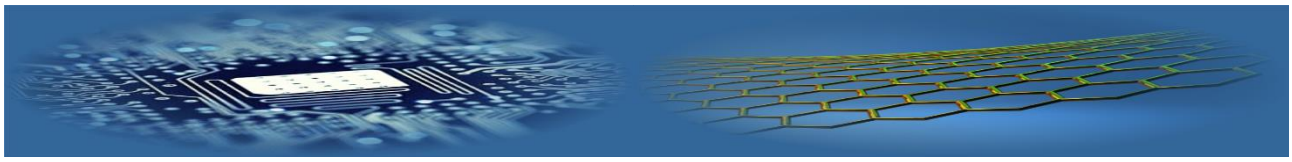

Handwritten digit recognition using combined feature extraction technique and neural network

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Abstract

Handwritten digit recognition is established and emerging problem in pattern recognition and computer vision. A very few volume of work related to research has been done in this field till now. Handwritten digit recognition is very useful in cheque processing in bank, form processing systems and many more. In this paper, a robust and novel technique has been introduced for handwritten digit recognition which is tested on well-established MNIST dataset. Histogram of oriented gradient technique and wavelet transform technique is used for feature extraction. Radial basis function neural network and back-propagation neural network have been used as classifier. Experimental analysis has been carried out and result shows that RBF yields good recognition accuracy as compared to back-propagation neural network.

Keywords:

Handwritten digit recognition (HDR), Back propagation Neural Network, Radial Basis Function, Histogram of Oriented Gradient (HOG)

1 Introduction

This Handwritten digit recognition is one of the main challenging and emerging problem of research in pattern recognition, computer vision and machine learning. Many researchers have done a lot of research work in the area of handwritten digit recognition; still there is a lot of scope to enhance the recognition accuracy of handwritten digits. Handwritten digit recognition is getting increasingly attention due to its wide application areas. Digit recognition has been used in several applications such as, processing of bank-checks, reading bank slips, distinct type of forms like loan, health insurance forms, tax, postal addresses, sorting post mail, examination paper, script recognition etc.

Handwritten Digit Recognition (HDR) is basically an art that detects and recognizes digits from scanned input images and then converts it into appropriate machine editable forms. However, handwritten digit recognition is improving the interface between machine and men in several applications. As we know due to wide variation in personnel writing styles, handwritten digits do not look same length, form, style, position, thickness and coordination, so it emerges as a major challenge in the field of pattern recognition. The first kind of difficulties is due to high variability in the digit shape by individuals and uncertainty in writing styles. Not only for the reason of that there is a huge variation in shape and pattern of digits, but also of interconnection and overlaying of neighboring digits [1]. Recognition of digits is a very common and easy task for the human but in case of machines it gives a serious problem especially in that case when there are digits having ambiguity, great similarity in shapes like 1, 7 and 8, 9 etc.

The performance of handwritten digit recognition system is highly depending upon two things: First it depends on feature extraction techniques which is used to increase the performance of the system and improve the recognition accuracy rate and the second is the neural network approach which takes lots of training time and automatically infer the rule for matching it with the correct pattern Recognizing handwritten digits by computer causes an intent problem because of the large variability in the digit shapes by individual [3, 4].To solve this problem system should be designed in such a way that it should have capability to read the handwritten digits and provide appropriate results.

This paper consists of six sections, where section 1 contains a brief introduction about HDR where as a brief survey has been discussed in section 2. Background related work to HDR is explained in section 3. Section 4 describes the proposed methodology. In section 5, experimental result has been shown and in section 6, conclusion of the paper is described.

2 Background and related works

D.K. Patel et.al [5] In this paper author proposed a multi-resolution method which is DWT and used Euclidean distance measurement metric to get better recognition rate. Discrete wavelet transform is used to extract features at appropriate level of multi-resolution and for getting minimum classification time class of pattern is described through mean vector. EDM is used to calculate distance of each input vector till every mean vector. Input pattern character is determined by the minimal distance calculated. By using proposed scheme result obtained with 90% recognition accuracy which is good. Recognition accuracy may improve by using other methods.

Malik et.al [7] In this paper author described a HCR method using Wavelet Transform and for classification purpose hop-field network is used. Relevant features are extracted from the images by using wavelet transform and image is decomposed at appropriate level for extracting suitable features. Evaluation has been done by using all the various distortion levels for 26 patterns. By using this method

result shows that at distortion level of 30% system identified all the characters but at 40% distortion level it recognized only some characters. So, the problem is that system was not able to identify the characters at above 40% of distortion levels.

M.C.Padma et.al [6], author used quad-tree based technique for feature extraction and KNN classifier is used to classify digit. By using this feature extraction input image is partitioned up to second level and divided into 4 quadrants Q1, Q2, Q3, Q4. It is further decomposed in 4 partition which is known as zone. To obtain consistent feature value a dataset of 3600 samples are used to train the classifier and tested on a dataset of 1200 samples. After all these training and testing result shows that the overall accuracy of the system is 85.43%.

Swapnilet.al [8], in this paper author used GRNN classifier and pre-processing techniques such as binarization and normalization to obtain accurate result. Positional feature extraction technique is used in this paper which depends on positional characteristics of particular pixels found in input images. All sample of image matrix are added, final outcome matrix is divided with sum of added matrix i.e. average matrix, after that minus it from particular sample image matrix which gives ultimate features. To obtain projection vector matrix singular value decomposition technique is used which gives better accuracy in results. The proposed method results 82.89% accuracy for devanagari character and 85.62% for kannada character.

Pasha et.al [2], in this paper author introduced a new technique for efficient feature extraction and classification of digits. The main idea behind this technique is to extract suitable and relevant feature which have some significance in output. Here structural features like Aspect ratio, Correlation, corner detection etc. and for extracting global features wavelet transform method is used. ANN classifier is applied to recognize the handwritten kannada numeral and character. Wavelet features and structural features are combined into a single feature set. For training dataset samples of 4351 are passed down to find out steady features and tested on 1450 samples. The result shows that overall accuracy obtained for kannada character is 91% and for numeral it is 97.60%.

S.horata et.al [10], in this paper histogram of oriented gradient is used for feature extraction and recognition ability of two classifiers compared with each other. DFBNN and ELM are used as classifiers. Three kind of handwritten datasets Thai, bangla and devanagari numerals are used and each dataset is divided into two parts i.e. with or without hog features. The experimental result shows that recognition rate of both the classifiers are improved by using hog feature. However, DFBNN classifier provides slightly better recognition rate than ELM classifier with all the three datasets.

Akhtar et.al [11] in this paper author proposed two acceptable approaches for feature extraction in digit recognition. Wavelet transform and wavelet packet Transform are used as feature extraction technique for extracting relevant features. Author used KNN and SVM classifiers for classification purpose and tested on MNIST dataset. The overall accuracy on wavelet transform by applying K nearest neighbour is 84.53% and with Support vector classifier the accuracy is 89.51%. Correspondingly on Wavelet Packet Transform by applying KNN the accuracy achieved is 96.24% and with SVM the accuracy percentage is 96.29% on training the dataset. The obtained outcomes by applying these two classifiers are equivalent with each other. In this paper accuracy may improve by using other sub-bands of wavelet transform.

Lauer [12] et.al suggested a trainable extraction technique for features which is based on LeNet5 architecture. The proposed method for HDR has been tested on well-known database MNIST. This paper introduced two classifiers which are LeNet5 CNN and Support Vector machine. To maximize the generalization efficiency of LeNet5, SVM classifier is used. To get better recognition rate elastic distortion and affine transformation based new training set are generated. However, system outperforms with both the classifiers and performances of both classifiers are comparable with each other. Moreover, combining these two algorithm results into higher complexity, this is the drawback of the proposed method in certain cases.

B.EL.Quancy et.al [13], In this paper author proposed four F.E. approaches which is basically related to discrete continuous transform. The main four approaches used in this paper are: DCT upper left coefficients (ULC), block based DCT coefficients, DCT zigzag coefficients and block-based DCT coefficients. SVM classifier is used to evaluate the performance of DCT variant. MNIST database are used in two variant i.e. raw data and pre-processed data. Based on classification, accuracy, all the four approaches are compared and it has been analyzed that block based DCT zigzag feature extraction technique provides better performance than all its supplements.

3 Background work

3.1 PATTERN RECONITION

Pattern recognition consists of two stages, first one is the feature extraction stage and second one is the classification stage. Feature extraction stage is mainly used for dimensionality reduction and for obtaining relevant features for the application. Second one is classification which is the most important and essential phase for decision making. Pattern recognition is an emerging area of study which is well known since many years of research, especially when we talk about the field of digit recognition. HDR is considered as a large-scale challenge in the field of pattern recognition and getting more attention towards researchers.

3.2 NEURAL NETWORK

A neural network is basically a knowledge refining unit which is highly motivated by biological neurology system functioning as brain. It consists of a huge number of powerful inter-connected refining elements called as neurons works in coordination manner to solve distinct problems. The main objective of neural network is to process information and solve problem in the same way as the human brain does. It is used in various potential application areas like data classification areas, pattern recognition, identifying learning rate and recognition rate [14].

In neural network, hidden layers are having a vital role in generating outcome of recognition task. Hidden layer size matters a lot to classify the digits. Output layer of the neural network is highly depended upon the hidden layer and the input layer.

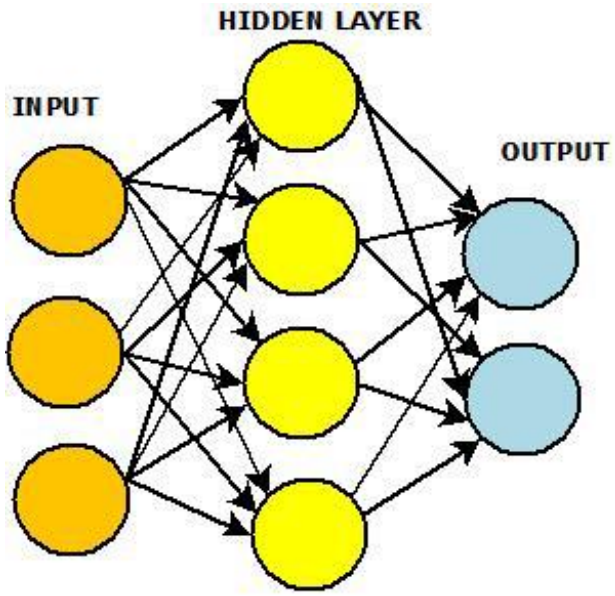

FIGURE 1 Neural network architecture

In the above diagram, there are 3 layers input layer, hidden layer and output layer which are interconnected with each other and work efficiently in a proper manner. In neural network information flows in parallel and knowledge is distributed between the neurons. In this paper, Radial Basis function and BPNN is used as a classifier for recognizing the digits.

3.3 RADIAL BASIS FUNCTION

It is a kind of artificial NN which uses radial basis function as its activation function. In this there are three layers which are as follows:

- Input layer: These are the origin nodes which join to the network to its surroundings.
- Hidden layer: These are the hidden units which provide a set of basis function and High dimensionality.
- Output layer: These are simply the linear combination of hidden functions.

It is sort of supervised neural networks which are having a shorter learning time [23]. There are several training parameters which affiliated with traingd: epochs, goal, show, min-grad, time and lr. The learning rate should be kept small for the better convergence.

3.4 BACK PROPAGATION NEURAL NETWORK

A neural network is a network with nodes of processing elements, and connections as data carriers. The architecture of neural network determines how inputs of the neural network are transformed into an output [22]. It is the most popular supervised learning multilayer feed-forward NN algorithm recommended by Rumelhart, Williams and Hinton [21]. This algorithm is the modification of least mean square algorithm by doing modification in network weights, it minimizes the mean square error between the real outcome and the target outcome. Back-propagation consists of three phases as follows:

- Forward phase
- Backward phase
- Weight update phase

3.5 STEP INVOLVED IN HANDWRITTEN DIGIT RECOGNITION

First step is to scan handwritten document, then transform it to processed image via several pre-processing techniques such as noise removal, slant angle correction, median filter etc. After pre-processing the next crucial stage is image segmentation where image will be decomposed into several sub-images, characters etc. The next step is the most important stage in any recognition process i.e. features extraction. This step is all about extracting suitable and appropriate feature because these features play an important role in training as well as testing the classifier, then the next is to classify the suitable class for input image and finally the last phase is post processing phase. This step is optional stage but sometimes improves recognition accuracy.

3.5.1 IMAGE ACQUISTION

It is also called as image scanning or image digitization. For recognition system input image acquires a scanned image through digital scanner or by capturing photograph or by directly using stylus. This captures input image may be gray scale, binary or colored but have a specific format like jpg, PNG, bmp etc.

3.5.2 PRE-PROCESSING

Pre-Processing is one of the major step and first phase in the recognition process. In this stage, raw image is transformed into a processed image and enhance the image to make it appropriate for the next stage. The raw image involves several operations or pre-processing stages like binarization, noise removal, skew detection or correction, normalization, thinning, slant angle correction. The main objective of this stage is to remove those elements which are not useful for recognition process. The main steps in Pre-Processing are as follows:

- RGB TO GRAYSCALE CONVERSION. In this process scanned images which are stored in different formats (jpeg, bmp.tiff, png) are converted into gray scale format in matrix representation form.
- BINARIZATION. This process convert coloured or gray scale image into black and white or binary image.
- NOISE REMOVAL. After scanning some images may contain various types of noises like gaps in lines, disconnected line segments, bumps, filled and unwanted types of loop which have no significance in output. So, it becomes necessary to remove such type of noise element. The main aim of this sub-step is to remove unwanted type of noise.
- NORMALIZATION. It is simply a procedure of transforming image of odd size into an image of accepted sized [2]. I f image size is too large or too small then in this stage manage the image size so that all the ambiguity related to normalization of image can be removed and appropriate results have been generated for next stage.
- THINING AND SKELETONIZATION. In this process, binary valued images which contain regions, should be reduced to pixel lines. The main objective of skeletonization is to reduce the digit area into one pixel line and produce the skeleton of the pixel.

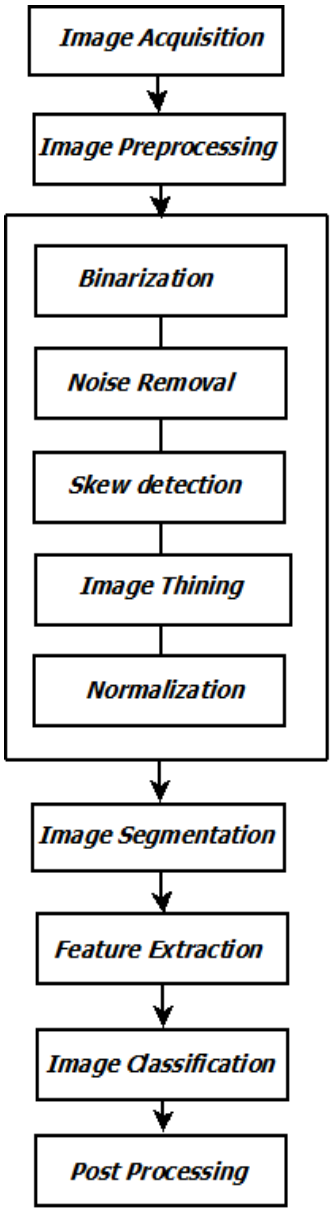

FIGURE 2 Steps of HDR

3.5.3 IMAGE SEGMENTATION

In this stage, an image which is present in the form of sequence of digits is decomposed into sub-images of respective digit. These sub-images provide information that how many number of digits contain in the image and for doing so labeling process is used in this stage by assigning a number to each digit. Accuracy of segmentation process is having a necessary role in the accuracy of final outcome in recognition process.

3.5.4 FEATURE EXTRACTION

It is the most influential steps in digit recognition process sometimes also called as the hearts of recognition process. It is most essential and crucial stage because final outcome of recognition process is very much depending upon this stage.

The main essential task in digit recognition is to extract features and then finally selecting appropriate feature from raw data. Choosing relevant features and affiliated parameters leads to moderate errors during the classification stage. In this stage, a feature vector is assigned to every digit, so that it can be easily identified. These feature vectors are used to discriminate the digit from other digits. To acquire newness in feature extraction it can be classified into 3 categories which are as follows:

- Statistical features
- Structural features
- Global Transformation and series expansion

1. *STATISTICAL FEATURES.* Statistical features are generally depending upon hypothesis. Probability theory, Zoning, loci, distance are the main Statistical features.
2. *STRUCTURAL FEATURES.* Structural features involve that type of features which contain information related to the structure of character like loops, joints, branches, curve, crossing points, aspect ratio, strokes etc.
3. *GLOBAL TRANSFORMATION AND SERIES EXPANSION.* Global transformation features implicate global deformations like rotation, translation etc. Hough transform, Gabor transform, wavelet transform is based on global transformation features.

3.5.5 CLASSIFICATION

In each digit recognition classification is the most essential decision making stage to analyze or identify the digits. As per to preset rules it has used the features extracted in the earlier stage to determine the digits. Several types of classifiers are used to classify the digits. These classifiers correlate the input feature with the pattern which are previously stored and identify the best appropriate class for the input.

3.5.6 POST PROCESSING

The main objective of this stage is to reduce or remove such errors which contain irrelevant information and also to find out the system even if it gives required outcomes or not, although this step is not so compulsory step, but sometimes this stage helps to improve the accuracy of the recognition processes.

4 Methodology

In this paper, a novel method is proposed that is we have combined Histogram of oriented gradient and Haar wavelet together for extracting of features and after that we have applied the RBFNN and BPNN as a classifier.

4.1 HISTOGRAM OF ORIENTED GRADIENT

Histogram of oriented gradients feature descriptors are extensively used in image processing and computer visions for the recognition purpose. It was first recommended by Dalal and Trigg's for detection of human body but having a great advantage over other descriptor it is now used in the area of computer vision and pattern recognition.

The main aim behind Hog descriptor is that local or confined shape information and appearance of object within an image can be determined by intensity gradient distribution or edge directions. As the Hog feature produce on localized

block, it justifies invariance to photometric and geometric transformation makes slight changes if they are much smaller than the orientation bin size or local spatial [18].

It decomposes image into some small sub-images often known as cells, these cells can rectangular or circular in shape i.e. R-HOG and C-HOG respectively. For each cell histogram of gradient direction is computed or histogram of edge orientation for the pixels within the cell is computed. The combine histograms are used as feature vector for describing the object. To get appropriate accuracy local histogram are normalized based on contrast, that's why Hog is stable on illumination variation. The main reason to use this feature is that it extracts histogram feature more efficiently which will further used in classification and recognition stage. In handwritten digit recognition, it can capture edge or gradient structure and gives information about the shape of the digit.

4.1.1 Use of HOG

- The main reason to use this feature is that it extracts histogram feature more efficiently which will be further used in classification and recognition stage.
- In comparison to SIFT and LBP, Hog is a quick and fast type of descriptor and being simple in computation Hog features are successful descriptor.
- In handwritten digit recognition, it can capture edge or gradient structure and gives information about the shape of the digit.

Hog feature extraction process consist several several steps.

First a scanned image is taken as input then normalization, smoothing of images are done in next step if images are too large or too small then apply resizing of images. In next step, gradient computation is done after that full image is divide into small regions, these regions are called as cells. After dividing images into cells compute the Hog features of each cell.

Then histogram of each cell is computed. For generating feature vector of each cell the computed histogram of each cell is combined. After all that above processes feature vector is generated.

These feature vectors contain necessary and useful information related to the image. From these feature vectors appropriate and relevant information should be extracted that can be very useful in outcome of digit recognition and having a great significance in final outcome.

4.2 WAVELET

Wavelets are the mathematical functions, which are most widely used in the area of signal analysis and image processing. The major advantage of using wavelet is that it cut up image or signals into distinct frequency components and after that it interpret and brief study about each component with a resolution equivalent to its scale.

Wavelets are used as the basis of multi-resolution process. Wavelet transform are of many types, the most basic wavelet transform is HAAR wavelet transform. Wavelets transforms are achieved through quadrature mirror filters. Two types of filters are used one is the high pass filter and other is the low pass filter. These filters are applied to every row/column of an image to decompose it into the four-appropriate frequency sub-bands.

As shown in the figure 4: A1 represents approximation coefficient, H1 represents horizontal, V1 represents vertical and D1 represents diagonal coefficients.

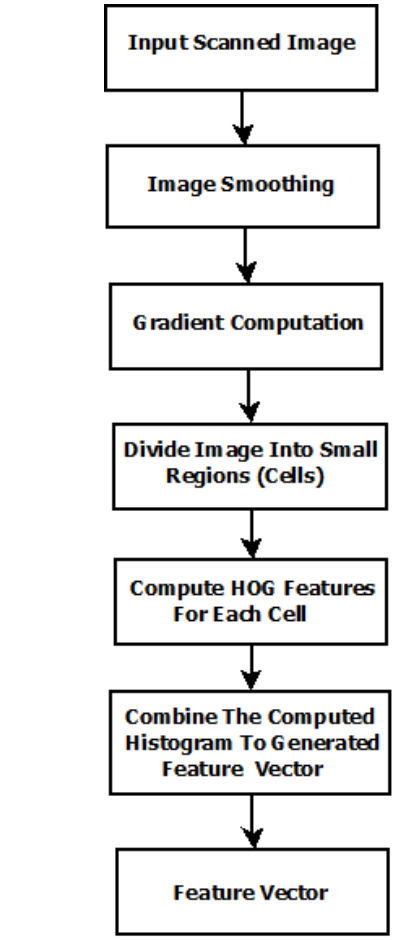

FIGURE 3 HOG feature extraction process

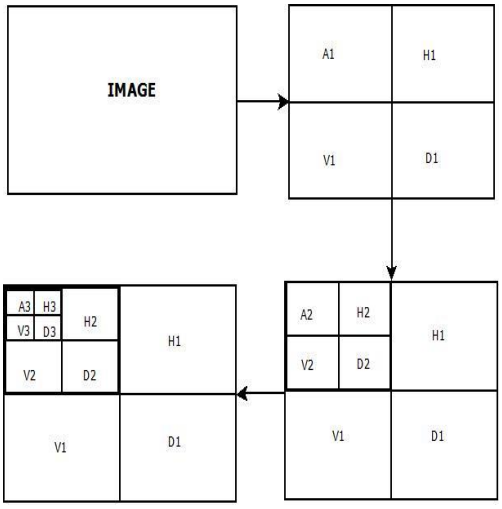

FIGURE 4 Wavelet decomposition of an image

Wavelet decomposition divides an image into approximation and detail coefficients. In case of wavelet decomposition approximation coefficient is further divided into other approximation and detail coefficients but detail coefficient remains same in this case. In case of wavelet packet decomposition approximation and detail both

coefficients are further divided. After wavelet decomposition, hierarchical type structure is obtained because approximation coefficients are divided again and again as levels are increases. Down-sampling is used in wavelet decomposition in each and every level. It will help in wavelet decomposition to decompose the images at every stage.

4.2.1 HAAR WAVELET TRANSFORM

Haar wavelet is one of the straightforward and smooth types of wavelet. It will provide a good foundation for understanding the more sophisticated wavelet transform. The main function of Haar is to compress signals and remove noises. Haar wavelet is a procession of rescaled 'square shaped' function which form a wavelet basis or wavelet family after combining. Haar is also known as Db1 wavelet. To approximate a function Haar used a square pulse as a wavelet.

Any continuous real function with compressed support can be approximated consistently by linear combinations of their shifted function. Haar wavelet transform is a process of decomposition or transform which uses recursive averaging and differencing. The overall data is shown through the resultant coefficients which are required for an image construction. Based on these outputs, are known as detail coefficients and these outputs helps in building the wavelet basis function. The main function of this wavelet is that if it necessary to reconstruct previous levels then construction of any decomposition is possible using averaging process. By using the process of averaging levels can be reconstructed easily.

- In haar the input and output length are same, though the length should be a power of 2, i.e. N=2^n, n ∈ N.
- It can be used to analyze the localized feature of signals.
- No requirement for multiplication, it needs only additions and in HAAR matrix there are many elements with zero value, that's why it will take less computation time.

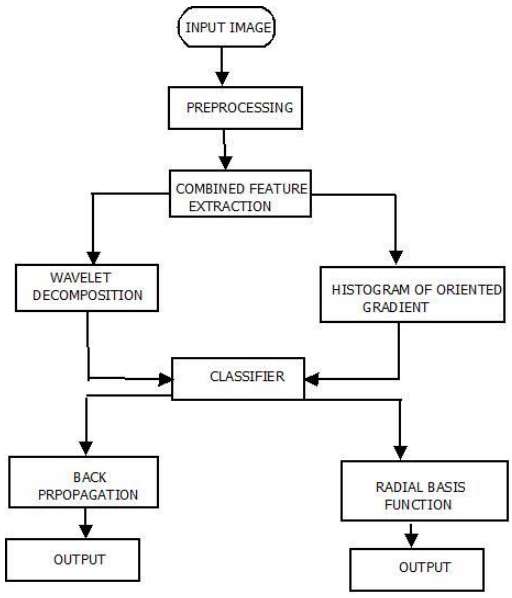

FIGURE 5 Flowchart of proposed method

Handwritten digit recognition learning model is implemented as supervised learning model. In supervised learning model, there are mainly two phases in which it highly depends, first one is training phase and the second one is testing phase. First of all, from handwritten digits' images i.e. training set images features are extracted using haar wavelet decomposition and histogram of oriented gradients. Wavelet decomposition decomposes images into 4 coefficients which are horizontal (h), vertical (v), approximation (a), diagonal (d) and similarly hog features of digits are obtained. After that these feature vector is taken as input to radial basis function NN and back-propagation network, so that weights of network get optimized. All this is done in training phase. In testing phase, the features of handwritten digits are extracted and feature vector of test image is given to decision unit. This unit is important for making decision and recognizing handwritten digits.

4.2 STEPS FOR PROPOSED WORK

Handwritten digit recognition steps are as follows:

Input: Image containing handwritten digits

Output: Recognized handwritten digits

Step 1: Input image is obtained from the pre-processed image.

Step 2: Perform the feature extraction process by using histogram of oriented gradient feature and haar wavelet transform method.

Step 3: Pre-processed image contains Hog feature vector and wavelet coefficients.

Step 4: Perform classification for recognizing digits using radial basis function and back-propagation classifier by using these features.

5 Result and analysis

This section represents the detailed implementation being conducted by the recommended method on MNIST database. This dataset is an extensively revolved benchmark, which dwell 42000 images of training data set and 28000 images of testing data set. Data files which consists of zero to nine hand-drawn digits are represent in the form of gray-scale images. In this every image consist of 28*28 pixels so a total 784 pixels are there in this dataset. A single pixel value that ranges from 0-255 is contained by each pixel corresponding with it, which specifies the darkness or lightness of that pixel.

We have taken 100 samples images of MNIST dataset and then train and test the dataset in matlab2016a environment. One of the sample images of MNIST dataset is shown below in the following figure.

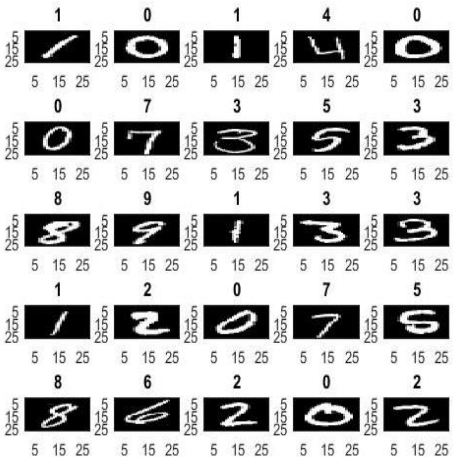

FIGURE 6 Sample image of MNIST dataset

Hog and wavelet features of digits are obtained after applying feature extraction method which are histogram of oriented gradient and HAAR wavelet transform. Extracted HOG features of some digits are shown below in the figure.

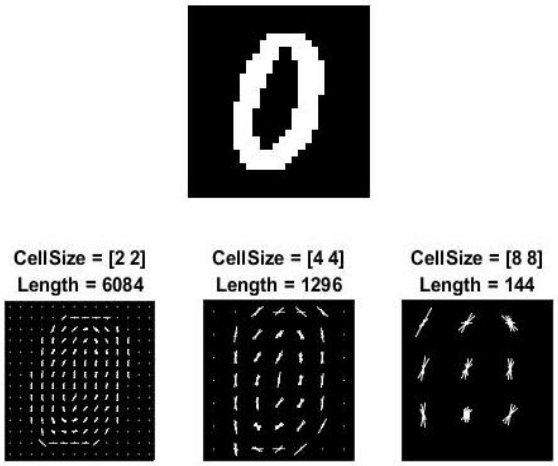

FIGURE 7 HOG feature of digit 0

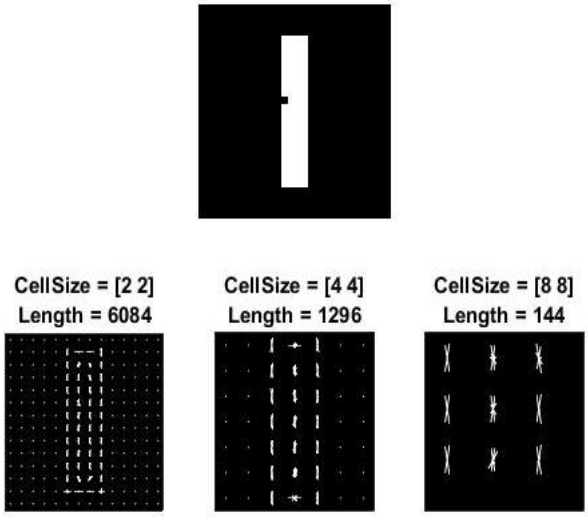

FIGURE 8 HOG feature of digit 1

Wavelet feature of some digits are shown below in the figure in which the four wavelet coefficients approximation coefficient, diagonal coefficient, horizontal coefficient, vertical coefficient are shown.

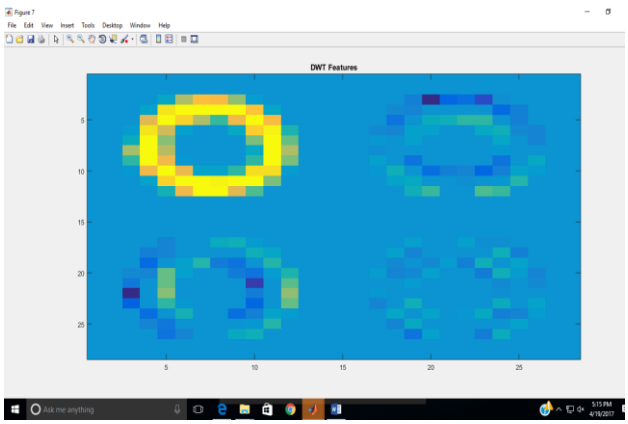

FIGURE 9 Wavelet feature of digit 0

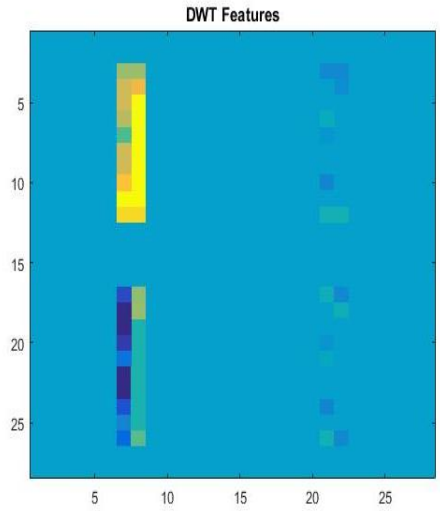

FIGURE 10 Wavelet feature of digit 1

After extracting relevant information from suitable Hog and HAAR features, appropriate classifiers such as back-propagation and RBF neural network are applied to find out the accuracy of the system.

We obtained following results of back-propagation neural network by using nntoolbox.

Regression plot, performance plot, error histogram plot and training state plot are as follows:

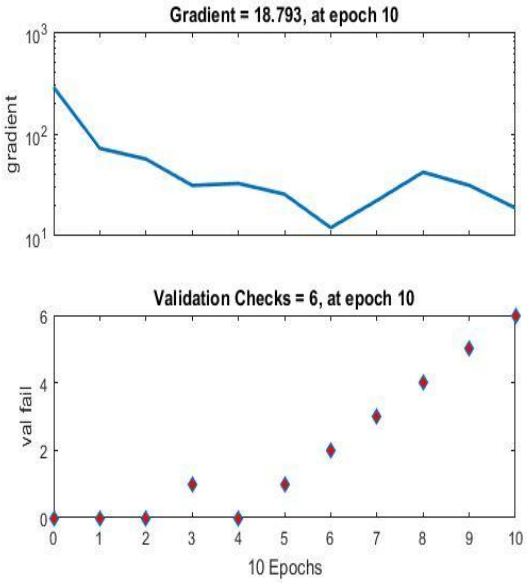

FIGURE 11 Plot of training state

In table 1 training time of both the classifier is given and from this it is clear that training time of radial basis function neural network is less as compare to back-propagation neural network.

TABLE 2 Analysis of both classifiers

Neural Network Classifier	Training Time	Accuracy
Back-Propagation neural network	13.4952	83.66%
Radial Basis Function neural network	13.3962	98.26%

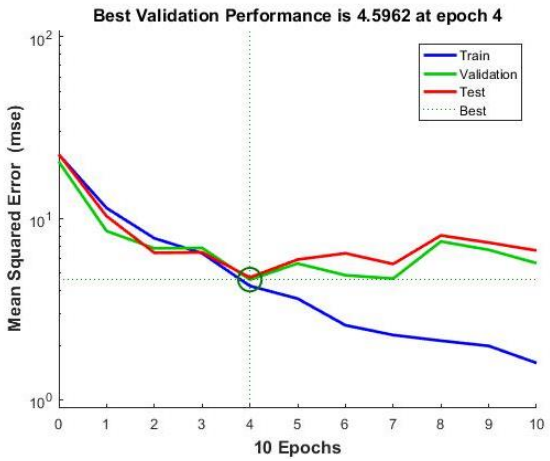

FIGURE 12 Validation performance plot

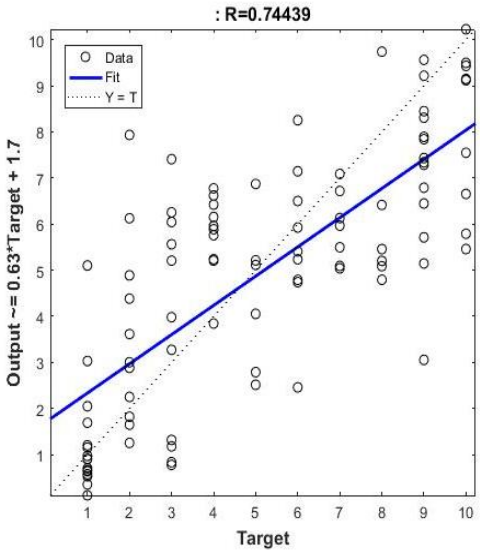

FIGURE 13 Regression plot

6 Conclusion

In this paper, Haar wavelet transform and Histogram of oriented gradient is used for feature extraction technique and classification task is handled using Radial Basis Function NN and back-propagation neural network. Main goal of the proposed work is to make the system which recognizes the digit in an accurate and faster way. In this paper, we have mentioned a new combined approach of feature extraction and neural network which increase the accuracy of the system. Accuracy of back-propagation neural network is 83.66% and radial basis function is 98.26% which is better than other existing methods.

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