

Indian Coin Recognition and Sum Counting System of Image Data Mining Using Artificial Neural Networks

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Abstract

The objective of this paper is to classify recently released Indian coins of different denomination. The objective is to recognize the coins and count the total value of the coin in terms of Indian National Rupees (INR). The system designs coin recognition which uses by combining Robert's edge detection method, Laplacian of Gaussian edge detection method, Canny edge detection method and Multi-Level Counter Propagation Neural Network (ML-CPNN) based on the coin Table 1. In this paper, it is proposed to introduce ML-CPNN approach. The features of old coins and new coins of different denominations are considered for classification. Indian Coins are released with different values and are classified based on different parameters of coin such as shape, size, surface, weight and so on. Some countries' coins are having same parameters, but with different value. This paper concentrates on affine transformations such as simple gray level scaling, shearing, rotation etc. The coins are well recognized by zooming processes by which a coin size of the image is increased. To implement the coin classification, code is written in Matlab and tested with simulated results. A method is proposed for realizing a simple automatic coin recognition system more effectively. The Robert's edge detection method gives 93% of accuracy and Laplacian of Gaussian method 95% of the result, the Canny edge detection method yields 97.25% result and the ML-CPNN approach yields 99.47% of recognition rate.

Keywords : Smoothing, Edge detection, Thresholding, Recognition, Classification.

1. Introduction

In all walks of life, machine automation is essential to make sophisticated approach to the mankind. Of course 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 tedious process. Coin counting machine is user friendly and makes customer operation a breeze. This machine is equipped with an operating system. This counting machine has a display and prompts the customer to operate the system. Coin sorting machine is attached with required number of

tagged bags to collect appropriate denominations of coin. Dirty coins require machine cleaning frequently. The effectiveness of the coins classification is ensured based on the parameters of the coin as shown in Table 1. In this paper, the variations in images obtained between new and old coins are also discussed. The polar coordinate of coins outer edge with coin center which represents radii is used for recognition of the coin. Finally, the database of the coin is fed to the recognition system to classify easily.

1.1 Previous Works

Several coin recognition approaches are mentioned in the literature. Fukumi et. al. describes a system based on a rotation-invariant neural network which is capable of distinguishing Japanese coins [4], a 500 yen and a 500 won piece. Rotational invariance is achieved by explicitly generating the rotational group for a coarse model of the coin in a pre-processing step and feeding the results into a neural network. The drawback of the neural network approach is that, it takes much time to train. Davidsson [3] compares several strategies, namely induction of decision trees, neural networks and Bayesian classifiers. He derives a decision tree algorithm to accept or to reject the coins. However, it is difficult to extend the approach to images. Adameck et al. presented an interesting method for a coin recognition system based on colour images [1]. The basic idea of the method of detecting a straight line in coin's image is discussed by Earl Gose, Richard Johnson Baugh, Steve Jost[6]. The criteria for coin classification based on gray-level, color, texture, shape, model, etc, are discussed by R.Bremananth[2]. The method which specifically addresses coin segmentation based on color or gray value is reported by P.Thumwarin and Petra Perner [9]. Many serious problems like shape of the coin, peak detection in surface of the coins are attempted by Reinhold Huber [7], but, it does not yield much result. Hence, it is proposed to use Robert's edge detection method, Laplacian of Gaussian edge detection method, Canny edge detection method and Multi-Level Counter Propagation Neural Network (ML-CPNN) using the coin Table 1 to recognize all the coin images with good precision.

In Section 2, coin feature extraction is discussed. Section 3 deals with coin segmentation based on labeling. Section 4 discusses coin classification using Hough Transform. Section 5 presents result and conclusion.

1.2 Denomination of Indian Coins

In ancient period the coins were printed in different forms as shown in Figure(16). Later the coins were printed as paper currencies. India became independent on 15th August 1947 and was left with a legacy of non-decimal coins as shown in Figure(19). One rupee was divided into 16 annas or 64 pice. In 1957, India shifted to the decimal system. The denominations in circulation were 1, 2, 3, 5, 10, 20 and 25 (naya) paise. In 1968, a 20 paise coin was minted. In 1982 a new coin, 2 rupees, was introduced as an experiment to replace 2 rupees notes. Stainless steel coinage of 10, 25 and 50 paise was introduced in 1988 and in 1992, a new rupee coin was minted. In 1992, a 5 Rupees Cupronickel coin was introduced. In 2006, 10 Rupees coin was minted for the first time as shown in Figure(20) and Figure(21). Also, India issues several types of commemorative gold and silver coins as shown in Figure(17) and Figure(18). They can be found in various denominations. Some of the commemorative coins include coins depicting Mahatma Gnadhi, Nehru, Indira, Ambedkar, Subash Chandar Bose, Chatrapati Sivaji and Annadurai were released.

2. Pattern Recognition

There are two basic approaches in pattern recognition. They are statistical approach and structural approach. In the first approach, the pattern is represented as a vector in a feature space. Then a decision algorithm, which is mainly based on the statistical concept, is used to decide to which class the pattern belongs. In the structural method, the pattern is represented by its structure. For example, a string of symbols, a graph connecting the primary elements, etc. The statistical method can be broadly classified into classical and Artificial Neural Networks (ANN) approaches [10, 11]. No single technique or model is suited for all Pattern Recognition (PR) problems. Hence, different types of PR approaches are to be adopted [7].

The coin classification technique is based on the following assumptions and computations.

- i) The coins should move on a conveyor belt.
- ii) Proper lighting is to be focused on the coin.
- iii) Each coin is separated and fed to the system for recognition.
- iv) Coins are weighed accurately.
- v) Both sides of the coin are to be collected.
- vi) The side view of the coin image can be captured.
- vii) The coin image can be rotated by any degree.
- viii) The Circular, Hexagon, Octagon, Polygon shape of coin's radius are measurable.
- ix) The coin Circumference/Perimeter and area are to be computed.
- x) The thickness of each coin can be computed by the system.
- xi) The coin images with 256 gray values are to be computed.
- xii) The coin average gray values are computable.

2.1. Coin Counting System

The coin baskets are mounted on the outside of the cabinet and are positioned at the most convenient height. They are fabricated from a durable plastic with the properties of flexibility and strength. Within the basket, is a flexible shock-absorbing back sheet, designed to dissipate energy and reduce the velocity of the coins as they are moved in. In this paper, the coin counting system is used as shown in Figure(15). The system is modified for sorting Indian Coins. The standard features of coin recognition system are as follows:

- Electromagnetic sampling coin detection
- Rejection of unauthorized coins
- Automatic removal of other objects
- Extensive self-diagnostics
- Unique anti-jamming facility on coin pickup wheel
- Local and remote alarm indications
- Modular design for ease of maintenance and repair
- Surge protection filters

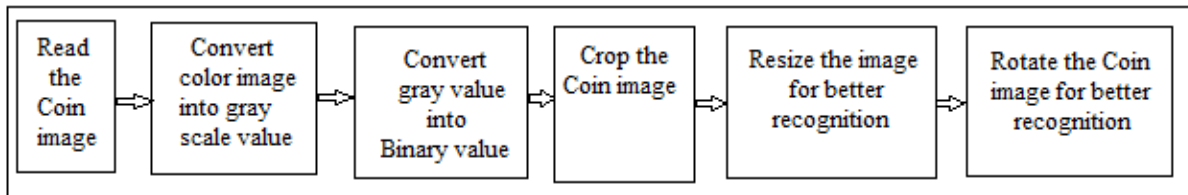
2.2. Pre-Processing

The Zooming and de-zooming are the important processes by which a coin image is increased or decreased in size. The zooming helps us to make the size of the coin image bigger, by which recognition rate is increased. The Coin Recognition of Pre-Processing of various stages like cropping, scaling, resizing, rotation are performed of Figure(1). The coin processing approaches are shown in Figure(2). The system designs coin recognition

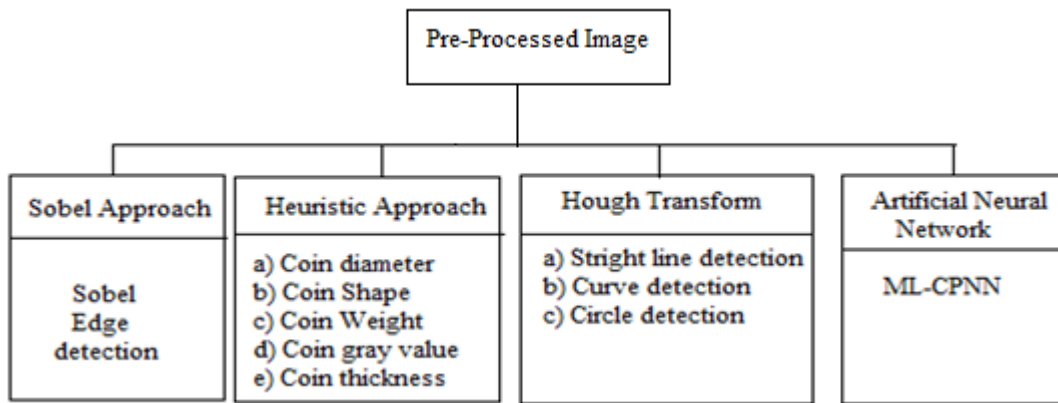
approaches, based on the coin table which stores parameters of each coin as shown in Table 1. The input Coin image is taken for pre-processing as shown in Figure(8). Then appropriate threshold value is applied to convert gray value image into binary image as shown in Figure(9). Also, Inverse image is computed as shown in Figure(12). The Coin Recognition of Pre-Processing of various stages like cropping, scaling, resizing, rotation is shown in the following Matlab code [14].

```

% Coin Recognition Code Pre-processing
%Reading the coin image
img = imread('c1.bmp'); figure ; imshow(img) ;
%To convert into Gray value
imgGray = rgb2gray(img); figure ; imshow(imgGray) ;
% Manual Cropping of coin image
imgCrop = imcrop(imgGray); figure ; imshow(imgCrop) ;
% Resizing of coin image
imgLGE = imresize(imgCrop, 5, 'bicubic'); figure ; imshow(imgLGE) ;
% Rotation of the coin image
imgRTE = imrotate(imgLGE, 35); figure ; imshow(imgRTE) ;
% Binary Image of the coin
imgBW = im2bw(imgLGE, 0.90455); figure ; imshow(imgBW) ;
    
```



Figure(1). Pre-Processing Steps



Figure(2). Coin Processing Approaches

2.3. Data Acquisition

Usually the ordinary Cartesian coordinate system is used to represent a pixel of an image. In this system, $g(x, y)$ is the gray level at the pixel (x, y) . Images can alternatively be thought

of as ordinary matrices in which the gray level of a pixel is represented as $g_1(i, j)$. The Table 1 stores values for parameters of each coin and fed to the system [12].

3. Extracting Features to Classify Labeled Coin Image

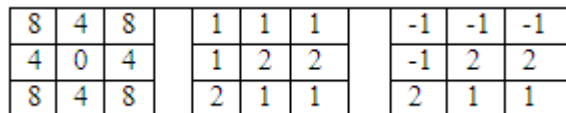
To the coin's image, appropriate threshold was applied and the pixels in each of the white regions of the image were given a unique numeric label using the region-labeling algorithm. Next the area in pixels of each coin was computed by counting the number of pixels having each label. The average gray level for each coin was also computed.

Table 1: Coin Parameter Table

Coin Value in Paise	Type of Coin	Coin Diameter/side in mm	Coin Shape	Coin Weight (grams)	Coin area In Cm^2	Coin average gray value	Coin Thickness In mm
1	Old	12	Square	1.15	1.5000	250	0.7000
2	Old	15	Octagon	1.55	1.9600	249	0.9000
3	Old	17	Hexagonal	1.89	2.4100	245	1.0000
5	Old	18	Square	2.00	2.4500	250	1.1000
5	New	18	Square	2.00	2.4500	250	1.1000
10	Old-1	26	Octagon	2.24	5.3114	225	1.0000
10	Old-2	24	Polygon	1.73	4.5257	225	1.0000
10	New	16	Circle	1.99	2.0114	75	1.0000
20	Old	25	Hexagonal	2.21	4.0595	240	1.2000
20	New	25	Circle	2.30	4.5590	240	1.2000
25	Old	20	Circle	2.95	3.1428	90	1.0000
25	New	21	Circle	2.82	3.1467	90	1.0000
50	Old	24	Circle	4.98	4.5257	100	1.6000
50	New	22	Circle	3.72	3.8028	100	1.6000
100	Old	27	Circle	5.97	5.7278	100	1.7000
100	New	26	Circle	4.93	5.3114	100	1.7000
200	Old	27	Polygon	5.91	5.7278	110	1.8000
200	New	27	Circle	7.72	6.1600	110	1.8000
500	Old	24	Circle	9.03	4.5257	200	3.0000
500	New	24	Circle	6.14	4.5257	200	1.5000
1000	New	26	Circle	6.20	4.7257	210	1.7000

3.1 Coin Segmentation and Labeling

The algorithm scans when an unlabeled pixel (x, y) is found. The algorithm will label all the pixels in the 4 connected region of (x, y) . We first obtain a new label L . We then label (x, y) as L and add (x, y) to an initially empty list of pixels. Next we remove the pixel (s, t) least recently placed in the list. If the list is not empty, we remove from the list, the pixel (s, t) which is least recently placed in the list. If unlabeled pixel found, we obtain a new label and restart the labeling process as shown in Figure(3) to Figure(5). Since each pixel goes on the list once, the total number of times that the body of the "while" loop is executed is n . Thus, part of the "for" loop is to be executed $4n$ times [5, 13].



Figure(3) Figure(4) Figure(5)

Figure(3). The center pixel denoted as 0, 4-neighbours (marked as 4) and 8-neighbours (marked as 4 / 8). Figure(4). An image region is labeled. Figure(6). The image after the region is labeled.

Algorithm 1: Region Labeling

- Step 1:** Let $g(x, y)$ represent the gray level of pixel (x, y) .
- Step 2:** As the algorithm executes, $g(x, y)$ is changed to the label of pixel (x, y) .
- Step 3:** Undefined gray levels outside the image such as $g(x, -1)$ and $g(-1, y)$ are considered to be unequal to any gray level in the image.
- Step 4:** If an image has n pixels, the scanning part of the region-labeling algorithm takes n steps.

3.2 Edge Detection

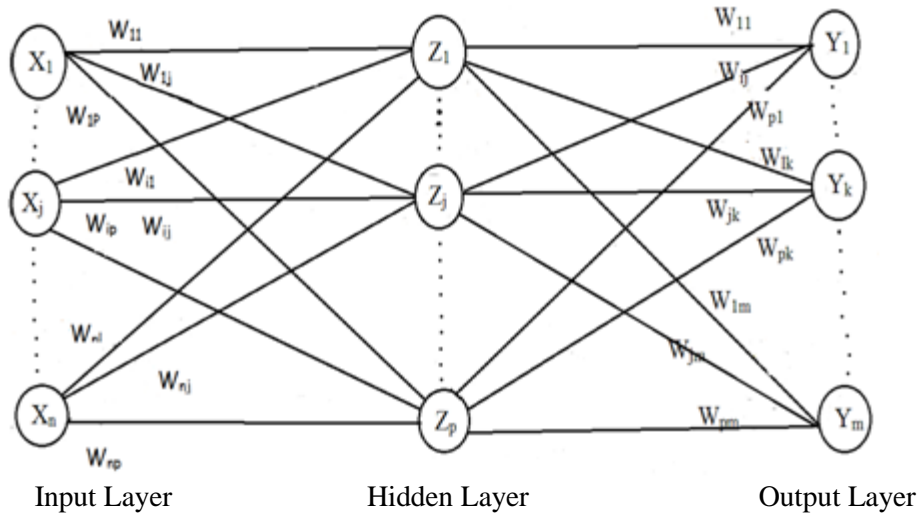
The edge detection of an image is implemented using localization properties. It also searches for the edge pixels. The edge image obtained prominently produces rectangular shapes in the image. There are many edge finding methods, among which the Roberts, Laplacian and Canny edge finding methods are important (Sonka et al. 2001). The Roberts method finds edges using the Roberts approximation derivative. It returns edges at those points, where the gradient of image 'I' is maximum as shown in Figure(10). The Laplacian of Gaussian (LOG) method finds edges by looking for zero crossings after filtering image 'I' with a LOG filter as shown in Figure(11). The Canny edge detector is a more sophisticated approach of an edge map for an image 'I', which can perform well in finding the edges as shown in Figure(13). The most commonly used techniques such as Roberts, LOG and Canny operators masks are shown in Figure(6) are selected and tested for edge detection of the coin.

-1	0	0	0	-1	0	-1	0	1
0	0	0	-1	4	-1	-2	0	2
0	0	1	0	-1	0	-1	0	1
Roberts			Laplacian			Canny		

Figure (6). Edge detection Operators

4. Multi-Level Counter Propagation Neural Network (ML-CPNN)

This ML-CPNN has interconnections among the units in the cluster layer. In ML-CPNN, after competition, only one unit in that layer will be active and sends a signal to the output layer. The ML-CPNN has only one input layer, one output layer and one hidden layer. But the training is performed in two phases. The architecture of the ML-CPNN is shown in Figure(7). The ML-CPNN can be used in interpolation mode and also, more than one Kohonen units have non-zero activation. By using interpolation mode, the accuracy is increased and computing time is reduced. It has many advantages, because, it produces correct output even for partial input. The ML-CPNN trains ANN rapidly. The parameters used are given below:



Figure(7). ML-CPNN Architecture

X - Input training vector $X=(x_1,x_2,\dots,x_n)$

Y - Target output vector $Y=(y_1,y_2,\dots,y_m)$

Z_j - Activation of cluster unit layer

W_{ij} - Weight from X input layer to Z -cluster layer

W_{jk} - Weight from Y output layer to Z -cluster layer

K_L - Learning rate during Kohonen learning

G_L - Learning rate during Grossberg learning. $K_L = 0.5$ to 0.8 and $G_L = 0.1$ to 0.5 .

The winning unit is selected either by the dot product or by the Euclidean distance method. To identify the winner unit, the distance is computed by using the Euclidean distance method. The smallest distance is selected as winner unit. The winner unit is calculated during both first and second phase of training. In the first phase of training, Kohonen learning rule is used for weight updating and during the second phase of training, Grossberg learning rule is used for weight updating.

4.1. Implementation procedure

The implementation procedure for ML-CPN is as follows:

- Step 0 : Initialize weights (obtained from training)
- Step 1 : Present input vector X
- Step 2 : Find unit J closest to vector X
- Step 3 : Set the activations of output units: $Y_k = W_{jk}$

The activation of the cluster unit is

$$Z_j = \begin{cases} 1; & \text{if } j = J \\ 0; & \text{otherwise} \end{cases} \quad (1)$$

The image is scanned and broken into sub-images. The sub-images are then translated into a binary format. The binary data is then fed into a ML-CPNN, which has been trained. The output from the neural network is saved as a file. A sample of various denominations

including 1, 2, 3, 5, 10, 20, 25, 50, 100 and 200 paise coins are fed into the system. Large volumes of coins are fed to the system for testing purpose and the system yields very good results and the outputs are shown in Figure(8) to Figure(14). The results are displayed in Table 2.

4.1.1 ML-CPNN Training Algorithm

The ML-CPNN training algorithm has the following two phases.

Algorithm 2: ML-CPNN

Phase I : Finding Winning Cluster

Step 0 : Initialize weights and learning rates

Step 1 : While the stopping condition for phase I is false, perform steps 2 to 7

Step 2 : For each training input X, perform steps 3 to 5

Step 3 : Initialize input layer X

Step 4 : Find winning cluster unit

Step 5 : Update weights on winning cluster unit $W_{ij}(\text{new}) = W_{ij}(\text{old}) + K_L(x_i - W_{ij}(\text{old}))$,
 where, $i, j = 1$ to n
 (2)

Step 6 : Reduce learning rate K_L

Step 7 : Test the stopping condition for phase I training

Step 8 : While the stopping condition is false for phase II training, perform steps 9 to 15.

Phase II : Adjusting Weights

Step 9 : For each training input pair X and Y, perform steps 10 to 13

Step 10 : Initialize input layer X and output layer Y

Step 11 : Compute the winner cluster unit

Step 12 : Update weights in unit Z; $W_{ij}(\text{new}) = W_{ij}(\text{old}) + K_L(x_i - W_{ij}(\text{old}))$; where, $i, j = 1$
 to n (3)

Step 13 : Update weights from cluster unit to the output unit

$W_{jk}(\text{new}) = W_{jk}(\text{old}) + G_L(y_k - W_{jk}(\text{old}))$; where, $j, k = 1$ to m
 (4)

Step 14 : Reduce learning rate G_L

Step 15 : Test the stopping condition for phase II training

$$Z_j = \sum_i X_i W_{ij}$$

(5) Euclidean distance is $D_j = \sum_i (X_i - W_{ij})^2$

(6)

Among the values of D_j , the smallest value of D_j is chosen and it is the winning unit.

Table 2: Coin's Average Recognition Rate

S.No.	Coin Value in Paise	Type of Coin	No. of Coins tested	Number of coins recognition percentage			
				Robert's Edge detection	Laplacian of Gausson Edge detection	Canny Edge detection	ML-CPNN Approach
1	1	Old	207	93.30	94.90	97.60	99.45
2	2	Old	345	93.50	93.90	97.50	99.35
3	3	Old	478	93.20	95.75	97.45	99.55
1	5	Old	545	91.90	94.70	97.20	99.20
2	5	New	670	92.60	94.80	97.25	99.25
3	10	Old-1	557	92.80	94.70	97.40	99.30
4	10	New	679	92.70	94.60	97.25	99.35
5	20	Old	723	93.50	93.90	97.50	99.45
6	20	New	835	92.60	93.80	97.60	99.60
7	25	Old	895	92.50	94.90	97.40	99.35
8	25	New	905	92.40	94.80	97.70	99.70
9	50	Old	980	93.20	94.40	97.50	99.60
10	50	New	995	93.30	94.90	97.60	99.35
11	100	Old	1007	93.40	95.50	97.45	99.60
12	100	New	923	93.40	95.90	97.70	99.40
13	200	Old	845	93.60	95.80	97.50	99.60
14	200	New	1225	93.40	95.65	97.80	99.60
15	500	Old	1078	93.20	95.75	97.45	99.65
16	500	New	1138	93.50	95.90	97.70	99.70
17	1000	New	714	93.50	95.90	97.70	99.70
Average recognition rate				93.07	95.02	97.25	99.47

5. Conclusion and Results

The conventional manual approach requires a lot of space for keeping the coin in stores for different denominations and it requires much time for computation. Our scope is limited on recognizing only the Hungarian coins (Head OR Tail) in the denominations of 5, 10, 20, 25, 50, 100, 200, 500 and 1000 paises of Indian Coin. The Canny edge detection searches for several occurrences of particular shape during the processing. In this paper, the perfect image of a coin is used for learning and recognition. The correct classification of acceptance of a coin was achieved for 99.6% in a test sample of 10,000 coins. The Robert's, Laplacian and Canny edge detection methods gives 93%, 95% and 97.25% of the coin image. The proposed ML-CPNN, yields 99.47% recognition rate. By analyzing the experimental results, it is evident that, ML-CPNN yields the best result. This paper can be extended to classify coins released during various time periods. Also, based on the coin shape, impression on the coin, metal of the coin etc, Moreover, the classification can be done based on the similarity measure of a coin and based on the size and spatial location of peaks in the parameter space.

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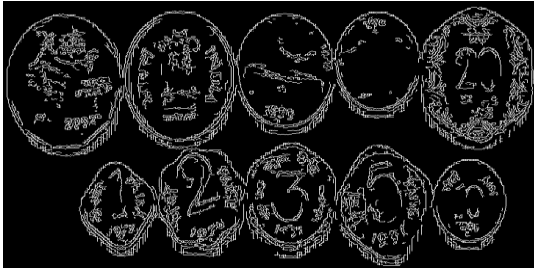
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Appendix:

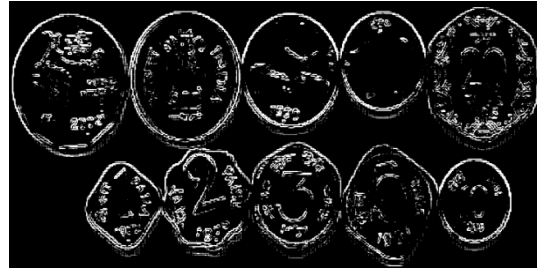


Fig.(8). Coin of 1,2,3,5,10,20,25,50, 100 and 200 Paise

Figure(9). Thresholded Binary Image



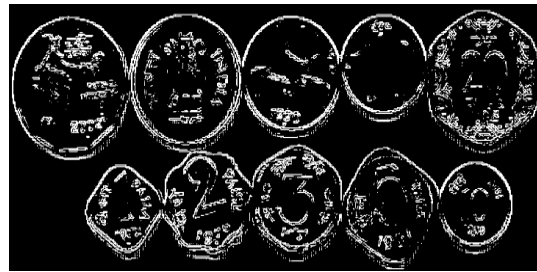
Figure(10). Robert's Edge Detection.



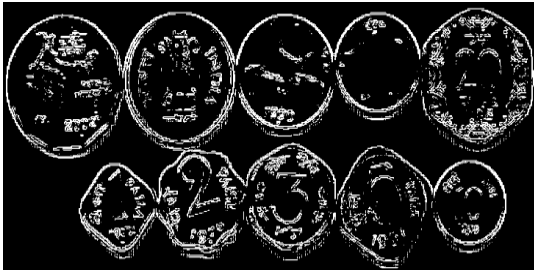
Figure(11). Laplacian of Gaussian Edge detection.



Figure(12). Inverse Image.



Figure(13). Edge Detection by Canny Operator



Figure(14). Edge detection by ML-CPNN.



Figure(15). Coin Classification Machine



Figure(16). Ancient Coins Released Before the Year 1947



Figure(17). Commemorative Gold Coins Released During the Year 1900-2010



Figure(18). Commemorative Silver Coins Released During the Year 1950-2010



Figure(19). Old Coins Released Before Independence (Before the Year 1947)



Figure(20). Recent Coins Released After Independence (After the Year 1947)



Figure(21). Recent Coins Released After Independence (After the Year 1947)

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