COUNTERFEIT CURRENCY IDENTIFICATION SYSTEM - A CASE STUDY ON ETHIOPIAN BIRR NOTE

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ABSTRACT

Counterfeit notes came into circulation right from the time of existence of genuine notes. A number of techniques like first line inspection methods, second line inspection methods and smart money counterfeit detector are being used in many countries to identify the genuine notes from the fake ones. The other method is manual inspection, which is currently used in Ethiopia at the banks. Though experts make right decisions based on their years of experience, it is however important to avoid any bias by humans. So, there should be some technique that should help the banks and insurance companies to precisely identify the counterfeit currencies. This work proposes and implements a Counterfeit Currency Identification System (CCIS) based on Cauchy–Schwarz inequality algorithm.

Keywords: *Banknote recognition, Cauchy-schwarz inequality, Counterfeit currency identification.*

INTRODUCTION

Currency counterfeiting is a common problem around the world, because highly sophisticated devices such as photocopiers, digital cameras, digital scanners, and printers which highly contribute to the work of counterfeiting are easily available to counterfeiters to reproduce pictures, logos, symbols, etc. Sometimes, it is very difficult to discriminate the fake notes from the genuine ones by simply looking at the paper notes. It needs additional means of identification using sophisticated currency identification hardware devices or machines. So, all countries are trying to tackle as much as possible, or at least minimize the risk of counterfeiting by enforcing different measures and techniques [1], [2].

Few of the existing techniques are: First-Line Inspection Methods, Second-Line Inspection Methods and Smart Money Counterfeit Detector Pen (Money Tester Pen). The other method is by just looking at the suspicious bank notes against bright light to check for the alignment of symbols, continuity of lines and for the availability of watermarks which are unique to genuine bank notes. This manual method is currently being used in Ethiopia at the banks. However, to avoid human errors, it is mandatory to automate the identification system.

So, the main objective of this work is to identify and implement a suitable technique to correctly identify the counterfeit currencies. Ethiopian 100 birr is taken as a case study in this work.

LITERATURE SURVEY

A number of techniques like first line inspection methods, second line inspection methods are being used in different countries to tackle the counterfeiting problem. First-line inspection methods are used on-the-spot by vendors and retailers to determine the authenticity of currency being exchanged. First-line inspection methods are Varied-Density Watermarks, Ultraviolet Fluorescence, Intaglio Printing, Micro text Holograms and Kinegrams. A second-line inspection method is one that cannot be verified by the naked eye alone, but requires an extra device to perform the verification process. These are more secure than visual methods, but the additional security increases the cost at both the manufacturing and verification ends. Second line inspection methods are Isocheck/Isogram, Fiber-Based Certificates of Authenticity, Color and Feature Analysis [9], [8]. The Patented Smart Money Counterfeit Detector Pen (Money Tester Pen) has revolutionized counterfeit detection. Since the advent of color photocopy machines and printers, there has been a surge in casual counterfeiting. This approach works by simply running the pen over the currency which required to be detected. While no method of counterfeit identification is foolproof, Smart Money Counterfeit Pen is a very good option and will detect a great majority of non-genuine notes. For more protection, it is recommended that this device be used in conjunction with other identification methods. This technique is widely used for US and Canadian notes [8]. Apart from this work, lots of other detecting techniques are also patented such as barcode scanner [5], ultraviolet detector [7], detecting using infrared beams [6] etc.

Apart from the techniques/methods mentioned above, countries have implemented and are implementing algorithms and enforcing different measures to discourage counterfeiters. Some of the algorithms are: Cellular Neural Network (CNN) Algorithm, Inductive Learning Rule-3 Algorithm, and Cauchy–Schwarz inequality Algorithm. CNN algorithm is efficient because of the use of CNN universal machine which is faster, but costly and more complicated, and is not applicable for counterfeit currency discrimination and identification; it is used only for discriminating the genuine banknotes [4]. Inductive learning rule-3 algorithm is used for the discrimination of the banknotes, i.e. to classify a given banknote to a predefined class (designation) of banknotes. This algorithm saves memory space, and it is easy and cheap compared to CNN, but it is complicated and expensive when compared to Cauchy-Schwarz. But, this algorithm is unable to recognize counterfeit banknotes and takes time for the learning process, thereby slows down the processing speed compared to CNN and Cauchy–Schwarz inequality algorithms. This algorithm has been implemented to discriminate all denominations of Turkish banknotes. The system has been trained for back and front sides of 5 different Turkish banknotes. The system also has been tested using 24 "unseen" examples and correctly classified all of them. The efficiency of the system has been found to be 100% [3].

Since both CNN and Inductive learning rule-3 algorithms are used only for discriminating genuine currency notes and not for identifying and discriminating the counterfeit currencies, an algorithm is needed to address this problem of discriminating and identifying both genuine and counterfeit banknotes. Cauchy–Schwarz inequality algorithm can be used for this purpose.

None of these above mentioned techniques/ algorithms are implemented in Ethiopia for banknote identification at present. So, this work proposes Cauchy–Schwarz inequality algorithm for the identification purpose.

CAUCHY–SCHWARZ INEQUALITY

The Cauchy–Schwarz inequality theorem is useful for measuring the similarity measure between two images. The algorithm is explained elaborately in [10].

ANALYSIS OF CCIS

It is important to analyze the requirements of CCIS before designing the system. The important requirement of the system is to distinguish the notes between genuine and fake based on the features of genuine note. So, it is important to understand the distinguishing features of the genuine note. Figure 1 shows the scanned image of genuine Ethiopian 100 birr note. The features that are pointed are considered as unique features of genuine 100 birr note by National Bank of Ethiopia (NBE).

Figure 1 Genuine Note: Image obtained using digital Scanner

The details of the features are: No.1 indicates thick bar consisting of logo of NBE, different colors, symbols and others. The circle that is shown by No. 2 is exactly aligning with a similar circle at the overleaf while seeing against sunlight. No. 3 points to the printing date in Ethiopian and Gregorian calendar. No. 4 shows a watermark of map of Ethiopia, with the text denoting the denomination of the birr note.

Apart from the features shown in Fig. 1, there are few more lines and watermarks which are visible only while seeing against sunlight. Bankers use those features also to check for an alignment of different symbols and for the continuity of lines available on the notes to identify the counterfeit currencies. Therefore, it is very important to capture those invisible features also to automate the identification process. The images are taken by digital camera using UV light to acquire those invisible feature. Figure 2 shows the corresponding image and the features that are pointed indicate the additional features of the genuine note. No. 1: A watermark of farmer plowing is seen on the white area while seeing against light. No. 2: The line looks discontinuous, but it is continuous in light. On this continuous line, the phrase "National Bank of Ethiopia is written in English and Amharic."

Figure 2 Genuine Note: Image taken by digital camera using UV light

The change in color is due to the UV light falling on the camera lens. Further, the features at the back side of the note overlap with the front side features.

Apart from the features mentioned in Fig.1 and Fig. 2, there are other important features which can be noticed in the genuine note such as the quality of the paper and the texts written on the note which can be felt when rubbed with fingers (embossed features).

Only one side of the birr note is enough for the identification purpose, because there are no watermarks and invisible lines on the other side of the note. Also, the bankers are verifying only the front side to discriminate the notes. Added to that, it is very easy for the counterfeiters to duplicate the back side as it is in the original note. Due to the above stated reasons, this work concentrates only on the front side of the note.

DESIGN OF CCIS

Hence, two approaches are proposed in this work: Approach I (image obtained using digital scanner) and Approach II (Image taken by digital camera using UV light). The proposed CCIS is shown in Fig. 3. The explanations of the block diagram corresponding to both the approaches are given below:

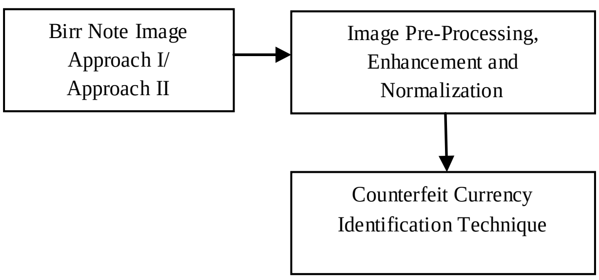


Figure 3 Proposed counterfeit currency identification system

Birr Note Image: Two approaches are suggested for collecting the test images. In the first approach, images are collected by scanning the genuine birr notes and in the second approach, images are obtained using digital camera and UV light.

Image Pre-processing, Enhancement and Normalization: Generally, the pre-processing of an image involves creating a uniform background and converting the image into binary format. Then the images should be filtered to reduce the noise. This noise can be due to the dirt on the birr notes, the quality of the digital scanner, digital camera used, and the background against which the images are taken. After filtering, the data must be transformed into a form useful for the selected algorithm.

Counterfeit Identification Technique/Algorithm: The image processed by the above steps will be given to a suitable CCI algorithm to identify the notes. Cauchy–Schwarz inequality algorithm is selected for this work to measure the similarity between the genuine and test images and to decide whether a given birr note is genuine or not. A threshold value will be set after performing the counterfeit test with large number of samples. If the similarity value is greater than or equal to the threshold value, the birr note will be considered to be “genuine”; otherwise will be considered as suspicious or fake.

IMPLEMENTATION PHASE

The process of implementing the CCIS involves three basic steps: Collection of genuine and fake currencies, processing the images of these currencies, and comparing the images of genuine with that of fake ones using Cauchy–Schwarz inequality algorithm.

Data Collection: In this work, genuine and fake birr notes are collected for the testing purpose. The notes are collected by taking into consideration the age of the notes and the dirt on the notes as criteria. New genuine note is used as a benchmark to compare against with any other sample note. Some of the genuine birr notes are old and some of them are very old and torn. The fake birr notes are almost new, except the number of hole punches (hole punched by the bank in order to avoid the circulation) on the birr notes. The number of fake notes collected for this work is very limited as it is very difficult to get the fake notes (even the hole punched ones) from authorized body.

Image Processing: The digital images (JPEG format) of both the genuine and fake 100 birr notes are taken using digital scanner (HP Scan jet 5100C, 600 dpi) and by digital Camera using UV light.

Some of the lines, symbols and watermarks are visible only if the birr notes are seen against light sources. In this case, UV light is used as light source. The color of the image in this approach has changed due to the fact that the UV light passes through the notes while the images are taken. Also, some of the features from the back side of the notes are overlapping with the front side features. However, the color of the old birr note has not changed much. This may be due to the fact that the age and dirt on the old birr notes blocks the light to pass through the notes.

Image Pre-processing Stage: In part-I of this stage, the size (5.813 inches by 2.813 inches) and resolution (90 pixels/inch to 200 pixels/inch) of the images (JPEG images) are adjusted using Adobe Photoshope 7. In part II, image processing toolbox of MATLAB is used to create a uniform background.

Image Enhancement: The images of the birr notes (genuine and fake) should be filtered to reduce the noise. This filtering is done at different levels using MATLAB functions. There are various types of noise removal techniques. A convenient property of filtering is that filtering a three-dimensional image with a two-dimensional filter which is equivalent to filtering each plane of the three-dimensional image individually with the same two-dimensional filter. So, it is sufficient to make use of a two-dimensional filter. In this work, linear filter which is a 2-dimensional filter has been used.

Normalizing the pixel values: The pixel values of the images ranges from ‘0’ to ‘255’. Since, Cauchy–Schwarz inequality algorithm yields the similarity measure value between ‘0’ and ‘1’, the pixel values are normalized to take values between ‘0’ and ‘1’.

Counterfeit Identification Technique /Algorithm: Similarity measuring technique is implemented using Cauchy-Schwarz algorithm. In this technique, the similarity values are calculated between the benchmark note (new genuine) and other genuine and fake (new and old) birr notes. This technique is applied to both the approaches. The results of these approaches with their respective drawbacks (limitations) are given below.

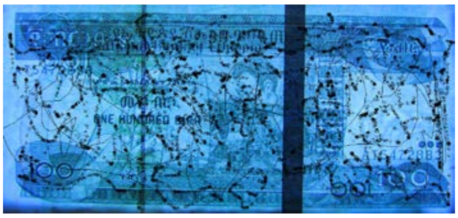
A number of tests are carried out. Sample results of approach I and approach II are shown in Table 1 and 2 respectively. In all these cases, the test images in Table 1 and 2 are compared against the benchmark images shown in Fig. 1 and Fig. 2 respectively.

Table 1: Sample results of approach I

No	Test Images	Similarity Values
1	New genuine note 	1.0
2	New genuine note: Noise added manually 	0.9635
3	Old genuine note : aged, dirty and lost some of the features of genuine note 	0.8573
4	Old genuine note : aged, torn with much dirt and folding 	0.8148
5	Old fake note : better paper quality compared to test image No.6 	0.7603

6	Old fake note : torn, lot of folding with poor paper quality 	0.7362

Table 2: Sample results of approach II

No	Test Images	Similarity Values
1	New genuine note 	1.0
2	New genuine note: noise added manually 	0.9721
3	Old genuine note : aged, dirty and lost some of the features of genuine note 	0.8904
4	Old genuine note : torn, aged, dirty and lost all the features of genuine note 	0.8836
5	Old fake note : better paper quality compared to test image 6 	0.7402
6	Old fake note : torn with lot of foldings 	0.7318

The following Table 3 depicts the average similarity measure value between the birr notes.

Table 3: Average similarity values between the birr notes

Approaches	Between Genuine notes	Between Genuine and fake notes
I	0.9116	0.7578
II	0.9293	0.7423

As it can be seen from the above Table 3, the results of approach II are better than that of approach I. The average similarity measure value of approach II between genuine birr notes is higher (0.9293) than that of between genuine and fake ones which is lower (0.7423). This interval between the genuine and the fake notes is higher in approach II than that in approach I. This is due to the visibility of some of the features such as watermarks, hidden lines and symbols on the images taken by digital camera while these are invisible on the images obtained using digital scanner. In spite of capturing the important features in approach II, the similarity interval between the notes is not much higher than that of approach I. This may be due to the change in color of the image and also due to the overlapping of the overleaf features with the front end features.

Finally, by considering the results obtained and the limitations of both the approaches, approach II is considered to be preferable compared to approach I for CCIS.

Based on the values obtained in Table 3, the threshold value is set to 0.80 (for this work) by considering the similarity measure values obtained for each test in both the approaches. When tested, the birr note with similarity measure value above the threshold (0.80) is considered as “genuine note” otherwise, the note is considered as “suspicious or fake birr note”.

CONCLUSIONS

The following conclusions have been drawn:

- A methodology for identifying the fake Ethiopian 100 birr note has been proposed and implemented based on similarity measure and the results are found to be promising to distinguish the notes with a threshold of 0.8.
- From the test cases, it is observed that torn, aged, folded and the dirty notes have less similarity compared to the new notes.
- From the fake note test cases, it is observed that paper quality is playing a significant role.

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