A Paper Currency Recognition System with Novel Features

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ABSTRACT

One simple method of recognizing paper currencies has been introduced. It considers different dimensions, areas, Euler numbers, correlations between images as features. It uses Weighted Euclidean Distance for classification. The method uses the case of Saudi Arabian paper currency as a model currency under consideration. It uses fifth series of currency, issued by Saudi Arabian Monetary Agency (SAMA), as a model currency under consideration. It produces quite satisfactory results in terms of recognition and efficiency.

KEYWORDS

Intelligent system, paper currency recognition, feature extraction, classification, images.

1 INTRODUCTION

Object recognition [1-7] is an important and highly demanded area of pattern recognition. An object can be anything in real life. It can be text in a document, a license plate of a vehicle, an iris in a person's eyes, a sign in a sign language, a face of a person, and so on. Similarly, paper currency recognition [8-17] is as important as any other object recognition.

This work is motivated by another version of the work of Sarfraz [17]. In [17], Sarfraz has suggested features of different dimensions, areas, Euler numbers, and correlations. It utilizes radial basis function networks for developing an intelligent system which can recognize paper currency. This research was specifically designed for recognizing paper currency from the Kingdom of Saudi Arabia (KSA). It uses fourth series (1984–2007) of currency issued by Saudi Arabian Monetary Agency (SAMA) [18] as a model currency under consideration.

The proposed work, in this paper, is a continuity of the work done in [17]. It uses same features as in [17]. That is, it considers different dimensions, areas, Euler numbers, correlations as features. However, it differs in the series of KSA currency for recognition. Instead of fourth series, it uses fifth series of currency [18], issued by Saudi Arabian Monetary Agency (SAMA), as a model currency under consideration. This fifth domination of the Saudi Riyal was issued in 2007 and is currently a running paper currency in KSA.

The proposed work, in this paper, also differs in its method of classification. It uses Weighted Euclidean Distance for developing an intelligent system which can recognize paper currency. The proposed paper recognition technique has been designed in such a way that it can be used for recognizing paper currency for all the values of KSA paper currency. To overcome the problem of recognizing dirty banknotes, the pre-processing stage is also considered. The proposed methodology produces very effective results which are much superior to the recognition results in [17] using radial basis functions.

The organization of the paper is as follows. Section 2 introduces the overall mechanism for PCR, In Section 3, the pre-processing steps are briefly introduced. The proposed PCR approach, together with feature extraction method as well as classification has been completely discussed in Section 4. Section 5

describes details of demonstration for the case of KSA Paper Currency. Finally, Section 6 concludes the paper.

2 STRUCTURE OF TYPICAL PCR SYSTEM

The system presented is designed to recognize paper currency. Input to the system is an image acquired by a scanner or a digital camera, containing the paper currency and its output is the features of the paper currency. The system consists of the modules: Image acquisition, pre-processing including noise removal, feature extraction, classification and recognition. The diagrammatic structure of the proposed system is shown in Figure 1.

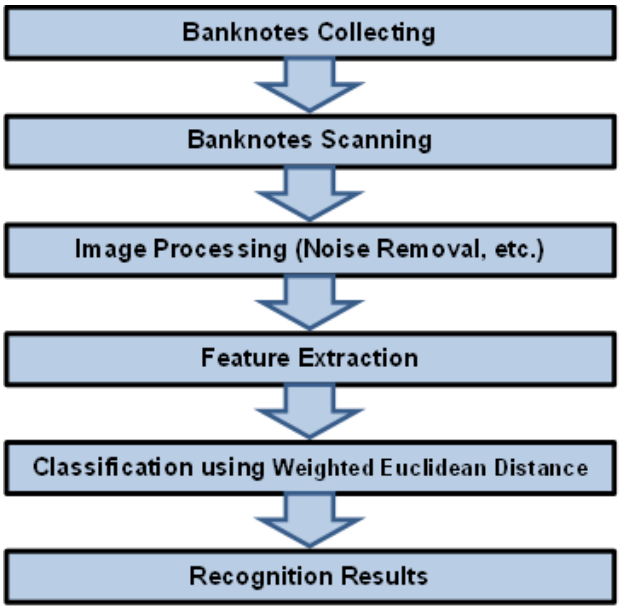

Figure 1. The Typical Structure of a Paper Currency Recognition System.

3 PRE-PROCESSING

In the proposed system a high resolution scanner is used to acquire the image. The acquired image of a paper currency is first converted to gray scaled image. Conversion to gray scale facilitates further pre-processing. The task of pre-processing is achieved by converting colored currency images into grayscale, then black-white images. After that, the edge of the image is filtered using Prewitt method. Then, the image edge is detected using Canny edge detection method.

This work is meant for Saudi Paper Currency Recognition System (SPCRS). The SPCRS is designed to just recognize Saudi paper currencies. Currently, there are six Saudi paper currencies, which are shown in Figure 2.

4 PROPOSED APPROACH FOR SPCRS

Since, the objective of the paper is to come up with an optimal technique which can lead to an intelligent system for SPCRS. Therefore, the interest would be to, first of all develop a mechanism to produce suitable features for each paper currency. A classification, afterwards, would be required for recognition part.

4.1 Feature Extraction

The novel features extracted constitute the input vector to the system. The input vector of the suggested features is $\{H, W, A_1, A_2, A_3, E, r\}$ where $H, W, A_1, A_2, A_3, E, r$ are defined as follows:

- H: the height of the image (in pixels),
- W: the width of the image (in pixels),
- A_1: the image area (sum of 1-pixels) without a mask,
- A_2: the image area with the Prewitt mask,
- A_3: the image area with the Canny mask,
- E: the Euler number of the image,
- r: the image correlation with the template images.

The details of $H, W, A_1, A_2, A_3, E, r$ can be seen in [17]. All of these features are robust and contribute in a very efficient way in the recognition of KSA paper currencies.

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Figure 2. Fifth series of paper currency issued by Saudi Arabian Monetary Agency (SAMA) [18] with six different values: (a) Saudi Riyal 1, (b) Saudi Riyal 5, (c) Saudi Riyal 10, (d) Saudi Riyal 50, (e) Saudi Riyal 100, (f) Saudi Riyal 500.

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4.3 Classification

The Weighted Euclidean Distance is the distance between two input vectors, with certain weights given to each element of the vector. It can be written in the general form as follows:

$$d^2(x_i, x_j) = \sum_{k=1}^{n} w_k (x_{ki} - x_{kj})^2$$

where x_i and x_j are the vectors to be compared, and w_k's are the weights for each vector component.

In this classification method, the two input vectors are compared using the following formula:

$$d = \sqrt{\begin{matrix} 0.5(a-\hat{a})^2 + 0.0005((a_1-\hat{a}_1)^2 \\ +(a_2-\hat{a}_2)^2 + (a_3-\hat{a}_3)^2 \\ +(e_1-e_2)^2) - 1000r \end{matrix}}$$

After computing all distances, the template with minimum distance value is selected, provided that the correlation value r is greater than a certain threshold, which was chosen to be 0.2.

Table 1. Experimental Results against an input currency of SR 50.

#	Description of Measures	Results
1.	Currency Input	SR 50
2.	H	397
3.	W	882
4.	A_1	18492.3
5.	A_2	7111
6.	A_3	9094.13
7.	E	4930
8.	r	0.980721
9.	Computation Time	1.000923
10.	Recognition	Yes

5 EXPERIMENTAL RESULTS

The above mentioned scheme has been implemented and tested for a database of 110 images. Reasonably quite elegant results have been observed. Table 1 demonstrates implementation results for an input currency of SR 50. One can observe various measures computed in the developed system. The table depicts the computed values of all the features together with computation time.

The Weighted Euclidean Distance Classifier was tested with a database of 110 images, 10 of which are tilted with an angle less than 15^o. The rest of the currency images consist of mixed including noisy and normal images 50 each. The recognition results are as shown in Table 2. Average recognition rate was seen as 99% which is most favorable and highly acceptable. As far as computation time is concerned, the Weighted Euclidean Distance Classifier took almost 1 second per image, in average, for classification.

Table 1. Experimental Results of the Weighted Euclidean Distance Classifier.

Normal Non-Tilted Images	Noisy Non-Tilted Images	Tilted Images	Average Recognition Rate
100%	99.09%	98.18%	99.09%

As shown in the experimental results, the Weighted Euclidean Distance Classifier has provided with quite satisfactory results. But, still one can search for an alternate or better method of recognition which can provide superior results than the Weighted Euclidean Distance Classifier. The reason for improvement can be seen due to the reasons of larger databases with more noise and tilts in the images, or efficiency in terms of time. The author intends to develop some statistical measures in future for further analysis of the scheme.

6 CONCLUDING REMARKS

In this paper, a method of recognizing currencies has been introduced. It is based on capturing novel features like aspect ratios, three kinds of areas, Euler Number and correlation

between images. The method uses Weighted Euclidean Distance as classifier. The method is quite reasonable in terms of accuracy. There is a reasonable achievement in the processing time too.

The proposed method is fully automatic and requires no human intervention. The author is also thinking to apply the proposed feature methodology for some other model of classification. This work is in progress as a subsequent work together with issue of considering multiple currencies with one system.

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