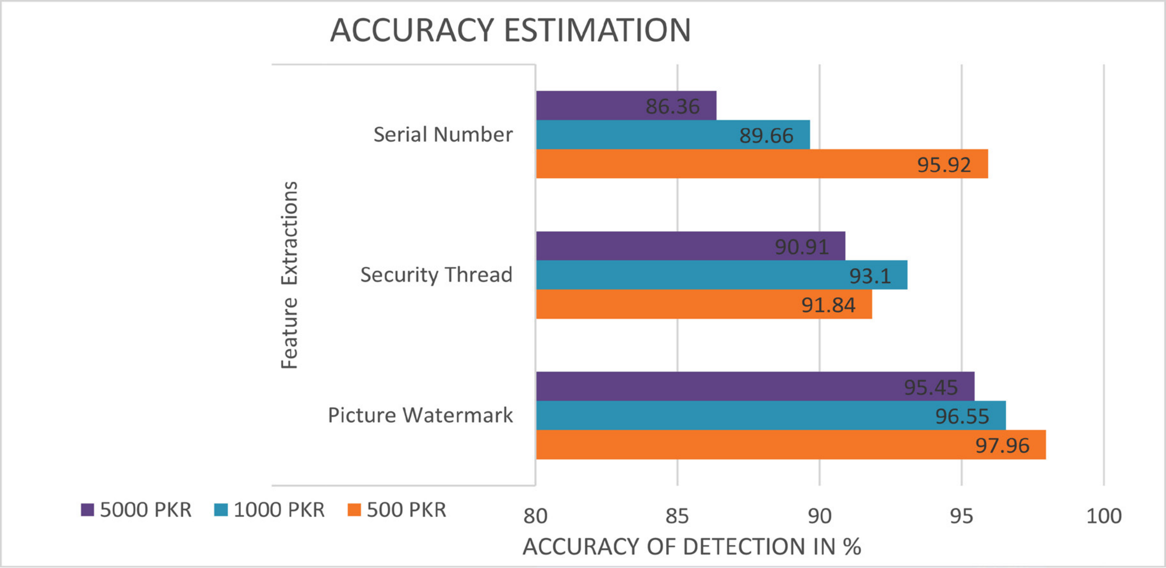


Figure 6: Accuracy Estimation of the proposed method

Figure. 7, shows the comparative results of the proposed method between the fake and original notes generated through the above describe demographic data. By observing the comparative analysis of the chart it can easily conclude that the results efficiency of fake notes is much better in the currency of 500 and 1000 PKR and the reasonable accuracy achieved in the detection of original notes.

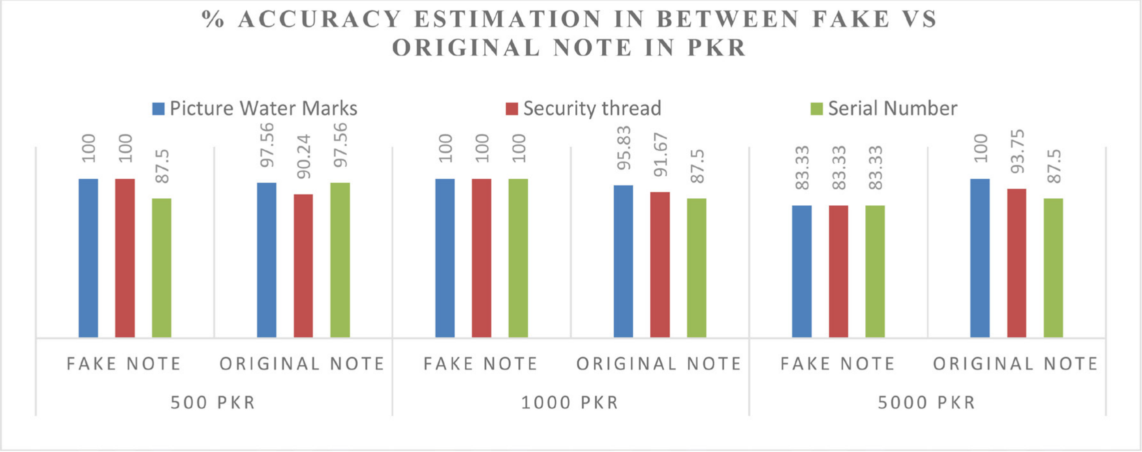


Figure 7: Accuracy Estimation between the fake and original notes

5. Counterfeiting Detection and Sorting Mechanism

Another method is proposed which is also implemented in the prototype for sorting the fake and genuine currency is categorized into three main processes.

- Detection of the Currency
- Recognition of counterfeiting
- Sorting of the fake note from the original

5.1 Designing Concept

The note is fed inside one by one on the conveyor. For detecting the presence of the note, sensors are placed at various points of the conveyor to start or stop the conveyor. The first sensor will start the conveyor after the note is placed on it. The conveyor is stopped after a 2-second delay when passed through the sensor so that the note will be in the desired location under the camera box. Arduino will send a signal to MATLAB to capture pictures and the camera takes a picture of the input note. If the input note entered is, e.g., of Five Hundred rupees, then MATLAB process it, and a message box appears showing the detected note through the relay, the UV light is turned on and a picture is taken again under UV light. Using image processing, the glowing strip on the note is checked, by which real or fake note is detected. After the detection of the note, the conveyor will start again. There is a secondary part, i.e., a sorter placed just near the end of the conveyor where the note will drop off. If the note detected is, e.g., of five hundred rupees will drop in the box of five hundred in the sorter. A sorter contains eight boxes where every denomination of note will be placed after being detected by MATLAB. The sorting mechanism contains boxes of 10, 20, 50, 100, 500, and 1000, fake notes, and one of origin. We have not worked on the 5000 rupees note in this system, but it can also be easily done.
The system will count the number of notes entered from the beginning and display on the LCD how many notes are entered of different denominations, whether it is the fake note or real note it will also show the number of fake notes entered into it. During this process, the controller used is Arduino, and serial communication of MATLAB and Arduino is taking place. Arduino controls the motion of the two motors is conveyor motor and the sorter motor and also relay, sensors, and LCD are controlled by Arduino.

5.2 Mechanical Design

The mechanical structure shown in Figure 8, consists of just material instead of using aluminum, steel, or wood due to its low cost. A conveyor is of about 8’ x 30’inch base and a height of about 5’inch. A camera box of about 8’ x 8’ inches of the base is attached to the conveyor. It contains a height of about 12’inch. The camera is mounted on the box. The motor is mounted on the conveyor to move its belt of it.

A stepper motor is mounted beneath the sorting mechanism to rotate the sorting mechanism with precision. The stepper motor position will be set according to the currency detected so that if a 50 rupee note is detected it will move in such a way that the box assigned to collect 50 rupees will directly come underneath a conveyor belt. Every currency note is collected in its predefined box aligned with the step count of the stepper motor.

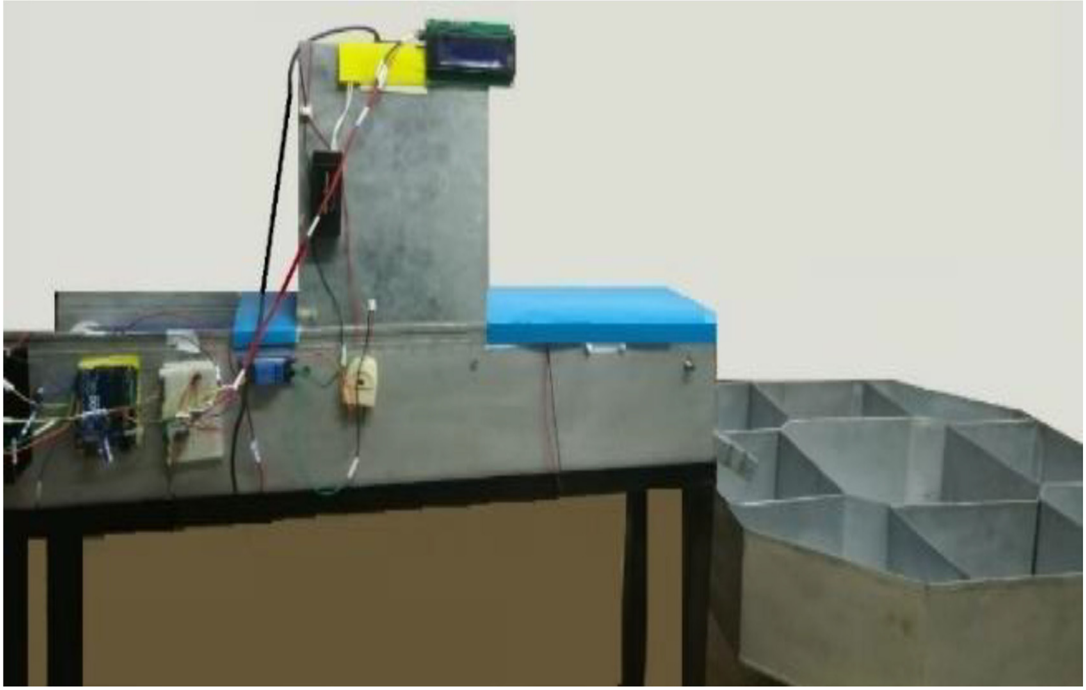


Figure 8: Proposed design mechanical structure.

5.3 System Design Flowchart:

Figure. 9, represents the complete process of the proposed system design. When the sensor detects the presence of the note, the conveyor is started. When the note is passed through another sensor then this detection is forwarded to Arduino which sends a signal to MATLAB to capture an image of the note using the webcam. After the image has been taken, it is further processed using the MATLAB tool to compare with reference images of notes in the database for identification. If the note detected is 500 or 1000, it will capture another image in UV light and check if the strip glows or not. If the strip glows, then MATLAB will declare it real otherwise fake. Once the process has been done MATLAB will send data to Arduino to restart the conveyor motor and stepper motor to make the detected denomination box in front of the conveyor

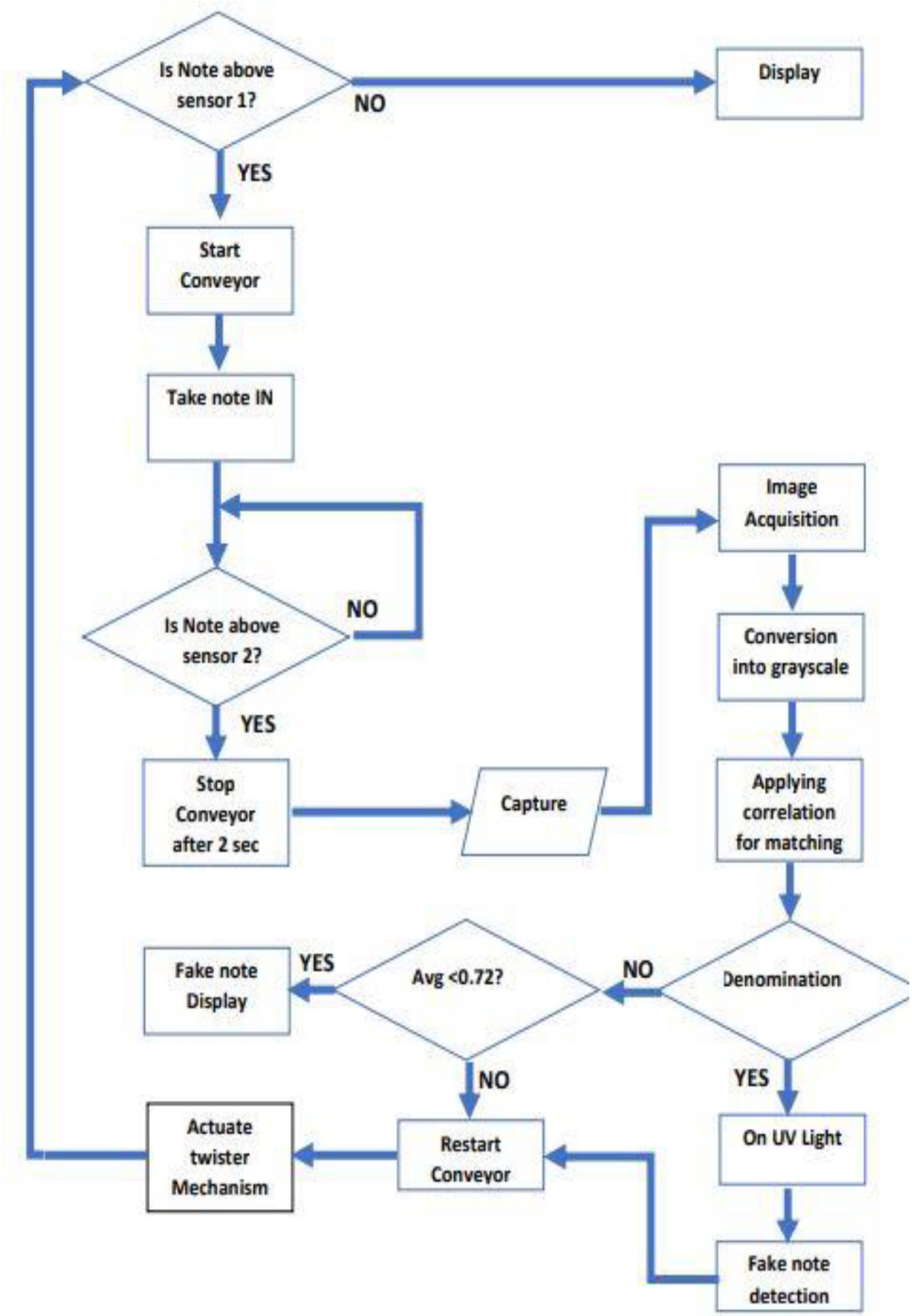


Figure 9: Flowchart of the proposed system

https://doi.org/163: 10.51153/kjcis.v6i1.163

5.4 System Block Diagram

The entire system is based on serial communication between the LAPTOP (MATLAB) and the microcontroller. Control functions are performed by Arduino and image processing by MATLAB. Figure. 10, represents the overall view of the proposed prototype.

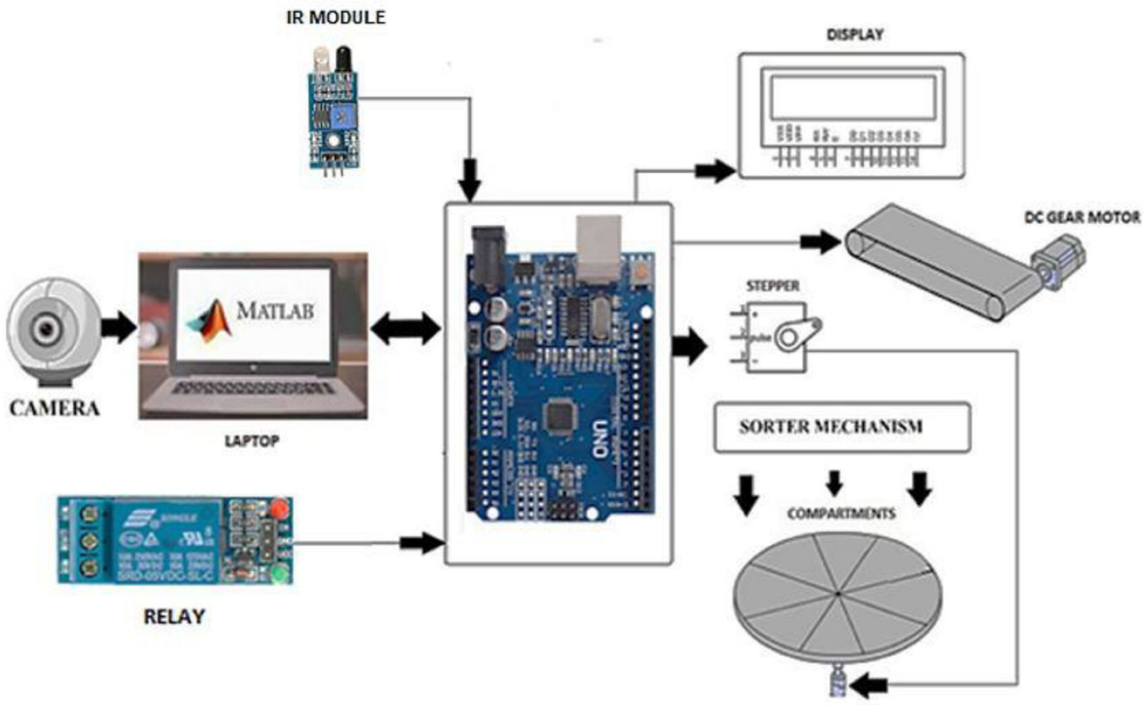


Figure 10: Block Diagram of the proposed system

- Arduino is used to controlling the process. The work of the controller is to instruct MATLAB to capture images using the webcam and control the sorting mechanism according to the data received from MATLAB. It is also controlling the sensors, the conveyor motor, and the relay.
- Image processing tool is utilized through MATLAB environment and serial communication will be achieved through Arduino
- For images, the webcam is used and it will take pictures of every incoming note and will forward it to the processing unit.
- The conveyor is used to convey the note from the start to the sorting mechanism.
- Based on suitable processing, the result sends by MATLAB to Arduino. The compartment of the detected denomination will be made in front of the conveyor so that the note drops in its respective compartment.
- IR sensors are controlled by Arduino. IR sensors are used to detect the presence of the note.

The first IR sensor will start the conveyor. The second IR sensor is used to stop the conveyor after a 2-second delay when so that note will be in the desired location under the camera box

- LCD used in our system is of dimension 20x4 to display our sorted/counted notes and counterfeit notes it's alphanumeric. An LCD that displays processed information
- Relay is used for switching led light to ultraviolet light in our system for detecting counterfeit notes

5.5 Recognition Technique:

Figure. 11 represents the proposed design method for the recognition of notes.

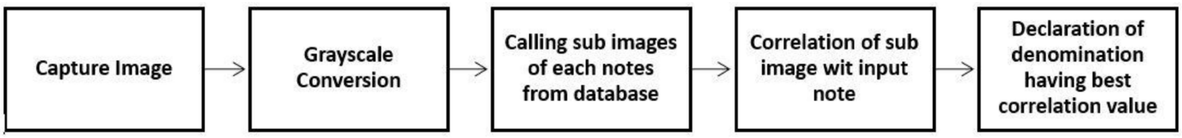


Figure 11: Proposed steps of note denomination recognition

- Image Capture: The image is captured using the webcam. Webcam A4 tech was used to capture the image. The captured image size should be of the same size as of images captured before being used as a reference for matching. The unique features of each note reference image are segmented into four sub-images, making it four unique features of one note. Sub-images are made using image segmentation and saved in the database.

- Grey Scale Conversion: For identifying the image, the first step is the conversion of the image from RGB to greyscale intensity image to remove the information of saturation and hue resulting, the only information of luminosity is retained. Figure 12, shows the proposed system's result of conversion RGB into greyscale.

Figure 12: RGB to greyscale

- Calling Sub Images From DataBase: After the greyscale conversion, the four sub-images of each note saved in the database will be called for further processing.

- Correlation For Matching: All four sub-images of each note will be correlated with the input image. Each sub-image will be compared with the input note. After that, the average of correlated values of the four sub-images will be taken. Fig. 13, represents the note denomination process [28].

- Declaration Of Denomination: The denomination having the greatest average will be declared as the input note. If the greatest average is below 0.72 then it is declared a fake note.

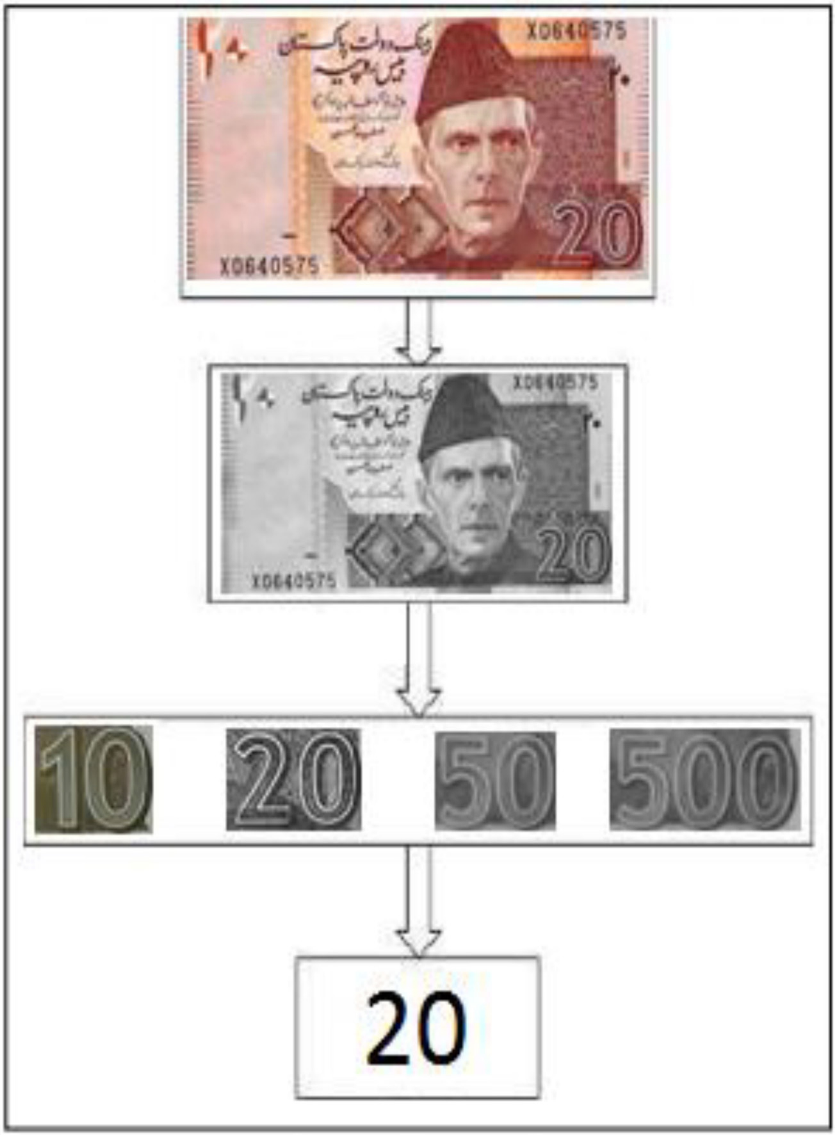


Figure 13: Note denomination recognition

For fake notes, the recognition image is captured in UV light, which is further processed. In this method, green color recognition technology is used for detecting real or fake notes. Figure 14,

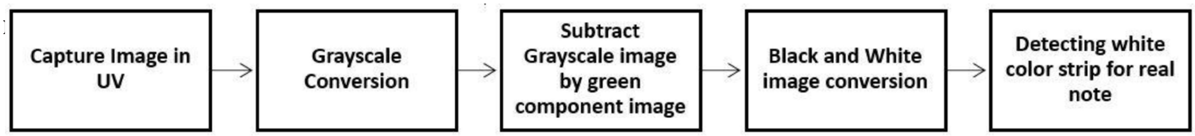


Figure 14: Proposed steps of fake note detection

Figure 15, shows if it is a real note, then the strip will glow otherwise strip will not glow. The detection can be done by the color of the strip by subtracting the greyscale image of the input note with a green component of the input image taken under UV light then the image will be converted to a black and white image. If a white color strip is detected, then it is declared a real note otherwise a fake note.

Figure 15: Images differentiating between real and fake notes

6. Hardware results

The system successfully accepts banknotes, including old notes and crumpled and worn-out notes. Through this system, denominations can be identified and sorted into their compartments. Counterfeit notes can also be detected and sorted in its compartment. Figure 16, shows the final results which display on LCD after sorting the currency

Figure 16: LCD of counting and sorting system

7. Conclusion and Future Recommendations

This research suggested a new approach for identifying genuine banknotes from counterfeit ones using the image processing technique that was implemented in MATLAB. The features of the banknote include a picture watermark, security thread, and serial number extracted. Many existing counterfeit detection technologies are very costly devices. The proposed method utilized ordinary RGB photos, and the algorithm is based on image processing. Image processing methods that do acquisition and characteristic extraction are used to accomplish this operation. The processing can be done quickly and efficiently because of the algorithm's simplicity. This algorithm can be further incorporated into android-based apps with various methods. For instance, MATLAB Coder is a toolbox that is used to convert MATLAB code into C/C++ code. It can be done either manually, using the MATLAB function in C to translate the MATLAB code into native C but it necessitates extensive and time-consuming programming work or automatically converts the MATLAB code using MATLAB coder but it necessitates the purchase of a very costly MATLAB Coder.

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