Bangladeshi Paper Currency Recognition System Using Supervised Learning

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Abstract—**The characteristics of currency note vary from country to country. The recognition of currency depends on the characteristics of currency note of a particular country. Due to use for a long time, currency note may be contaminated by noises. It is difficult for a system to recognize old, torn, and noisy images of currency. This work focuses on Bangladeshi paper currency recognition based on supervised learning. Here a recognition system for Bangladeshi banknotes has been proposed. Initially, it receives the images of Bangladeshi banknotes as input. Then each image is divided into three channels. Filtering is applied to each channel. Finally, the red, the green, and the blue channels are recombined to get back the RGB image. Different features such as HSV, edge, and grey-level co-occurrence matrix are extracted from the RGB image. Total features are stored. Then Euclidean distance of features between the input image and the template images are computed. The minimum distance provides the required output. The performance of the proposed system has been evaluated using a challenging dataset with a wide variety of conditions, such as old, dirty, and torn banknotes.**

Keywords—Currency recognition; Supervised learning; Image processing.

I. INTRODUCTION

The purpose of the currency recognition system is to recognize the currency note by utilizing different techniques and methods on it. This system can be used in many places, such as banks, ticket counters, currency exchange services, hotels, shops, and automated teller machines (ATM), etc. Pattern recognition has been applied in various application domains for solving real-world problems. These problems include direct and parallel implementation of matching and searching algorithm, feature extraction from complex datasets, forecasting, and prediction in a rapidly varying environment, image processing, and recognition applications, etc. One of the important application domains of pattern recognition is the recognition of currency. Here supervised learning is used to recognize Bangladeshi paper currency.

II. RELATED WORKS

The authors of [1] presented an invariant feature extraction method that is not sensitive to the variation of scale, rotation, and translation of banknotes. This method declines data variety and ameliorates the reliability of the classification of banknotes. Furthermore, its computational complexity is low to meet the requirements of real-time classification of banknotes. It has performed effectively when it is applied in banknote sectors. This invariant feature extraction method is well suited for the low-quality images which are acquired at high-speed banknote channel. Furthermore, the computation is simple in order to finish the banknote image processing and classification in real time. Then, a 3-layer back-propagation network is used to predict the face and value of a banknote.

A currency recognition system is proposed using Ensemble Neural Network (ENN) in [2]. This system can only recognize noisy & old images. It requires a large number of training examples.

"Ref. [3]", the author developed a scheme for the recognition of Bangladeshi banknotes using the neural network. It can be implemented efficiently in inexpensive hardware which may be very useful in many places. The input images of banknotes are scanned by the low-cost optoelectronics sensors and then, fed into a multilayer perceptron. This perceptron is trained by the back-propagation algorithm to recognize the banknotes. In the preprocessing stage, Axis Symmetric Masks are used that reduces the size of the network and ensures the correct recognition even if the banknote is flipped.

The authors in [4] implemented a new technique for the recognition of paper currency that utilizes three characteristics of currencies, such as size, color, and texture. The limitation of this technique is that the currencies of different countries may have to be same in size.

In [5], a technique using two sensors has been proposed where one sensor is used to discriminate the known image and another is to exclude the unknown image. This method required too much time to recognize.

The authors have represented a heuristic analysis of characters and digits of the serial number of currency notes to recognize Indian currency notes [6]. This method is sensitive to various types of transformations.

"Ref. [7]", the authors presented a new technique to recognize paper currency that employs two classifiers namely the weighted Euclidean distance using suitable weights and the neural network. This technique is based on finding and

extracting some specific features of paper currency, and it also includes various processing steps. In the recognition process, many factors, such as image size, edge detection, Euler number, and correlation coefficient play important roles.

III. Proposed Currency Recognition Method

The proposed framework of the Bangladeshi paper currency recognition method is shown in Fig. 1 and it comprises of several steps. Those steps are presented as follows:

i. READ the input RGB currency image
ii. Separate into Red, Green and Blue channels
iii. Denoise each channel of the image
iv. Recombine channels
    a. SET *fet* to [color feature, edge feature, texture feature]
    b. SET size of the database to zero
v. READ the size of the database
vi. FOR counter is less than the size of the database
    a. READ database image [counter]
    b. Denoise each channel of the image
    c. Recombine channels
    d. SET *fet1* to [color feature, edge feature, texture feature]
    e. SET D[counter] to [CALCULATE Euclidean distance between *fet* & *fet1*]
vii. END FOR
viii. GET the index & distance for minimum D
ix. READ the value of index from the database
x. DISPLAY the value
    a. IF distance < 0.003 && distance == 0
    b. ADD image & value to the database
xi. END IF

A. Searching and Input RGB Image

The first step is to read the input image from the database folder. Here all images are Bangladeshi paper currency images. The *imread()* function browses the folder and selects an input image to open which is an RGB image.

B. Dividing Channels of RGB Image

The RGB image is divided into three channels- Red, Green, and Blue.

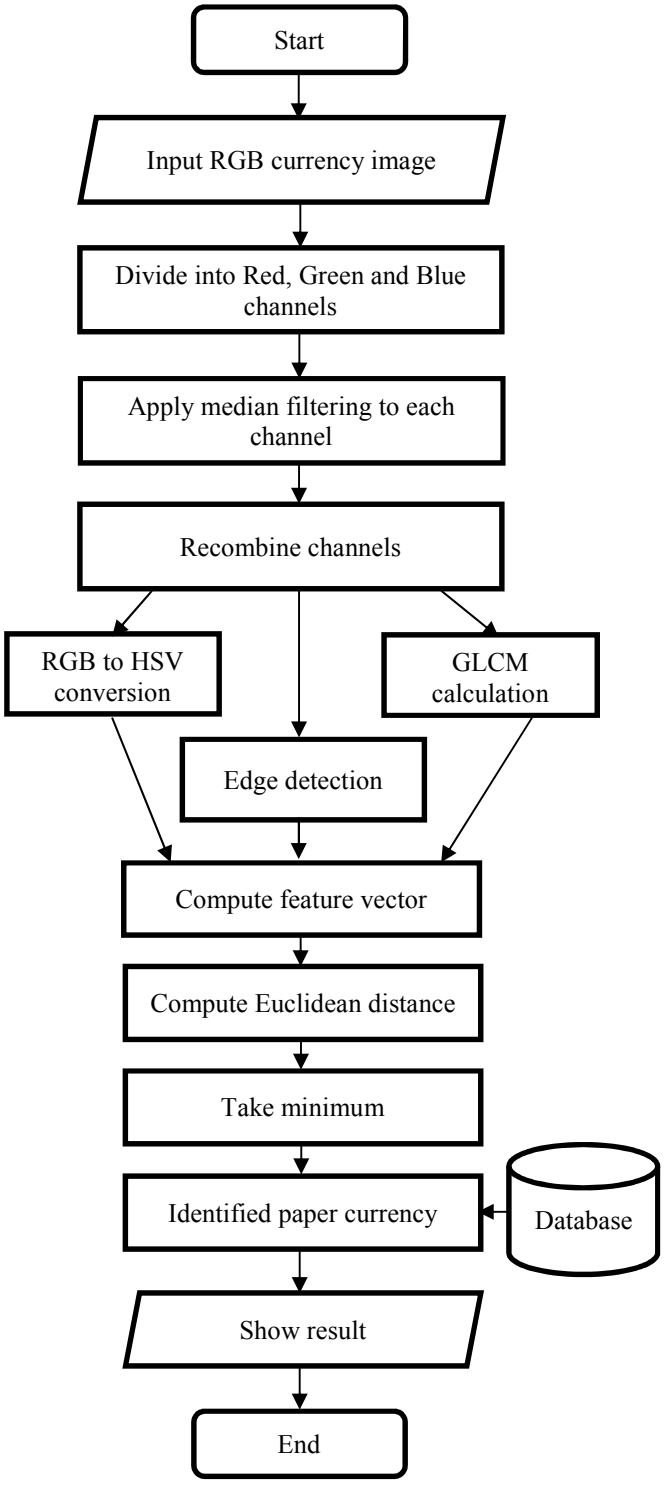

Fig. 1. The proposed framework

C. Removal of Noise

Noise is removed from each channel by applying median filtering. After removing noise, channels are recombined into RGB image.

D. Supervised Learning

In the pattern recognition method, the supervised classification of input data utilizes the supervised learning algorithms. Those algorithms create classifiers based on the training data from different object classes. Then the classifier takes input data and allocates the appropriate object or class label. The supervised pattern recognition techniques are applied for optical character recognition (OCR), object detection, face detection, and object classification, etc. in computer vision.

IV. RESULTS

The banknotes are divided into three categories, such as new, old, and torn. We have used a total of 185 notes of different types under these categories as shown in Table I.

TABLE I. NUMBER OF NOTES IN EACH CATEGORY

Note Type	New (111)	Old (36)	Torn (38)
2 Taka	8	5	5
5 Taka	16	4	5
10 Taka	17	5	4
20 Taka	14	3	6
50 Taka	13	4	6
100 Taka	15	6	3
500 Taka	11	4	5
1000 Taka	17	5	4

Some sample images of new Bangladeshi banknotes are given in Fig. 2. A number of sample images of old and torn banknotes are shown in Fig. 3.

Fig. 2. Some sample image of fresh Bangladeshi banknotes

The performance of the proposed system is evaluated using the following formula:

$$\text{Recognition accuracy} = \frac{\text{No.of recognized notes (old or torn)}}{\text{No.of total notes (old or torn)}} \quad (1)$$

Fig. 3. Some sample images of old, and torn Bangladeshi banknotes

The experimental results of old and torn categories of banknotes are summarized in the following tables. The system has tested 36 banknotes which have become old and wear out due to being used for a long period of time. The accuracy analysis of old notes is given in Table II.

TABLE II. RECOGNITION ACCURACY OF OLD BANGLADESHI CURRENCY NOTES

Note Type	No. of Testing Sample	Recognition Accuracy
2 Taka	5	79%
5 Taka	4	80%
10 Taka	5	78%
20 Taka	3	81.2%
50 Taka	4	80%
100 Taka	6	82%
500 Taka	4	81.81%
1000 Taka	5	80%
Average Accuracy		80.25%

The results show that this system can successfully recognize the old banknotes with an average accuracy of 80.25% in spite of having some incorrect recognition. An example of recognition of an old 10 taka note is depicted in Fig. 4.

Fig. 4. The recognition result of an old 10 taka note

TABLE III. RECOGNITION ACCURACY OF TORN BANGLADESHI BANKNOTES

Note Type	No. of Testing Sample	Recognition Accuracy
2 Taka	5	80%
5 Taka	5	83%
10 Taka	4	83.22%
20 Taka	6	80%
50 Taka	6	77%
100 Taka	3	85%
500 Taka	5	85%
1000 Taka	4	85%
Average Accuracy		85.28%

We have also tested 38 banknotes which have become partially torn for being used for a long time. Table III shows the recognition accuracy of the torn notes. The average accuracy of recognition of this category is 85.28%. A recognition example of an old and torn 1000 taka note is shown in Fig. 5.

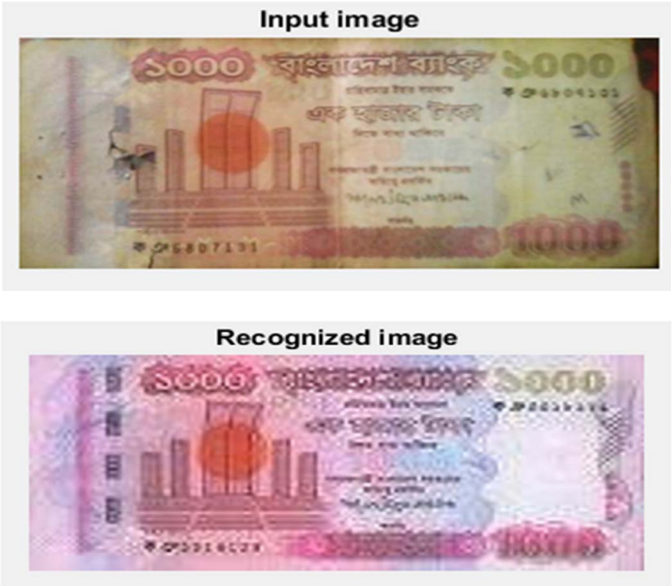

Fig. 5. The recognition result of an old and torn 1000 taka note

The overall recognition accuracy of above mentioned 74 old and torn banknotes of these two categories are summarized below in Table IV.

TABLE IV. OVERALL RECOGNITION ACCURACY OF OLD AND TORN BANGLADESHI BANKNOTES

Note Type	No. of Testing Sample	Recognition Accuracy
2 Taka	10	79.50%
5 Taka	9	81.50%
10 Taka	9	80.61%
20 Taka	9	80.60%
50 Taka	10	78.50%
100 Taka	9	83.50%
500 Taka	9	83.42%
1000 Taka	9	82.50%
Average Accuracy		81.27%

All of the experiments are carried out in a core(TM) 2 duo 2.4 GHz personal computer with a RAM of size 2048MB. The programs are written in MATLAB software. The latest version (R2015b) of the MATLAB software has been used.

V. CONCLUSIONS

This paper represents a system for recognizing Bangladeshi banknotes using supervised learning. Currently, there exist a few numbers of techniques for the recognition of paper currency. Most of the existing methods are limited to function under certain restricted conditions. But our system overcomes many of the restrictions and it is invariant against different rotations. The design of the system keeps very simple to implement it in the hardware easily. In order to evaluate the performance of the proposed method, a challenging dataset with different conditions has been used. It provides successful results for different types of currencies available in Bangladesh. It uses various effective and efficient image processing methods and algorithms to furnish accurate and reliable results. It also has the expected level of accuracy in recognizing old and torn banknotes. In future, our goal will be to develop a low-cost and high-precision banknote reader so that it can help the visually impaired people; and to make a system invariant against all types of transformation.

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