ROBUST FEATURES AND PAPER CURRENCY RECOGNITION SYSTEM

Allah Bux Sargano[1], Muhammad Sarfraz[2], NuhmanUl Haq[3]
[1,3]Department of Computer Science, COMSATS Institute of Information Technology, Tobe Camp, Abbottabad-22060, Pakistan.
Email: allahbux@ciit.net.pk
[2]Department of Information Science, Kuwait University, Adailiya Campus, P.O. Box 5969, Safat 13060, Kuwait.
Email: prof.m.sarfraz@gmail.com

Abstract

This paperproposes a new intelligent system for paper currency recognition. Pakistani paper currency has been considered, as a case study, for intelligent recognition. This paper identifies, introduces, and extracts robustfeatures fromPakistani banknotes. After extracting thesefeatures, the paper proposes to use three layers feed-forward Backpropagation Neural Network (BPN) for classification. The proposed technique and system are simple and comparatively less time consuming which makes it suitable for real-time applications. Implementation and experimentation of the proposed technique certify the authenticity to a high recognition.

Keywords - Intelligent system, currency recognition, feature extraction, classification, neural networks.

1. INTRODUCTION

Different paper currency recognition techniques have been proposed by many researchersfor differentcurrencies [1-8]. Existing currency recognition techniques are mainly based on processing of whole image using image processing techniques and neural networks.Sun and Takeda[2] proposed a new activation function to improve the rejection capabilities of NN for unknown patterns. They have used Gaussian function in hidden layer and output layer of NN in the place of sigmoid function. They have shown that the Gaussian function is more effective than sigmoid function for the recognition of known patterns and rejection of unknown patterns.

Frosiniet. al.[6]proposed a technique for currency recognition and verification used in banking machines. They used optoelectronic device to produce the signal from the light refracted by the banknote. The recognition and verification of the currency was performed by multilayer perceptron on micro-controller based environment. Verification was done with the help of auto-associaters by generating close separation surfaces in pattern space. They have tested their system for Italian banknotes. The accuracy of the system is 94.4%.In [7],Hassanpour and Farahabdi proposed a paper currency recognition technique using Hidden Markov Model (HMM). They have used texture based features for currency recognition. According to them, system has 98% accuracy for different currencies of the world.

This paper proposes robust features from Pakistani banknotes. After extracting these features, the paper proposes to use three layers feed-forward Backpropagation Neural Network (BPN) for classification. The proposed technique and system are simple and comparatively less time consuming. They provide 100% recognition in real time.

The rest of the paper is organized as follows. Section 2 describes the proposed methodology in detail. It includes various phases including collecting and scanning banknotes, preprocessing steps, and feature extraction. Section 3 describes the neural network training and recognition process. The experimentation and results are presented in Section 4. Finally, the paper is concluded in Section 5.

2. PROPOSED METHODOLOGY

The proposed methodology consists of three parts. In the first part, the banknotes are scanned and the database is developed. After scanning, the banknotes are preprocessed for noise as second part of the system. In the third part, important currency features are selected and extracted.The selected features are easily extractable, and have good discrimination power. These features are passed to neural network for classification in the fourth part. The fifth part shows experimentation results. All these parts have been described in the subsequent sections.

2.1 Banknote Collecting and Scanning

Unlike other recognition systems, where standard databases are available for training and assessing the performance of the recognition systems, no such standard databases are available for currency recognition in general to the best of authors' knowledge. This is specifically very true for Pakistani currency. This work has developed a database of 350 Pakistani banknotes, which includes 7 kinds of Pakistani banknotes (Rs. 10, Rs.20, Rs.50, Rs. 100, Rs. 500, Rs. 1000, and Rs. 5000). These banknotes have been scanned with the settings and assumptions explained in Table 1.

Table 1: Settings and assumptions for the proposed system.

#	Items	Specifications
1.	Resolution	200ppi, 24-bit picture scan mode
2.	Image Type	Jpeg
3.	Number of Banknotes scanned	350 including clean, noisy, worn and torn banknotes
4.	Values of Notes (in Rs.)	10,20, 50, 100, 500, 1000, and 5000

Figure 1: The effect of applying Wiener filter on 500 rupees noisy banknote, and 500 rupees clean banknote: (a) 500 noisy banknote before applying Wiener filter;(b) after applying Wiener filter on (a);(c) 500 rupees clean banknote before applying Wiener filter; (d) after applying Wiener filter on (c).

2.2 Preprocessing

Preprocessing step can significantly improve the performance of a recognition system. It is essential for the recognition of worn, torn, and noisy currency images [7]. During circulation, banknotes become worn and torn, and noise is also added with them. In order to minimize the effect of the noise and improve the quality of the image, it is important to apply a proper preprocessing filter. We have used Wiener filter for this purpose. Wiener is an adaptive low-pass filter [7] that is used to filter the gray-scale image degraded with constant power additive noise. It uses adaptive filtering based on the mean and variance estimation of local neighborhood of each pixel. This filter is equally useful for dirty and clean banknotes. Wiener filter also preserves the edges and other useful details. Figure 1 shows the effect of applying Wiener filter on 500 rupees noisy banknote, and 500 rupees clean banknote.Wiener filter estimates mean (μ) and variance (σ^2) around each pixel as shown in Eq. (1) and Eq. (2) respectively.

$$\mu = \frac{1}{NM} \sum_{n1,n2 \in \eta} \alpha(n1, n2) \quad (1)$$

$$\sigma^2 = \frac{1}{NM} \sum_{n1,n2 \in \eta} \sigma^2(n1, n2) - \mu^2 \quad (2)$$

where$\alpha$is $N\times M$ local neighborhood around each pixel in the image [11], then Wiener filter is created using Eq. (3).

$$b(n1, n2) = \mu + \frac{\sigma^2 - v2}{\sigma^2}(\alpha((n1, n2) - \mu) \quad (3)$$

wherev^2 is the noise variance, if it is omitted the Wiener considers the average of all local variances.

2.3 Feature Extraction

Instead of processing whole image, this paper proposes carefully selected very important and effective features from the currency banknote. These features have been selected from the list of featuressuggested by the issuing authority of the banknotes for banknote recognition. After reviewing and analyzing the user manual issued by the state bank of Pakistan [9], we concluded that following set of features would be the best to be used to distinguish different currency denominations.

- Aspect Ratio of the banknote
- Set of effective color features
- Binary pattern of Lettering Block of the banknote
- Binary pattern of See Through Block of the banknote
- Binary pattern of Identification MarksBlock of the banknote

2.3.1 Aspect Ratio of the Currency Image

Aspect Ratio is related to width and height of an image. Aspect Ratio (AR) of an image can be calculated as mentioned in Eq. (4). Aspect ratios of all Pakistani banknotes are different.

AR= Height of an image/Width of an image (4)

2.3.2 Set of EffectiveColor Features

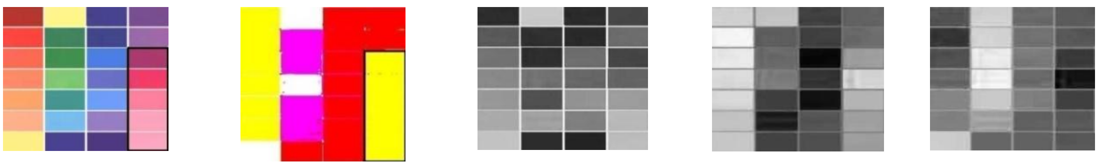
Color is one of the important features of any object. Many objects can be differentiated on the basis of colors. The effectiveness of color features set may be judged by the quality of segmentation results and calculation involved in transforming data from RGB to other forms [10]. In [10], I1I2I3 is a feature model rather than a color space. In an eight randomly chosen color images and eleven color spaces,I1I2I3achieved best segmentation results in color image processing. We have used this color model in our proposed system for color features. The orthogonal features I1, I2, and I3 can be calculated asshown in Eq. (5), (6), and (7) respectively.

I1=(R+G+B)/3 (5)

I2=(R-B)/2 or I2= (B-R)/2 (6)

I3= (2G-R-B)/4 (7)

In I1I2I3 space, all colors,having same characteristics, would always be mapped to the same color regardless of effect of noise as indicated by black rectangle inFigures2(a) and 2(b). Figures 2(c), 2(d), and 2(e) show I1,I2, and I3 imagesrespectively, calculated from RGB image given in Figure 2(a).



(a) (b) (c) (d) (e)

Figure 2: The effect of colors in I1I2I3 space: (a) RGB Image; (b)I1I2I3 Image; (c) I1 Image; (d) I2 Image; (e) I3 Image.

2.3.3 Lettering Block

Lettering is one of the important features indicated by the State Bank of Pakistan [9]. This is a denomination which appears in Urdu numeral at right top of the banknote, showing the value of the banknote. This is very important feature because each banknote will have a different denomination number. This feature is available in all Pakistani currency denominations on the same location with respect to their height and width and can easily be extracted. Figure 3 shows lettering figure in one thousand rupees banknote. To extract this feature, we have obtained the geometrical location of the feature and then extracted it from the currency image. After extracting lettering block, we have applied certain threshold“T” to get the prominent edges. The disconnected links of these edges are linked using morphological bridging and holes filling. Finally, we applied morphological erosion to remove the outliers and other unnecessary pixels surrounding the lettering block. The result of these operations is a complete lettering block in binary format. We calculate the binary (0/1) feature from this block by counting the number of ones and zeros in a block. Figure 4 shows the diagrammatic view of the step wise process of Lettering Block extraction.

Figure3: One Thousand Rupees Banknote.

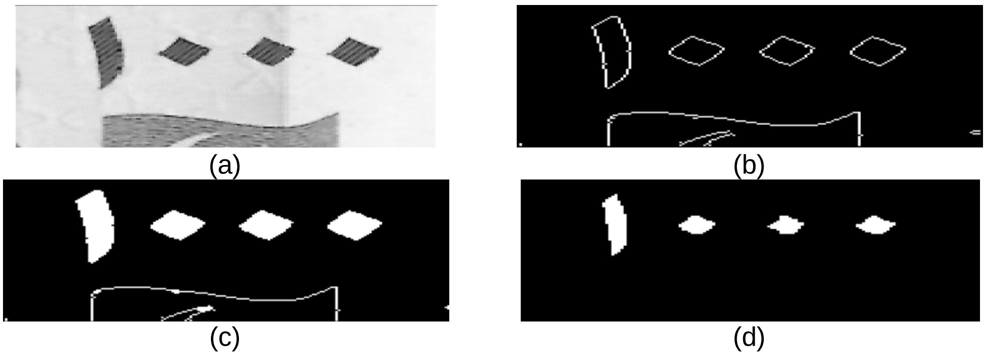
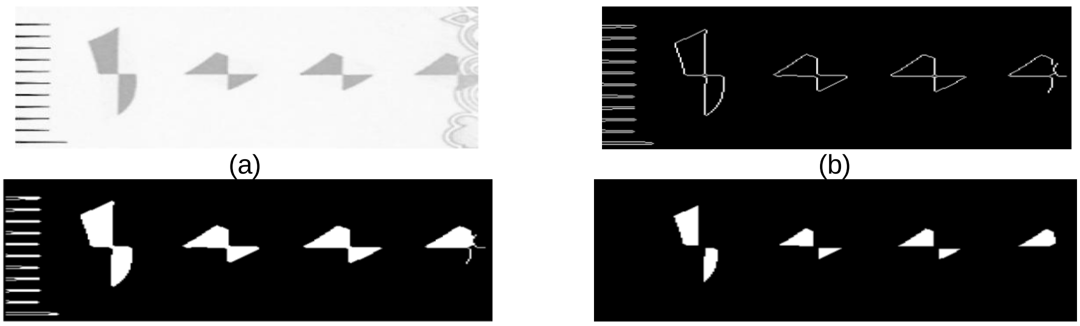


Figure 4: Step wise process of Lettering Block extraction: (a) Lettering Block; (b) After thresholding; (c) After bridging and hole filling; (d) Final image after erosion.

2.3.4 See Through Block

See Through figure is also an important feature highlighted by the State Bank of Pakistan [9]. This is value figure of the banknote that appears partly on the frontage left top and partly on reverse right top. This figure can be seen completely when viewed through light. It depicts the value figure of the banknote, thus provides information to differentiate banknotes denominations. Thisfeature is available in all Pakistani banknotes on the same location with respect to height and width of the banknote. Figure 3shows the See ThroughBlock in one thousand rupees banknote.



(c) (d)

Figure 5: Step wise process of See ThroughBlock extraction: (a) See Through Block; (b) After thresholding; (c) After bridging and hole filling; (d) Final image after erosion.

In order to extractthis block, we have obtained its geometrical location, and then extracted it from the currency image.We calculate the binary (0/1) feature from this block by counting the number of ones and zeros. Figure 5 shows the diagrammatic view of the step wise process of See ThroughBlock extraction.

2.3.5 Identification Marks

Identification Marks are also important features to differentiate the banknotes. These are raised perceptible circles or lines at left bottom side of the banknote. In case of 500, 1000, and 5000 denominations there are one, two, and three raised perceptible circles respectively. Similarly, in case of 20, 50, and100 denominations, there are one, two, and three raisedperceptible lines respectively. The currency Banknote of Rs.10 has no identification marks.Figure 3shows the Identification Marks on one thousand rupees banknote.

(a) (b) (c) (d)

Figure 6: Step wise process of Identification Marks Block extraction: (a) Identification Marks Block; (b)

We calculate the binary (0/1) features from this block by counting the number of ones and zeros. Figure 6 shows the diagrammatic view of the step wise process of Identification Block extraction.

3. BACKPROPAGATION NEURAL NETWORK TRAINING

After extracting currency features, a classifier is used to recognize the pattern of currency denominations. According to topological structure there are two types of NN: Feed-forward network, and Feed-back network.

In the proposed system, we have used Backpropagation Neural Network.The databases of 350 images is divided into two parts, half of the images are used for training the neural network and remaining half are used for evaluating the performance of the system. The training dataset consists of 175 images, including (10, 20, 50, 100,500, 1000, and 5000) rupees banknotes. Three layer feed forward Back propagation Neural Network with sigmoid activation function is trained with the learning parameters shown in Table 2.

Table 2: Backpropagation NN learning parameters.

Parameter	**Value**
Number of Banknotes	175
Banknote Types /Classes	7
Number of Hidden Neurons	30
Number of Inputs	10
Number of output neurons	7
Maximum number of iterations	1000

We have used feature vector of ten inputs, which includes aspect ratio, color features in I1I2I3space, and binary features of See through Block, Identification Marks Block, and Lettering Block. On hidden layer, 30 neurons have been placed. This number has been finalized by various experimentations.

Training database is commonly divided into three parts, Training part, Validation part, and the Test part. Usually 70% samples are kept for training, 15% data samples are kept for each validation and test respectively. The validation part is used for cross validation during training process of NN. It is used to validate that the system has been trained properly, and there is no over fitting or local minima problem.

4. EXPERIMENTAL RESULTS

To evaluate the performance of the proposed system, we tested 175 Pakistani banknotes of different denomination (10, 20, 50, 100, 500, 1000, and 5000). The test database includes clean, worn, torn, and noisy images. To measure the Recognition Ability (RA) of the system, we have used the formula shown in Eq.(8).

$$\mathbf{RA} = \frac{\textbf{Number of correctly recognized banknotes}}{\textbf{Total number of banknotes evaluated}}\ \mathbf{X100} \tag{8}$$

We have tested the system in two parts. In the first part, we have tested the system by passing 151 banknotes of different classes individually, including 10, 20, 50, 100, 500, 1000, and 5000 rupees banknotes. The recognition results are shown in Table 3. The results indicate that system has 100% recognition ability on all kinds of Pakistani banknotes.

Table 3: Recognition Results (RA=151/151*100 = 100%).

Banknote Type	Total Banknotes tested	Banknotes correctly recognized	Recognition Ability
10 PKR	10	10	100%
20 PKR	10	10	100%
50 PKR	28	28	100%
100 PKR	26	26	100%
500 PKR	28	28	100%
1000 PKR	38	38	100%
5000 PKR	11	11	100%

In the second part, we have tested 175 banknotes; 25 banknotes from each class (10, 20, 50, 100, 500, 1000, and 5000) of rupees banknotes. These banknotes are from the test dataset, passed against the targets. It can be seen that the system has 100% ability to recognize all kinds of banknotes including noisy banknotes.

5. CONCLUSION

In this paper, we have proposed a new technique and system for Pakistani banknotes recognition. It is based on robust monetary characteristics of the banknotes rather than processing the whole image. The methodology adopted is comparatively less time consuming and suitable for real-world applications. We have used three layers feed-forward Backpropagation Neural Network (BPN) for classification. In order to evaluate the performance of the recognition system, we created a database of 350 Pakistani banknotes; half of the images are used to train the network, while remaining half of the banknotes are used for testing purpose. The results indicate thatwith properly captured images system has 100% recognition ability.

References

[1] A Ahmadi, S Omatu, and T Kosaka, "A methodology to evaluate and improve reliability in paper currency neuroclassifiers," IEEE International Symposium on Computational Intelligence in Robotics and Automation, vol. 3, pp. 1186 - 1189, 2003.

[2] Sun Baiqing and Fumiaki Takeda, "Proposal of Neural Recognition with Gaussian Function and Discussion for Rejection Capabilities to Unknown Currencies," Knowledge-Based Intelligent Information and Engineering Systems, vol. 3213, pp. 859-865, 2004.

[3] Euisun Choi, Jongseok Lee, and Joonhyun Yoon, "Feature Extraction for Bank Note Classification Using Wavelet Transform," 18th International Conference on Pattern

[4] Bu-Qing Cao and Jian-Xun Liu, "Currency Recognition Modeling Research Based on BP Neural Network Improved by Gene Algorithm," 10. Second International Conference on Computer Modeling and Simulation, vol. 2, pp. 246 -250, 2010.

[5] K.K Debnath, J K Ahdikary, and M Shahjahan, "A currency recognition system using negatively correlated neural network ensemble," 12th International Conference on Computers and Information Technology, pp. 367 -372, 2009.

[6] A Frosini, M Gori, and P Priami, "A neural network-based model for paper currency recognition and verification," IEEE Transactions on Neural Networks, vol. 7, pp. 1482 -1490, 1996.

[7] Hamid Hassanpour and Payam M Farahabadi, "Using Hidden Markov Models for paper currency recognition," Expert Systems with Applications, vol. 36, no. 6, pp. 10105-10111, 2009.

[8] Ying-Ho Liu, Anthony J.T. Lee, Fu Chang, "Object recognition using discriminative parts," Computer Vision and Image Understanding, Vol. 116, no. 7, pp. 854–867, 2012.

[9] http://www.sbp.org.pk/Notes/, "Banknotes and Coins," Sate Bank of Pakistan, April 30, 2012.

[10] Yu-Ichi Ohta, Takeo Kanade, and Toshiyuki Sakai, "Color information for region segmentation," Computer Graphics and Image Processing, vol. 13, pp. 222 - 241, 1980.

[11] Rafael C. Gonzalez, Richard E. Woods and Steven L. Eddins, Digital Image Processing using MATLAB. Pearson Education, 2009.