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Indian Coin Recognition using Image Subtraction Technique

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***Abstract*— This paper recognizes the Indian coins of different denomination using Image Subtraction Technique. The features of Indian coins of different denominations are considered for classification. Indian Coins are released with different values and dominations which are classified based on different parameters of coin such as shape, size, surface, radius and so on. Considering these factors, a system of Indian coin recognition has been created which recognizes Indian coins based on the technique of image subtraction. This process checks the radius, centroid, coarse and fine subtraction on the input image. The mentioned subsequent checks enable Rotation Invariance, which helps to place the coin at a certain angle by rotation. A subtraction between the input object image and database image is performed. A proposed method is a simple automatic coin recognition system. Image subtraction provides fast recognition with good accuracy.**

***Keywords*- Image subtraction technique, Rotation-invariant image subtraction technique, Coarse Subtraction, Fine Subtraction.**

I. Introduction

Machine automation is essential to make sophisticated approach to the mankind in all walks of life. The machines cannot be replaced by human beings in exact recognition of coins. Nowadays, most of the work of the human being is replaced by machines. The coin classification of various denominations and finding the sum of the coins is a long process. Since Indian coins recognition algorithms can easily fail when the coins are in very poor conditions. The criteria for coin classification can be based on gray-level, color, texture, shape, model, etc, are discussed by R.Bremananth[5]. The traditional coin testers would fail to distinguish the different coins, if physical similarities exist between coins.

The COINS recognition method provides an efficient image based algorithms for coin identification. This method focuses on permanent identification and traceability technologies related to coins. The goal of the image based coin recognition tool is two-fold. At first, it addresses the classification of an Indian coin based on its visual representation. Secondly, the identification of individual coin based on peculiar features, as use-wear traces.

Many pattern recognition systems insensitive to transformation of an input pattern have now been presented. P. Thumwarin [4] presented the rotation invariance feature by the absolute value of Fourier coefficients of polar image of coin on circles with different radii. Minoru Fukumi[3] had proposed a neural pattern recognition system, which is insensitive to rotation of input pattern by various degrees. Results show that the neural network approach works well for variable rotation pattern recognition problem.

II. SYSTEM OVERVIEW

A. Introduction To Coin Recognition :

The paper proposes a coin recognition method using image subtraction technique[1] which has an advantage over the conventional identification methods used commonly in slot machines. Most of the coin testers in slot machines, work by testing physical properties of coins such as size, weight and materials. The image subtraction technique takes two images as input and gives a third image as output, whose pixel values are simply the pixel values of the first image minus the corresponding pixel values of the second image. Modus operandi consists of the above mentioned technique. The radius check is also performed, which would helps in choosing the befitting coin from the database images.

In this the centre of the coin is located and concentric rings are used to achieve rotation-invariance. A rotation-invariant pattern recognition system has been constructed using neural networks[6] to recognize the patterns. The centroid is calculated and by identifying the centre point alone in a coin may not be sufficient to localize the numeral in the coin because in some coins, the numeral is seen only at the bottom of the coin where the centre point identified by the automatic coin-classifying machine may fail to detect the numeral in the coin thus giving a new idea for further studies.

Fig. 1. Head side and tail side of various Indian coins

This paper proposes an image subtraction recognition system which is insensitive to rotation by any number of degrees. Hence, this method is helpful in sorting problems related to coin recognition.

B. ROTATION-INVARIANT IMAGE SUBTRACTION TECHNIQUE:

Image rotation invariance is introduced by rotating the image at fixed angular interval thus providing us with the exact angle of difference between the coins on analysing the plot of the subtracted values. Extracting the minima of the plot and on comparing it with a standard threshold value, the object coin can be determined as coin of same denomination or not. Thus, coin stands recognized.

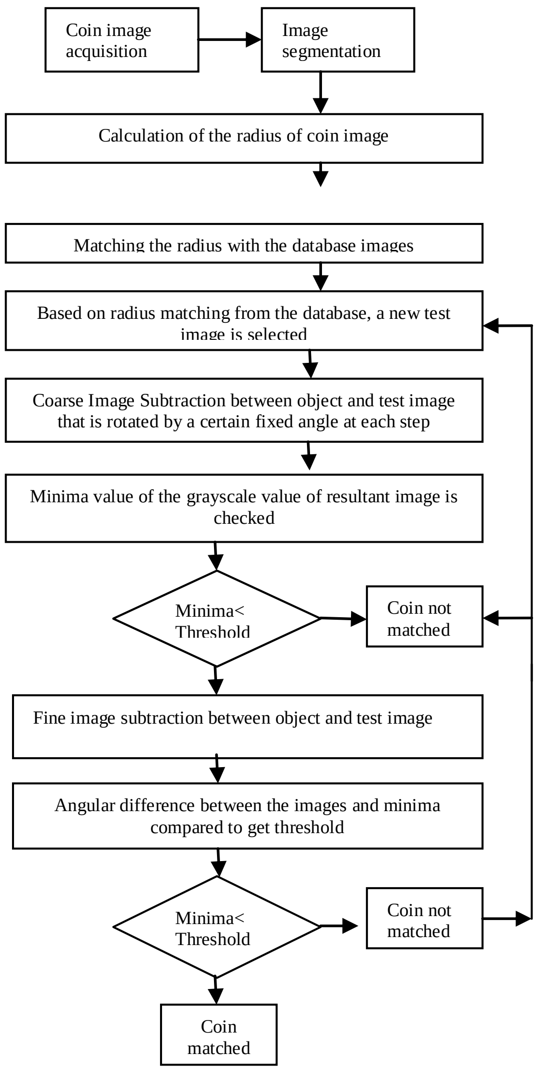


Fig. 2 Block diagram of the methodology

The proposed approach of coin recognition consists of five modules namely, image acquisition, image segmentation, radius calculation, image subtraction and Threshold comparison. Input image of size (320 X 320 pixels) is acquired and coin is segmented through it. Fig. 2 shows the block diagram of the proposed methodology.

C. IMAGE ACQUISITION AND SEGMENTATION

Image acquisition and segmentation describes the image required for coin recognition. image segmentation, the coin image is separated from the background. Fig. 4 illustrates the process of image segmentation wherein the image is firstly converted into grayscale image in accordance with the formula described

$$gray = (0.299*r + 0.587*g + 0.114*b) \qquad (1)$$

the contrast of the image is increased and then converting it into a binary image by setting the pixel whose value is greater than a certain threshold value to 1 otherwise 0. Traversing row wise we get two positions which depicts the two ends of diameter. We get the centre in terms of horizontal axes. Following the same methodology column wise, we get the centre in terms of vertical axes. Thus, we get the exact position of the coin into which the parent image is readjusted shown in last image of fig. 3

Fig. 3: Image Segmentation

Convert RGB Coin Image to Grayscale:

In the first step the image we got is a 24-bit RGB image. Image processing of colored images takes more time than the grayscale images. So, to reduce the time required for processing of images in further steps it is good to convert the 24-bit RGB image to 8-bit Grayscale image.

Crop and Trim the Image

After shadow removal the image is cropped so that we just have the coin in the image. Then after cropping, coin image is trimmed to make it of equal dimension of 100 × 100.

Generate Pattern Averaged Image

The 100×100 trimmed coin images become the input. But to reduce the computation and complexity, these images are further reduced to size 20×20 by segmenting the image of coin using segments of size 5×5 pixels, and then considering the average of pixel values within the segment. This can be represented by mathematical equations below:

$$\mathbf{Sum_i} = \sum_{j=1}^{5}\sum_{k=1}^{5} \mathbf{P_{ijk}}$$

$$\mathbf{SegAvg_i} = {}^{\mathbf{Sum_i}}/_{\mathbf{25}}$$

where *i*, *j*, *k* is the segment no., row no. and column no. of a particular segment respectively, $\mathbf{Sum_i}$ is the sum of the pixel values *Pijk* of the segment *i*, $\mathbf{SegAvg_i}$ is the average of pixel values of segment *i*.

Radius Calculation

Radius is calculated from the diameter, which is calculated by finding the difference between maximum and minimum position of white pixels of the binary image formed during image segmentation.

D. ROTATION OF THE COIN

The coin image is represented by the Cartesian Co-ordinates and it is given by

$$\boldsymbol{f(x,y)} = \sum_{p=0}^{k}\sum_{q=0}^{k} \boldsymbol{F(p,q)\emptyset(x-p,y-q)} \qquad (1)$$

where, $\varphi(x - p, y - q) = (\sin \pi x/\pi x)(\sin \pi y/\pi y)$

and $\mathbf{k}$ is an integer related to the image size. F(p,q) is the gray level at a pixel (p,q). Then the following function is defined by letting x=r cos θ, y=r sin θ in above equation as

$$\bar{\boldsymbol{f}}(r, \theta) = f(r\cos\theta, r\sin\theta) \qquad (2)$$

Where 0≤r≤R, 0≤R≤360º and $\bar{f}$ (r, θ) is defined inside the circle of radius R for coin recognition, for coins of same size, the design on the coin surface are the important features for extraction. To extract the rotation invariance feature of the coin image, it is considered that,

$$\bar{f}(r, \theta) = \bar{f}(r, \theta + 2m\pi) \qquad (3)$$

where m=0,1,2,…..

From the above equation, it is observed that the absolute value of Fourier coefficients, k of circle which is derived from the coin with different radii are rotation invariant. Rotation of the coin image involves movement of a coin to certain degree of rotation, by which one can match the coin with the existing data base of coin image. This process rotates the coin by an angle of θ degree to the right.

Coin Image Magnification

Zooming and de-zooming are processes by which a coin image is increased or decreased in size. This technique recognizes 100% of the coin image. The recognition rate is increased by zooming which makes the coin size bigger. The Coin Recognition of Pre-Processing of various stages like cropping, scaling, resizing, rotation are done.

Coin Centroid, Circumference and Area Computation

The area of a coin image is calculated by total number of pixels representing the coin image. The perimeter is the number of pixels along the outer contour of the coin. Using radius or side of coin image, we can compute circumference or perimeter of the coin depending upon its shape namely circle, square, hexagon, octagon, polygon using suitable formula. The centroid of the coin may be calculated as,

$$Xc = \Sigma\, Xi/n, \qquad (4)$$

$$Yc = \Sigma\, Yi/n, \qquad (5)$$

where, i=1 to n. A is the area of the coin, N is the number of pixels in the coin, X,Y are the coordinates of the pixel in the coin.

Coin Gray Scale Range Normalization

The original image has gray levels ranging from lowest value ‘a’ to highest value ‘b’. We make the range ‘c’ to ‘*d’*, the change is made in three steps:

Step 1. Subtract *a* from each gray level to make the range as 0 to *b* - *a*.

Step 2. Multiply the result by *(d – c)/(b - a)* to make the range as 0 to *d* - c.

Step 3. Add c to the result obtained from step 2, to obtain the range c to *d.*

These three steps are summed up to convert from the range [a, b] to the range [c,d].

$$g_2(x, y) = ((d-c) / (b-a))[g_1(x, y) - a] + c \qquad (6)$$

Thresholding

The thresholding transformation sets each gray level <=T is set to 0, and each gray level > T is changed to *K* - 1. Thresholding is useful when one wants to separate bright coin image from a darker background or vice versa[8]. The thresholding transformation is shown in fig.(3) and is defined by

$$\boldsymbol{g_2(x, y)} = \begin{cases} \boldsymbol{0} & \boldsymbol{if\ g_1(x, y) \le T} \\ \boldsymbol{k-1} & \boldsymbol{if\ g_1(x, y)} > T \end{cases} \qquad (7)$$

The recognition of coins image can be classified into four classes based on gray levels according to g2(x,y), as follows, but, it is not giving accurate results[8].

$$g_2(x,y) = \begin{cases} 64 & \text{if } 0 \le g_1(x,y) \le 63 \\ 128 & \text{if } 64 < g_1(x,y) \le 127 \\ 192 & \text{if } 128 < g_1(x,y) \le 191 \\ 255 & \text{if } 192 < g_1(x,y) \le 255 \end{cases} \quad (8)$$

Coin Brightness and Contrast Normalization

The contrast in an image is the amount of variation of its gray levels. Oneway of quantifying this variation is by the root-mean-squared difference of the gray levels from their mean, and standard deviation of the gray levels. The average gray level in an *M* x *N* image *g1(x, y)* is

$$\mu = \frac{1}{M}\frac{1}{N}\sum_{x=1}^{M}\sum_{y=1}^{N} g_1(x,y) \quad (9)$$

and the standard deviation of the gray levels is

$$\sigma = \sqrt{\frac{1}{M}}\sqrt{\frac{1}{N}}\sum_{x=1}^{M}\sum_{y=1}^{N}\{g_1(x,y) - \mu\}^2 \quad (10)$$

The following transformation will convert the image $g_1(x, y)$ with

parameters μ and σ into one with a new mean gray level μ_n and a new standard deviation σ_n is given by

$$g_2(x,y)=[\{g_1(x,y)-\mu\}/(\sigma/\sigma_n)]+\mu_n \quad (11)$$

Alternatively, brightness and contrast could be defined to be the median

gray level and the Mean Absolute Deviation (MAD) of the gray levels from the

where,

$$\mathbf{MAD} = \frac{1}{M}\frac{1}{N}\sum_{x=1}^{M}\sum_{y=1}^{N}|g(x,y) - \text{median}| \quad (12)$$

To adjust the brightness and contrast with the median and MAD, where μ and μ_n now represent the old and new medians, and σ and σ_n now represent the old and new MADs. If *K* - 1 is the largest possible value for a display device and $g_1(x, y) > K - 1$ in an image, then the display device shows that pixel at the brightest gray level possible is *K* - 1.

E. IMAGE SUBTRACTION WITH ROTATION INVARIANCE

Coarse Subtraction

The test image is given one full rotation in steps of fixed angular distance of say 10º. At each instance of rotation image subtraction is carried between the rotated test image and the input object image. The two images basically are a 2-d array consisting of gray values. Subtracting these array yields gray values begetting a third image.

Subtracted (r,c) = object (r,c) – test (r,c) (2)

Fig. 4 Image subtraction at 90º difference

Fig. 5 Image subtraction at 135º difference

Fig. 4,5 illustrates the subtraction at various angles. These figures elicit that resultant image exhibits darker regions that persistently increases until the rotation crosses the angle of object image. If we plot a sum of gray values of the resultant image we get a minima at some angle near which the test and object image tend to overlap.

Fine Subtraction

The central theme of this step is same as the coarse subtraction with the only difference being the step size greatly abated (say 1º) to perform a thorough check and check window limited to angles near minima obtained from the plot. Proceeding further on the previous readings we get minima at around 320° so the rotation window will be ranging from angle of 310° to 330° with the step size of 1°.

Threshold Comparison

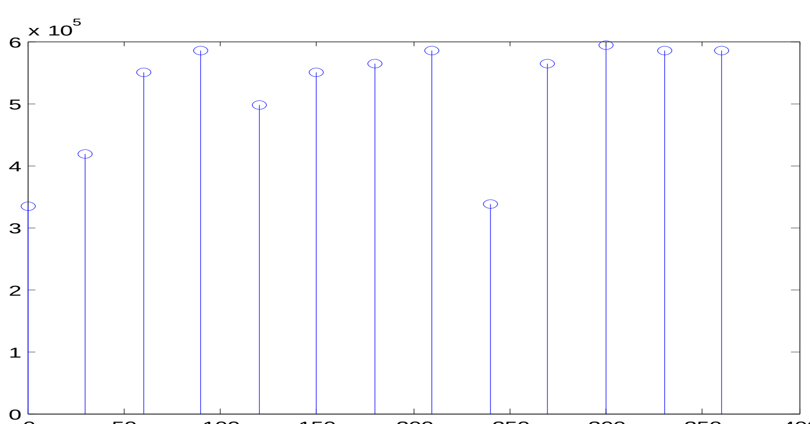
Once we get the minima of the gray value sum, based on comparison with a standard threshold, deductions are made whether the coin matches or not. If the minimum value lies below the threshold, coin identification is established.

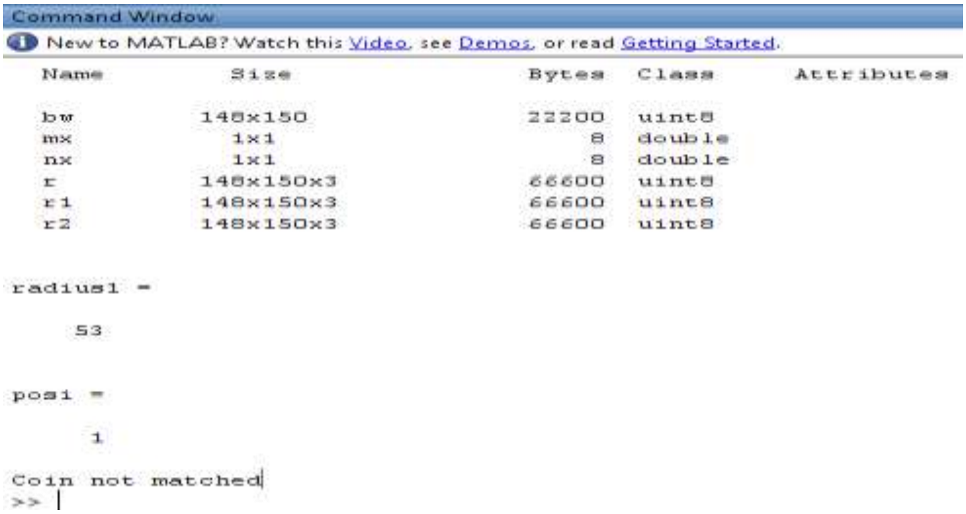
III. EXPERIMENTAL RESULTS AND ANALYSIS:

a) Experimental Image -1

Fig. 6 Input image (left) and database image (right)

The two coins shown above are one and the same, the difference being is that they are the two faces of the same coin. The input image will pass the radius test but fail at coarse subtraction. The plot for the coarse subtraction technique is shown below along with the command window. As we can see, the minima lies well above our standard threshold value of $1x10^5$.





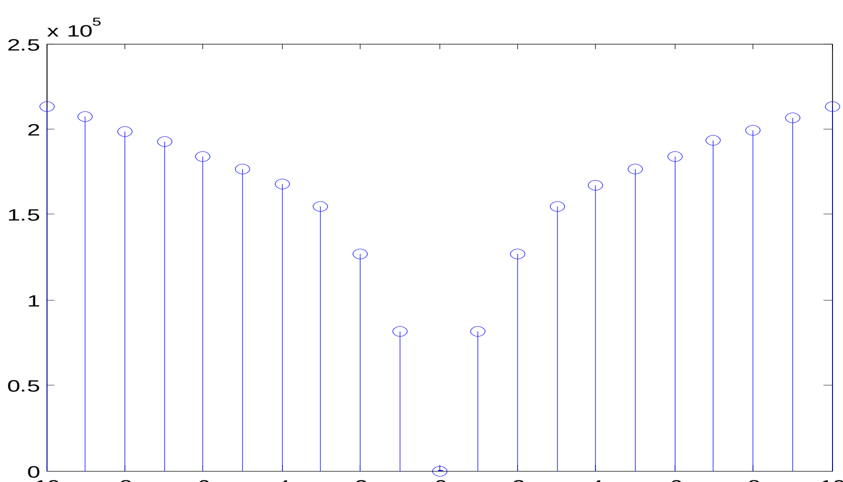
```
Command Window
New to MATLAB? Watch this Video, see Demos, or read Getting Started.
  Name          Size                   Bytes  Class     Attributes

  bw          148x150                  22200  uint8
  mx            1x1                        8  double
  nx            1x1                        8  double
  r           148x150x3                66600  uint8
  r1          148x150x3                66600  uint8
  r2          148x150x3                66600  uint8

radius1 =

    53

posi =

     1

Coin not matched
>>
```

Fig. 7   Resultant plot and Command window.

b)   Experimental Image -2

Fig. 8 Input image (left) and database image (right)

Here, the input image exactly matches with the one in our database. As expected, this will pass the radius test and coarse subtraction. On fine subtraction, with the rotation angle narrowed down to -10 to 10 degrees, the following plot is obtained.



```
Command Window
New to MATLAB? Watch this Video, see Demos, or read Getting Started.
  Name          Size                 Bytes  Class     Attributes

  bw          148x150                22200  uint8
  mx            1x1                      8  double
  nx            1x1                      8  double
  r           148x150x3              66600  uint8
  r1          148x150x3              66600  uint8
  r2          148x150x3              66600  uint8


radius1 =

    53


posi =

     1

Coin matched
>>
```

Fig. 9 Fine subtraction plot and command window.

c) Experimental Image -3

Fig. 10 Input image (left) and database image (right)

Here, the input image is larger than the one we are comparing to in the database, hence this comparison will not go beyond the radius check test. The following command window will illustrate the fact.

```
Command Window
New to MATLAB? Watch this Video, see Demos, or read Getting Started.
  Name          Size                 Bytes  Class     Attributes

  bw          148x150                22200  uint8
  mx            1x1                      8  double
  nx            1x1                      8  double
  r           148x150x3              66600  uint8
  r1          148x150x3              66600  uint8
  r2          148x150x3              66600  uint8


radius1 =

    53

Coin not matched
>>
```

Fig. 11 Command window after comparison of the above two coins

IV. CONCLUSION

This paper has introduced an efficient method for Coin recognition using image subtraction shows positive signs for coin recognition. Image segmentation used as the first step which substantially reduces the amount of data to be dealt with, thus decreasing the processing time. Image subtraction provides fast recognition with good accuracy provided the conditions are made standard. Also two subsequent checks are provided to give precise results. This solves a real life problem where physical similarities between these coins led to abusing slot machine.

Future works will include modifications of the technique and also merging of other image processing techniques, such as, Neural Networks training using Edge detection which would extricate the process from the dependency over standard light intensity and standard distance between coin and camera during image acquisition adding on to the accuracy of the process.

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