ISSN:0975-9646

Loveneet Kaur et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5 (5) , 2014, 6532-6537

An Indian Coin Recognition System Using Artificial Neural Networks

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***Abstract*- Coins are an integral part of our life. Coins are used everywhere as in banks, grocery stores, supremarkets, buses, trains etc. So, there is an obvious need of coins to be automatically recognized and sorted by computers. The machines should be able to recognize coins properly as the further transactions would depend upon the accuracy of recognition. The coin recognition systems must be robust in the manner as they should be able to recognize coin images efficiently even if noise is present. Indian coin recognition system recognizes the Indian coins of denomination `1, `2, `5 and `10 with rotation invariance and classify them according to their worth. Performance of Indian coin recognition system is evaluated under noisy as well as noise free environment. Scanned images of Indian coins have used as input. After preprocessing, features are extracted from images using Discrete Wavelet Transform (DWT) and neural networks are used for classification. Median and wiener noise filters are used for image enhancement when gaussian and salt-and-pepper noise is present, respectively. The performance of neural netwrok is evaluated on the basis of mean square error, time taken and number of epochs to train the network.**

Keywords*- Artificial Intelligence, Image Processing, Artificial Neural Networks.

I. INTRODUCTION

Coin recognition is one of the emerging research fields in modren times. There is vital need of an efficient and robust coin recognition system in our daily life. Coins are an integral part of our life; we cannot imagine our daily life without them. Inspite of daily uses, coin recogniton system can prove helpful for recognition purpose in research organizations who deal with ancient coins [1]. Hence, there is an obvious need of coins to be automatically recognized and sorted by computers. The recognition system should be able to recognize coins properly, as the further transactions would depend on the accuracy of recognition. There is problem of false image recognition due to the presence of noise in input data. The coin recognition system must be robust in the manner as it should be able to recognize images efficiently even if noise is present; as all capturing devices, analog or digital, have attributes which make them noise susceptible. There is need of a robust coin identification system, which can recognize images in normal as well as in noisy environment. The system must also be fast and cost effective.

Up till now, mainly three kinds of systems for the coin recognition exist in the market. These systems are [2], [3]:

a) Mechanical method based systems
b) Electromagnetic method based systems
c) Image processing based systems

Mechanical based method uses the physical properties of the object or coin. The physical parameters of coin like radius, weight, thickness, area, etc. are used to differentiate between coins of different denomination. But these systems are unable to make a distinction between the coins made up of different materials. Mechanical method based systems can be easily fooled by providing two coins as input, one fake and other original having same physical parametes as weight, thickness, etc. It will treat both coins as original. So, these systems are not much efficient for recognition of coins in real time applications.

Electromagnetic methods cover some of the problems associated with mechanical method based systems.These systems can differentiate between coins of different materials because in these systems coins are passed through an oscillating magnetic field. When coins of different material tested under electromagnetic method based systems, will show variation in amplitude and direction of frequency and with the help of these changes and other parameters like radius, weight and thickness; we can differentiate between coins. These systems provide better results than mechanical method based systems but still they can be tricked easily by some coin game.

Image processing or digital image processing based systems came into picture recently and are simply effective than other techniques used for coin recognition. Digital image processing referes to various techniques perform processing on digital images with the help of digital computer [4]. It provides a wider range of algorithms for processing of images and also keeps them away from the signal deformation during processing. Images of the coins to be recognized can be taken with any scanning device or camera, but it should retain all the features. These images can be processed using various image processing techniques like FFT, image segmentation, DWT, etc. and features are extarcted from images. These features are then further used for recognition pupose and classification is done on the basis of these features.

The various challenges faced by the image based recognition systems are occurrence of noise due to which image pixels do not reflect their true intensity, reduction or removal of noise effects completely and accurate classification of images on the basis of extracted features. Since image/pattern recognition is about the classification of images among appropirate classes and neural networks are known for their potential in classification, the main objective of this work is to apply artificial neural networks to recognize Indian coins of denomination `1, `2, `5 and `10 with rotation invariance. Feedforward backpropagation neural network has been identified for implementation using MATLAB®. Performance of selected Indian coin recognition system is evaluated under noisy as well as noise free environment. After preprocessing, features are extracted from images using Discrete Wavelet Transform (DWT) and neural networks are used for classification. Image enhancement techniques are used when noise is present. The performance of neural netwrok is evaluated on the basis of mean square error. Lesser is the mean square error, better is the performance. Other parameters like time taken, number of epochs to train and recognition rate also have been considered.

II. Noise in Digital Images

Images are often degraded by various kinds of noise. It is a random varition in image intensity or pixel information which could occur in image during acqusition or transmission. The image is said to be noise affected when the pixels in image do not reflect true pixel intensity. Image of `2 coin having gaussian noise and salt-and-pepper noise are shown in Fig. 1.

Fig. 1: Guassian and salt-and-pepper noise affected images.

Getting a noise free image before processing them for further computation is a challenging task. All capturing devices, analog or digital have attributes which make them noise susceptible [5]. But for the best recognition results, it is required to remove or lessen the effects of noise.

A. *Various Sources of Noise*

Noise is mainly introduced in images during capturing and transmission. The noise corrupted image pixels are either set to maximum value or have single bits. There are various conditions under which noise get introduced into images are [5], [6]:

- The sensors get affected by environmental conditions during image acqusition.
- Improper lightning and sensor temperature may introduce noise.
- Interference in transmssion channels also result in image degardation.
- Electronic transmission can also cause noise in images.
- The noise may be added by the sacnner or capturing device itself.

1) Different Types of Noise: Removing noise from the digital images before processing is one of the major challenges in digital image processing and pattern recognition. Different kinds of noise found in digital images are:

- Gaussian noise or Additive noise
- Impluse noise (Salt-and-pepper)
- Poisson noise
- Speckle noise
- Short noise
- Uniform noise, etc.

Gaussian noise is one of the frequent occuring noise types in digital images. Principal sources of gaussian noise in digital images occur during data acqusition due to sensor characteristics e.g. sensor noise, high temperature and/or due to transmission. Gaussain noise is additive in nature, where each pixel in image will differ by small value from original. It follows Gaussian distribution, i.e. every pixel in noisy image will be equal to the sum of original pixel value and a random gaussian distributed noise value [5]. It is idealized form of noise which is caused by random fluctuation in signal intensity [6]. Salt-and-pepper noise is also known as impluse noise, spike noise, random noise or independent noise. It occurs randomly in black and white pixels, as a result of which an image containing salt-and-pepper noise will have tiny black and white dots in it, hence called salt-and-pepper noise. Speckle noise is noticed in conventional radar systems. It can be modled by multipying random value with image pixel values. Short noise is typicly caused by statistical quantum fluctuation in image signal. Uniform noise has a uniform distribution. Levels of gray values of the uniform noise are uniformly distributed across a specified range [7].

III. Noise Removal by Filters

Noise Filtration is the process of removing unnecessary information from image which got added during acquisition or transmission. When images are sent over transmission channels, they get affected with various kind of noise. Most commonly occuring noises in digital images are gaussian and impulse noise. Noise removal from images before processing is one of the challenging tasks as one should remove the noise from image, while preserving the details. Noise can be removed from images by using various noise filtration techniques. Noise filtration can be linear or non linear. Linear filters are simple and fast but they do not preserve the details, while non linear filters are more efficient [5].

Fig. 2: Noise Filtration Process.

In this study, median and wiener filters have been used in order to remove noise from coin images. The brief introduction of both is given below:

A. *Median Filter*

Median filter is best and powerful order static non linear filter. It is widely used method for image smoothing. In median filter we do not replace the image pixel value with mean intensity but we replace it with the median. Median filters are best used for reducing salt-and-pepper noise. The major advantage of meadian filters is that it can remove the noise with large magnitude efficiently.

B. Wiener Filter

Wiener filter is based on statistical approach. Its main objective is to filter noise due to which a signal has been corrupted. The wiener filter follows different approach from others. Wiener filter try to reduce the mean square error as much as possible. Hence, performance criterion for weiner filter is MSE (Mean Square Error).

IV. ARTIFICIAL NEURAL NETWORKS

Artificial neural network is a kind of computational artificial neuron model inspired from human neurons. From past few years, artificial neural netwroks have proved themselves as a better alternative for solving complex problems in various fields. Neural networks contain three types of layers: input layer, hidden layers and output layer. Hidden layers perform intermediate computation to produce required output from the various inputs received [2]. For pattern recognition applicatons, efficiency of neural network depends on the learning algorithm adopted. The learning can be supervised in which correct answer is provided for every input to the network; unsuprevised learning in which result is derived from prior assumptions and inferences; however the correct result is not known to system and hybrid learning, which is combination of both supervised and unsupervised learning [8].

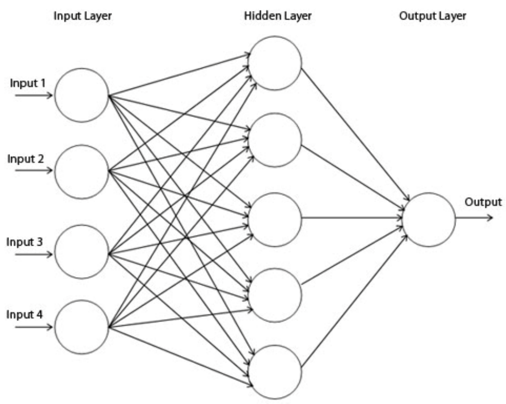

Fig. 3: Artificial Neural Netrork [2].

In this study, feedforward backpropagation neural network has been considered for Indian coin recognition. Feedforward backpropagation neural network is composed of two neural network algorithms. The term “feedforward” refers to method by which a neural network recognizes a pattern and the term “backpropagation” describes a process by which neural networks will be trained. In other words, “feedforward” describes how neural network processes and recalls patterns. Backpropagation is a form of supervised training, i.e., network must be provided with input as well as desired output. The desired outputs are compared with actual outputs to compute errors. Backpropagation is a method which takes calculated error and then weights and input threshold of neural network are altered in a way that causes the error to be reduced.

V. LITERATURE SURVEY

Minoru Fukami *et al.* [9] designed a rotation invariant neural pattern recognition system with applications to coin recognition. They had considered the 500 yen coin and 500 won coin which have similar size, shape and similar pattern. In this paper, they have discussed the rotation invariant neural pattern recognition system having preprocessor composed of many slabs to provide rotation invariant. A rotation invariant intelligent coin identificatiom system (ICIS) has been presented by Adnan Khashman *et al.* [10] in their work. ICIS uses pattern averaging and neural network for recognition of coin. Authors have performed the experiment using Turkish 1 lira and 2 euro coins, rotated at various degrees. 58 out of 60 images were recognized, hence the results were found to be quite encourging. Ancient coins are tough to recognize as weather and other natural causes mortify their structure. Md. Iqbal Quarishi *et al.* [1] proposed an ancient coin recognition system which can classify ancient coins from scanned images. Standard deviation of image histogram considered as feature and feedforward backpropagation neural network has been used for classification.

VI. PROPOSED SYSTEM

The architecture of the proposed Indian coin recognition system implemented in MATLAB® is discussed in following sub sections:

A. Acquire RGB Image of Coin

Image acqusition is the first phase of the coin recognition process. RGB images of Indian coins of different denomination are acquired with the help of sacnning device. Five samples of denomination `1, `2, `5 and `10 are scanned using color scannar.

B. Convert RGB Image to Grayscale

RGB or Color images usually take more time for processing. In order to reduce the complexity of processing and time duration, we convert the RGB image to grayscale image using MATLAB® built-in function *rgb2gray*. It converts the 24-bit RGB image to 8-bit grayscale image.

C. Preprocessing of Image

Gray scale image has been resized to 256X256. The resized image is further passed on to next steps. The edges of the coin image are detected by canny edge detection method.

D. Noise Filteration

If input image of coin is noise affected then various noise filtration techniques are applied to reduce the effect of noise. After noise filtration, image is passed to next step. In this study, only gaussian and salt-and-pepper noise has been considered. For gaussian noise images, noise removal is done by wiener filter and if image is affected with salt-and-pepper noise then median filter is applied. Noise filtered images are passed to further step.

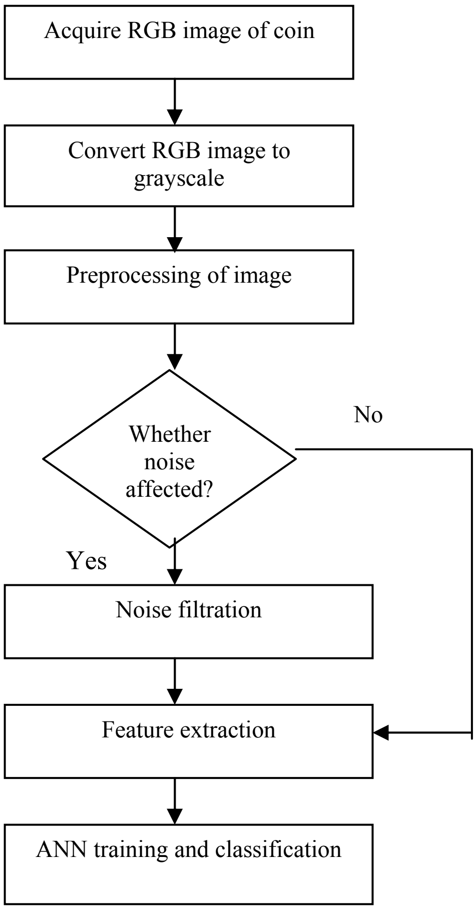

Fig. 4: Architecture of Proposed System.

E. Feature Extraction

Feature is any numerical value or data by which any image can be described efficiently. In the proposed method, as image is a 2-Dimensional signal, the 2-D DWT using Haar wavelet to decompose the Indian coin image into approximation and detail components at different levels, is being used. Wavelet analysis allows complex information like images, pattern, etc. to be decomposed at elementary level and subsequently reconstruct them with more precision [11]. Single level 2- D DWT decomposes the image into four subimages, one low frequency subimage LL and three high frequency subimages; HL details in vertical, LH details in horizontal and HH details in diagonal direction. The main power is in the approximation of lower frequency image, so selected as feature and are further passed to neural network [12].

F. ANN Tarining and Classification

Artificial Neural Networks have proved themselves in the field of pattern recognition. The feedforward backpropagation neural network trained by Resilient Backpropagation training algorithm has been used. 5 samples of each Indian coin denomination (`1, `2, `5 and `10) were scanned. Afterwards, the coin images were rotated by 0, 90, 180 and 270 degrees and were used for training and testing the neural network. Four classes have been created in order to classify the coins. If the input coin image belongs to class 0 then the trained feedforward backpropagation neural network will identify it as `1 coin. Similarly, `2 coin belong to class 1, `5 coin belong to class 3 and `10 coin belong to class 4. Randomly images were selected for training and testing the feedforward backpropagation neural network. In each scenario, the respective neural networks were trained using only 20 images of the available 100 coin images. Remaining 80 coin images are testing images, which were not exposed to the network during training phase and shall be used to test the robustness of the trained neural network in identifying the coins despite the rotations. The learing rate and error values were adjusted in order to achieve minimum mean square error.

VII. Results

For the defined scenarios, the selected neural network architecture has been trained and performance is evaluated in terms of mean square error, number of epochs, time taken, recognition rate, etc. Lower is the mean square error; better is the performance of neural network architecture. Similarly, lesser is the number of iterations (epochs) and time period, better is the performance. Recognition rate has been considered in order to check the efficiency of proposed system.

Scenario 1 - In this scenario, the scanned Indian coin images of zero or negligible amount of noise are given as input to the system. Feedforward backpropagation neural network has been used for classification of images. The results of Scenario 1 reveal that the proposed architecture achieved lowest mean square error in least number of training iterations. The proposed architecture achieved 92% recognition accuracy for Scenario 1. Hence, under given conditions, Scenario 1 performed best with highest recognition rate.

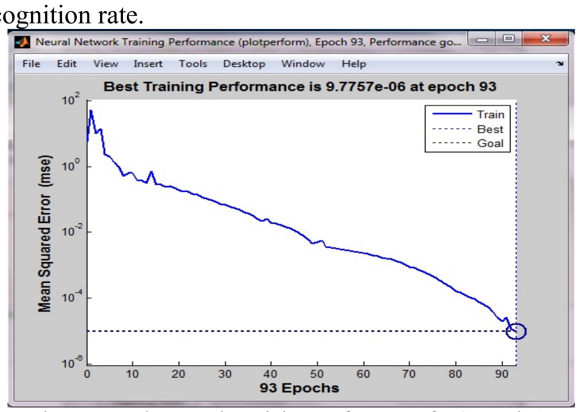

Fig. 5: Neural Network Training Performance for Scenario1.

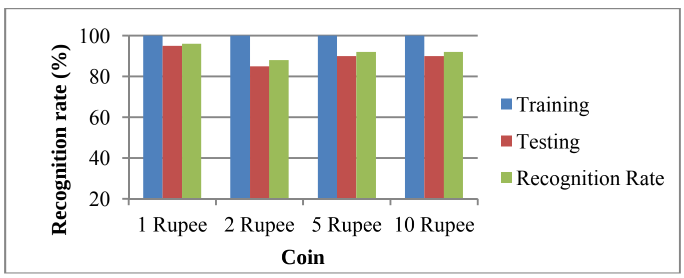

Fig. 6: Graphical Representation of Performance for Scenario1.

Scenario 2 - In this scenario, the performance of the system is tested under the gaussian noise affected environment. One standard value of gaussian noise is added to scanned images with the built-in MATLAB® *imnoise* function. Wiener filter has been used for image enhancement or noise reduction and after preprocessing, classification is done by feedforward backpropagation neural network. The simulation results of Scenario 2 depict that by introducing gaussian noise, an increment have been noticed in the value of mean square error and number of iterations for network training. In Scenario 2, the time taken to train the network is less as compared to others. The proposed architecture achieved 87% recognition rate for Scenario 2.

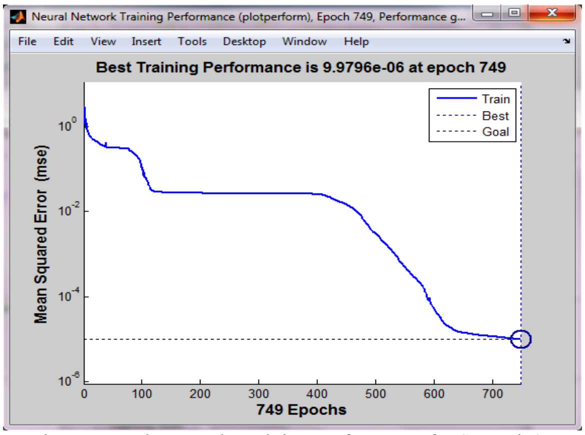

Fig. 7: Neural Network Training Performance for Scenario2.

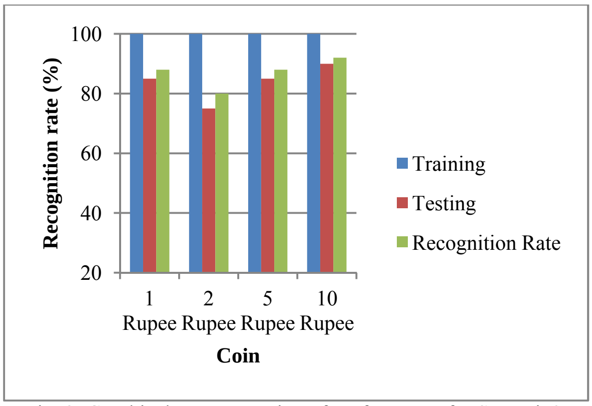

Fig. 8: Graphical Representation of Performance for Scenario2.

Scenario 3 – For this scenario, the salt-and-pepper noise affected images have been considered. Noise is added to scanned images with the *imnoise* function available in MATLAB®. Median filter has been used for salt-and-pepper noise reduction. After preprocessing, features are passed on to feedforward backpropagation neural network for classification of images. From the results of Scenario 3, it is observed that the proposed architecture perfomed well too with the introduction of salt-and-pepper noise. The time taken from training is approximately same with modest increase in number of iterations as compared to Scenario 1. The proposed architecture achieved 89% recognition rate for Scenario 3.

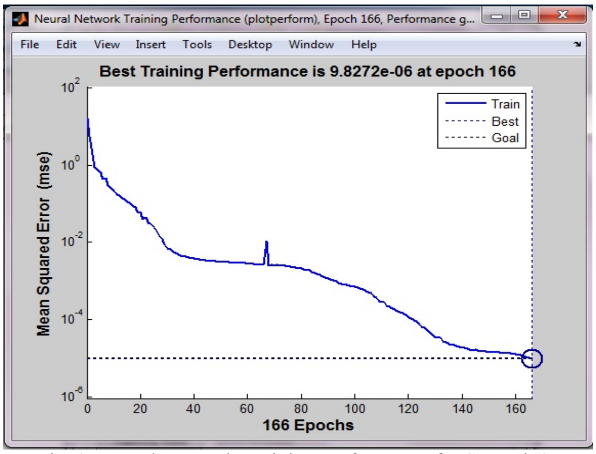

Fig. 9: Neural Network Training Performance for Scenario3.

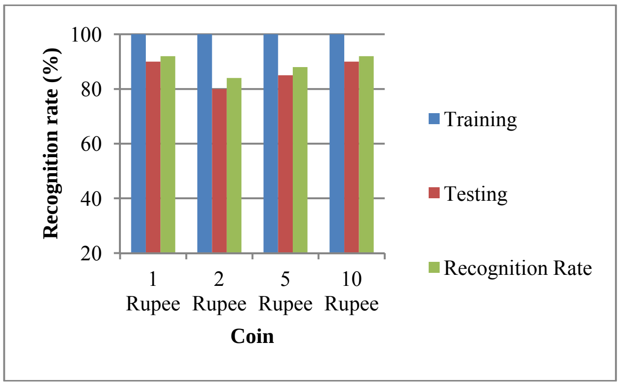

Fig. 9: Graphical Representation of Performance for Scenario3.

The results for all defined scenarios are shown in Table I.

VIII. CONCLUSION

Image recognition is one of the emerging reaserach fields in modren times. The complex computing environment of image based recognition systems results in various issues. The current study aims to apply artificial neural networks to recognize Indian coins with rotation invariance. Feedforward back- propagation neural network has been identified for implementation using MATLAB®. The selected neural network architecture is tarined under different scenarios so as to conclude its performance and efficiency with noisy data. Different scenarios have been designed to assess the effect of noisy and noise free environment on the performance of neural network. The simulation results reveal that the performance of feedforward neural network architecture is not much affected with the introduction of noise in input images. Athough with the introduction of noise, the number of iteration taken to train the network had been increased with little variation in mean square error and time duration

TABLE I: RESULTS FOR ALL DEFINED SCENARIOS

	MSE	No. of Epochs	Time Taken (in seconds)	Recognition Rate (%)
Scenario 1	9.7757e-06	93	0.217	92
Scenario 2	9.9796e-06	749	0.19	87
Scenario 3	9.88727e-06	166	0.215	89

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