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A novel approach for coin recognition using GLCM and Sweep line algorithm

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Abstract

Handling of coins and sorting is a tedious job and so automatic coin sorting methods get wide importance in today's world. In this paper we describe a texture based method used for identification and sorting of coin. In current scenario sorting of coin get much importance since coins are widely used in banks, stores, temples, churches etc. Most of the conventional coin sorting systems are hardware based or electro-mechanical based. Texture based method can also be used for coin recognition, since texture has distinct properties such as direction, periodicity, coarseness and pattern-complicity. The proposed method is compared with other existing coin recognition method such as pattern averaging method; neural network based method etc and is found to outperform the existing schemes with less computational cost.

Keywords: Gray level co-occurrence matrix, edge detection, thresholding, back propagation, feed-forward network, training.

1. Introduction

Life style of human beings changes drastically, that is in all fields manual works is reduced and machine automation get wide acceptance. The main advantage of machine automation is accuracy and reduced time. Manual operation can lead to erroneous result, due to factors such as tiredness and boredom. In today's world coins are widely used in shops, buses , stores etc. Manual method of coin sorting take much amount of time and accuracy is also limited. Currently coin recognition method can be classified in to three [1]. They are mechanical method, electromagnetic method and image processing method. The disadvantage of mechanical based method is that, it cannot identify the defect/fraud coin. The solution is electromagnetic method, which can identify fraud coin by analyzing the frequency produced by the coin when passes through an oscillating coil. This method also do not get wide acceptance because of its cost. Solution is to use image processing method for coin recognition. Digital image processing is the processing of two dimensional images with the help of a computer. Image processing has wide range of applications such as robotic vision, inspection systems, education, manufacturing industries etc.

In [2] presented a rotational invariant neural pattern recognition system for coin recognition. They have used 500 yen coin and 500 won coin to perform the experiment. In this work they have created a multilayered neural network and a preprocessor consists of many slabs of neurons. In [3] presented a novel coin identification system, which uses neural network and pattern averaging for recognizing rotated coins at various degrees. The method consists of two phases. First phase uses image processing concepts for preprocessing and features extraction. In second phase a back propagation neural network is trained. Once neural network converges and learns then only one forward pass is used that yields the identification results. In [4] proposes an Indian coin recognition system of image segmentation by heuristic approach and Hough transform. This method uses HT transform for identification of curves, lines and circle in coin image. From the acquired image, coin area is identified which can also be used for classification of coin. This method gives 97% accuracy during coin recognition. Fukumi et al [5], tried to achieve 100% accuracy for recognition of coins. They have used 500 yen coin and 500 won coin. In this work they have used Back Propagation (BP) learning and Genetic Algorithm (GA) to design a neural network based coin recognition system. After training the network using BP, GA is used to reduce the size of network by varying the architecture to achieve 99% recognition accuracy rate.

In this paper, we propose a novel approach for coin recognition based on statistical texture features using

gray level co-occurrence matrix (GLCM) and sweep line algorithm. The rest of this paper is organized as follows. In section 2, we give a brief introduction of GLCM, Sweep line algorithm and Circle drawing algorithm. Section 3 deals with the proposed coin recognition method. Experimental results are discussed in section 4 and conclusion is presented in section 5.

2. Theories used in Proposed System

2.1. Gray Level co-occurrence Matrix

The Co-occurrence matrix is a two dimensional array wherein row index and Colum index represent gray value of the image. Let G be the gray level Co-occurrence matrix, then G (i, j) represents how many times gray value **i** co-occurs with gray value **j**. Co-occurrence can be measured in different directions such as horizontal, vertical and also in diagonal directions. We also want to specify a distance known as displacement vector, which is used for specifying distance between the two gray values in different directions. GLCM [6] matrix in straight contains no information regarding the image and we can use this matrix for extracting the features.

2.2. Plane Sweep algorithm

The plain sweep algorithm [7-8] is a widely used algorithm in computational geometry. The main idea behind this algorithm is that a sweep line is operated in a plane to solve various problems in Euclidean space. The sweep line can traverse the plane in either direction, horizontal or vertical. Geometric operations are restricted to geometric objects that either intersect or are in the immediate vicinity of the sweep line whenever it stops.

2.3 Midpoint Circle algorithm

In midpoint circle algorithm [9] the circle function is defined using the following equation:

$$f(x,y) = x^2 + y^2 - r^2 \qquad (1)$$

For unit step in $'x'$ direction use a decision parameter to determine, which of the two possible $'y'$ positions is closer to the circle path. The initial value of decision parameter is:

$$p_{0=5/4-r} \qquad (2)$$

At each x_k position, starting at k=0, if $p_k < 0$, the next point along the circle is (x_{k+1}, y_k) and

$$p_{k+1} = p_k + 2x_{k+1} + 1 \qquad (3)$$

Otherwise the next point along the circle is $(x_k + 1, y_{k-1})$

$$p_{k+1} = p_k + 2x_{k+1} + 1 - 2y_{k+1} \qquad (4)$$

where $2x_{k+1} = 2x_k + 2$ and $2y_{k+1} = 2y_k - 2$,

In the same way symmetry points are calculated for other octants also

3. Proposed Coin Recognition System

The proposed system is implemented using textural features extracted from GLCM and a feed forward network. The proposed system can be divided into two. The first phase is feature extraction phase and the second is training phase. Before the training phase image should be preprocessed.

3.1. Segmentation of coin from acquired image

First step of preprocessing is shadow removal and segmentation of coin image from the acquired image.

Thresholding method can be used for removing the shadow. But after the thresholding operation a narrow border of shadow is present around the coin. Since we are using texture based method for coin recognition, this narrow shadow part is not considered for creating GLCM matrix, and hence for creating feature matrix. The narrow part can be removed with the help of midpoint circle algorithm, edge detection algorithm and plane sweep algorithm.

The Canny edge detection algorithm [10] is applied on the acquired image after thresholding operation. Subsequently a scan line is operated on the edge detected image from top to bottom, bottom to top, left to right and right to left. Whenever a pixel with white value is found by the scan line algorithm, scan line stop there. Using scan line as explained above first point from left, right, top and bottom is identified and with the help of these four points center (x, y) of coin image is identified .With the help of midpoint circle algorithm a circle is constructed with center (x, y) and its radius R, is calculated as:

$$R = round\left(\frac{(p-a)+(q-b)}{2}\right) \qquad (5)$$

Here p, a represents x coordinate value of top and bottom point formed by sweep line algorithm. q, b Represents y coordinate value of left and right end point produced by sweep line algorithm.

Fig 1: Acquired RGB image of coin and its segmented image for feature extraction

The coordinate value inside the circle boundary is used for selecting pixel value from the original image and the gray value of pixel outside the circle boundary is kept as zero. The above operation is done on the image acquired using baseler camera [11] and the result is shown in Fig 1.

The extracted image is used for generating GLCM and is used for extracting features such as entropy, contrast, correlation, and homogeneity. The calculated features are used to produce a feature vector and which is used for training

the neural network. The algorithm for segmentation and feature extraction is given in Table 1.

Table 1: Algorithm for segmentation and feature extraction

Step 1: Convert the acquired RGB image to gray level image
Step 2: Resize image to 150 × 150 image
Step3: Edge detection algorithm applied on image ob trained in step2 to get border pixels information of coin
Step 4: A scan line is operated from top, bottom, left and right to obtain first left, first right, first top and first bottom point
Step 5: Center point of the coin image is identified using the four points obtained in step 4
Step 6: Midpoint circle algorithm is used for generating circle with center (x, y) and its radius is calculated using equation (1).
Step 7: Inner points of circle are filled with pixel value obtained from original image and points outside boundary is filled with gray value '0'.
Step 8: GLCM matrix is created from image obtained after applying step1 to 7. Some numeric value is calculated from GLCM matrix and which is used for creating feature vector

3.2. GLCM Features

Using the GLCM method, approximately about two dozen co-occurrence features can be obtained [6]. In this study, the representation is restricted to four features only, which will provide useful information for pattern recognition. The expressions for features are given below:

Contrast

This gives the amount of local variations in the image and is measured as

$$Contrast = \sum_{i=0}^{G-1} n^2 \left(\sum_{i=0}^{G-1} \sum_{j=0}^{G-1} g(i,j) \right) \quad (6)$$

Where G represents distinct gray value present in the image and $g(i,j)$ represents value of GLCM matrix at location (i,j).

Entropy

Homogeneous images have high entropy value and inhomogeneous image have low first order entropy and it is measured as:

$$Entropy = -\sum_{i=0}^{G-1} \sum_{j=0}^{G-1} g(i,j) log\big(g(i,j)\big) \quad (7)$$

Correlation

This feature measures the relationship between the gray tone and it represents linear-dependencies in the image. Correlation of gray tone in an image can be measured using the following formula:

$$Corr = \sum_{i=0}^{G-1} \sum_{i=0}^{G-1} \frac{[i \times j] \times g(i,j) - [\mu_x \times \mu_y]}{\sigma_x \times \sigma_y} \quad (8)$$

$Where\ \mu_x, \mu_y, \sigma_x\ and\ \sigma_y$ are means and standard deviations of $g_x\ and\ g_y$. $g_x(i)$ is i[th] entry in the GLCM matrix obtained by summing the rows of $g(i,j)$

Homogenity

The homogeneous image contains only a few gray levels. So this gives GLCM with only few entries but relatively high values of $g(i,j)$. So the sum of squares will be high. Angular second moment (ASM) feature is used for measuring homogeneity. The equation used for measuring homogeneity of an image can be represented as follows:

$$ASM = \sum_{i=0}^{G-1}\sum_{j=0}^{G-1}[g(i,j)]^2 \qquad (9)$$

3.3. Neural Network Classifier

In our work a multilayer feed-forward network with back propagation (BP) training algorithm is used as the classifier, the structure of neural network used consists of an input layer, two hidden layer and one output layer. Here ten neurons are used and the transfer function used is TANSIG with training function TRAINLM. This neural network is trained with the texture feature obtained from the implementation of equation (6-9) given in section 3.2. The nn tool box in MATLAB is used for the implementation of neural network classifier.

4. Experimental Results

To conduct the experiment in the proposed system, an experimental set up is built up with basler camera [11], a constant light source, and a personal computer with a 2.4 GHz Intel Core2 i3 processor, 2G memory and 250 GB hard disk with Windows 7 operating system. Denominations of one, two, five and ten rupees coins are considered and a total of 72

Images of each denomination, considering both sides of the coin are taken using the basler camera with ten degree rotation.

The experiment is conducted by training the network with textural features obtained from 72 images of each denomination. The neural network learnt and converged after 560 iterations and within 14 seconds of training time. 100 % recognition is obtained as expected when testing is done using the training image. 98.6 % is the recognition rate provided by the proposed system when the trained system has been tested with the data which has not been seen by the system during the training. 362 test images have been used for testing the performance of the system, out of which 357 images have been recognized properly and the remaining 5 images recognized improperly. For comparison, four other methods for coin recognition from literature have also been implemented. Table 2 shows the comparative performance of the methods including the proposed method. The proposed method outperforms all the other methods except method 2 with a recognition rate of 98. 6 %.

Table 2 : Comparison of different methods including the proposed method

Sl. No.	Technique used	Accuracy
1	Neural network using Genetic Algorithm	96.00 %
2	Multi-Level Counter Propagation Neural Network	99.47 %
3	DCT,Neural Network,Pattern Averaging	96.5 %
4	Hough transform	97.00 %
5	Proposed method	98.6 %

5. Conclusion

This paper explains a new approach of coin recognition system using GLCM, sweep line algorithm and midpoint circle algorithm. The system has been trained with rotated coins at intervals of 10 degree. Experimental results have shown an acceptable recognition rate 98.6% with a low recognition time compared to the other methods which have been taken from literature for comparison. This work is an investigative preliminary work as part of an ongoing project of developing a prototype automated coin sorting system.

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