AN ENHANCED NEURAL NETWORK APPROACH WITH HYBRID FEATURE EXTRACTION TECHNIQUE FOR RECOGNITION OF OFFLINE HANDWRITTEN MATHEMATICAL EQUATIONS

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Abstract— Recognition of handwritten digits, characters, mathematical symbols and equations is an intricate task due to its 2 dimensional layout, variation in writing style, different font, shapes, complex semantics, and spatial structure. Extracting mathematical equations from the scan document is more complex. The proposed recognition system completes the task by using feed forward back propagation neural network and hybrid feature extraction technique. The experiment has been carried out for different types of handwritten mathematical equations. The system verifies its accuracy. By using neural network with scaled conjugate gradient training, the accuracy increases with enhancing the speed of recognition.

Index Terms— Offline recognition, Neural network, Math equations, Complex semantics, Hybrid feature.

I. INTRODUCTION

The Role of Mathematics is a most important for the growth and development of all science fields viz. engineering and technological development as well as in daily life. Characters, digits, math symbols and math equations are widely used in a lot science field. If the mathematical equations recognition system is available then it would be benefited to the human being to enter mathematical equations into the computer system. To achieve this goal of recognition of mathematical equations, need to identify texts, graphics, notations, extract the other information from the image and essential to develop an validated algorithms and methods for recognition of it. It is a most challenging and valuable issue in the field of pattern recognition. The various modern tools viz. LATEX, MathML etc are used to achieve the task of converting mathematical symbols and equations, graphics into scientific documents [1]. However in day to day life, there are various kinds of documents are available that

Includes graphics, images, characters with digits and symbols.

The basic steps to achieve better accuracy in recognition are extracting the symbols from mathematical equations and analyze the structure of it [2]. As the different writer having their own writing style with variations in shape, size, and font. Handwriting is a friendly accessible interface for inputting mathematical equations to computer [3]. No one is the better than human being in pattern recognition [4]. Currently the different documents are handling by computerized systems. Actually the OCR systems are good in processing the text but failed to process special math symbols, graphics, equations, tables etc. [5]. There are two different methods viz. offline and online method for the recognition of characters, digits, math symbols and equations. In online method, information with statistics is captures during writing with stylus and in offline method; data with statistics are captured after the writing on the document has been finished [6].

The recognition of text with symbols and equations is a union of human intelligence and machines [7]. Nowadays the special math symbols, various notations can be generated by computers but recognition is much critical [8].

The complications in recognition have been appeared due to diversity in writing style, size, and pattern of the writer as well as quality of image to be recognized. Due to tangled semantics and spatial structure of mathematical equations, the recognition of it not easy. It is a challenging issue [9]. The automated system which includes the recognition of handwritten characters, digits, symbols and mathematical equations are mostly useful for the blind people to compensate or to regain the information and for their comfort [10]. Moreover the trouble with recognition of various components in the mathematical equations is not addressed much as view in the survey till date. In proposed system for the recognition of offline handwritten mathematical equations, neural network architecture with input layer, single hidden layer and output layer has been used and has been trained with scale conjugate gradient. The thresholding segmentation has been used to separate an image into different regions based upon its gray level distribution. The key features are extracted from the scanned image of handwritten mathematical equation are height to width ratio, boundary box, zoning density, area of element and counting total elements. For mathematical equation recognition, the brute force algorithm that is Template matching has been used so that the pixel by pixel matching of template with the image be scanned. It uses the principle of similarity metric like normalized cross correlation and confusion matrix shows recognition rate of system.

II. LITERATURE SURVEY

The first character recognition systems were available in the 1950s. Moreover the method for the structural analysis of two dimensional mathematical expressions proposed in 1970s. The two major strides namely the grouping operator sequences and building a structure tree. In 1971, the problem associated with computer input and output of mathematical equations and symbols has been considered. Human being frequently does character recognition. There are number of applications of character, digit, symbol recognition viz. cheque processing, pin code, postal mail, reading notes, books with character, special symbols and numerals with math calculations. It is essential to elaborate the aid for the blind people with the help of machine learning with pattern recognition. Moreover, in research between 1980 to 1990, the attention on handwritten character recognition has been incorporated.

In [11], kanada and tamil numerals has been recognized. Zoned based hybrid feature extraction with neural network classifier provides 97.5 % and 93.9% accuracy for kanada and tamil numerals respectively. English handwriting recognition has been presented. Graheme segmentation with sliding window is the feature extracted. Multilayer perceptron used as a classifier provides very fast recognition with low accuracy [12]. The handwritten English word has been recognized. DWT with multiresolution technique are the feature extracted. Neural network with Euclidian distance matrix has been used as a classifier which shows good accuracy upto 99.23% but speed of recognition too slow [13]. Farsi cursive text recognition has been presented in which hidden markov model used as a classifier and feature extracted are chain code histogram, distribution of foreground density across zones. Recognition rate 89% [14]. In [15] Chinese handwritten alpha-numeric recognition. Gradient features are extracted with hidden markov model as a classifier. It gives average recognition rate 97.13%. Arabic handwritten character recognition using back propagation neural network. Many areas of research with challenging issues remain. Not a single method or technique exists that fulfills all the requirements of handwritten character recognition [16]. In [17], represents mathematical expressions in context free grammars with cocke-younger-kasami algorithm to parse 2D structure. Employ stroke order to reduce complexity of the parsing algorithm and solve local ambiguities so that recognition rate and processing time has been improved. Mathematical formula identification in the images of PDF documents by visual C++. Results obtained after adjusting threshold column, threshold height and width with parameter adjustment algorithm related to character sized is designed and the method improves adaptability [18]. In proposed method, the enhanced algorithm has been used to solve ambiguities and to improve recognition rate with processing time. The experiment has been carried out with five input layer, number of class output layer and two hidden layer. This network architecture has provided good results in handwritten character as well as in handwritten math recognition [19]. Multilayer perceptron used as a classifier which obtains accuracy of 92 %. Contextual information has been used to overcome the trouble of similarity and dissimilarity in characters [20].

III. SYSTEM ARCHITECTURE AND METHODOLOGY

The flow of proposed system for the recognition of offline handwritten mathematical equation has been depicted in Figure.1. The complete process of recognition will be achieved using training phase and testing phase. Preprocessing, segmentation, feature extraction, training of classifier and testing of classifier are the basic steps involved in it.

1) Image Acquisition- The image of handwritten mathematical equations viz. quadratic equation and convolution summation has been captured as an input through Scanner. It is essential for digital image to go through preprocessing stage to get filtered, binarized and skew corrected image.
2) Preprocessing- It is executed on the scanned input image in order to render the resulting image more worthy for further actions. Noise can be removed by adaptive wiener filter, smoothing linear filter and statistic filter. Get binary filtered image.
3) Segmentation- In segmentation, separation of words, lines, characters with decomposing into sub-images has been done. Image is decomposed into sub-images of individual characters. Line segmentation is used to separate text lines. Each character is resized into 4x4 matrix of image. Image is binarized, where part of expression is segmented as a 1 and background as a 0. Actually the accuracy of recognition rate is mostly depends on the segmentation.
4) Feature Extraction- Mostly two methods of feature extraction techniques namely statistical feature in which statistical distribution of pixels of an image take care of variations in writing style and structural Features in which geometrical as well as topological properties are considered. In proposed system, Zoning, area of input image, Counting Total Elements, H to W ratio and boundary box has been considered.
5) Classification- In proposed system, neural network being used as a classifier with scale conjugate gradient descent training algorithm. Neural network better in terms of speed and recognition rate.

6) Recognition- The trained classifier has been tested by recognizing various handwritten math equations and with the help of confusion matrix degree of accuracy for recognition has been measured.

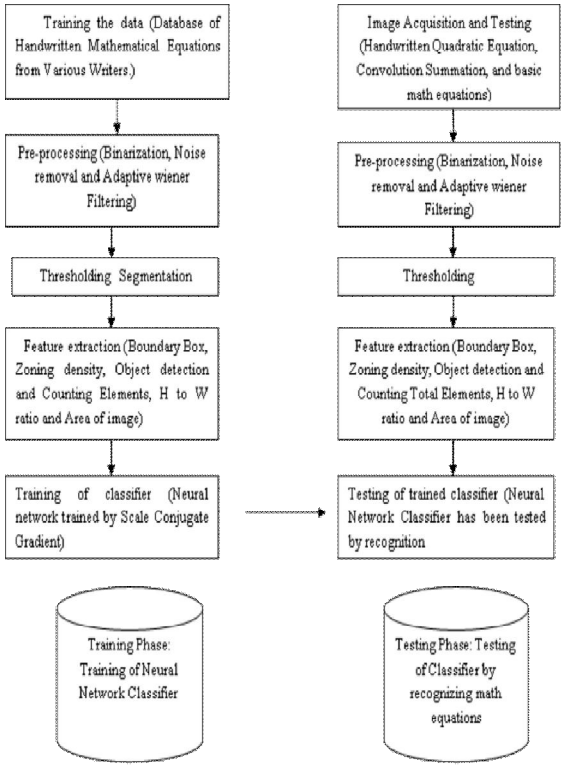

Figure. 1: Proposed system for handwritten mathematical equation recognition system

IV. EXPERIMENTAL RESULTS WITH SIMULATION

The system performance has been determined with different types of handwritten mathematical equations viz. convolution sum, quadratic equation, straight line equation and rule of indices. The each and every steps of recognizing the input image of convolution summation has been explained. The operations like gray conversion, adaptive wiener filtered image and binary image are depicted in Figure. 2 also the filtered binary image, object detection in image, cropped image and mask of equation are depicted in Figure.3. Boundary box approach, zoning density, H to W ratio, area of image and counting elements are the various features has been extracted from input image. There are totally 330 images of math equations have been taken as a database from different person with variation in handwriting. Training algorithm is scaled conjugate gradient. In Proposed methodology neural network classifier and hybrid features yields 97.5% accuracy with good recognition speed. The neural network architecture with one input layer with three neurons, one hidden layer with 20 optimal neurons and one output layer with five neurons in which one neuron for each class has been depicted in figure . 4. and the progress of neural network training which involves epoch with iteration, time and performance has been depicted in Figure. 5. The training parameters of the network are shown in Table I. The best validation performances R: 0.92884 at epoch 14 were depicted in Figure. 6. Training state shows the gradient 0.016867 at Epoch 20 has been shown in figure 7. Error histogram with training, validation, testing and error has been displayed in Figure. 8 and finally the regression plot of target and output in which training with R: 0.97495, validation with R: 0.92884, Testing with R: 0.95806 and finally all with R: 0.9648 are displayed in Figure. 9. The main key and vital point is confusion matrix shown in Figure. 10, in which target class and output class has been examined and it have been displayed 95% recognition rate. Generally in the all domain of machine learning and statistical classification, the confusion matrix has been used. It is a certain table layouts that afford that judge the performance of supervised learning algorithm. Each column of matrix shows the instances in a predicted class while each row shows the instances in an actual class. Confusion matrix has been explained more data analysis than basic proportion of accuracy. Actually accuracy is not decent metric for the real potential of a classifier if the numbers of samples in different classes vary at great extent. Finally for simplicity the template matched with the handwritten expression of convolution sum is viewed in Figure. 11.

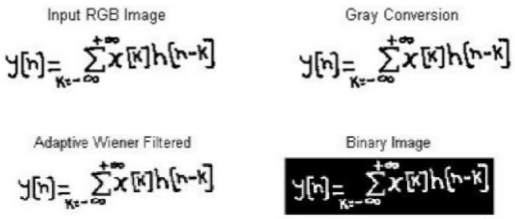

Figure. 2: Preprocessing of handwritten Convolution equation

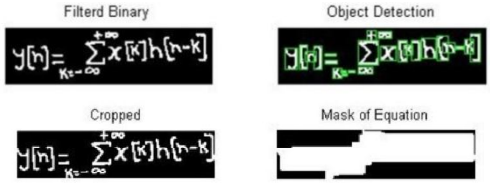

Figure. 3: Convolution equation with object detection and boundary box.

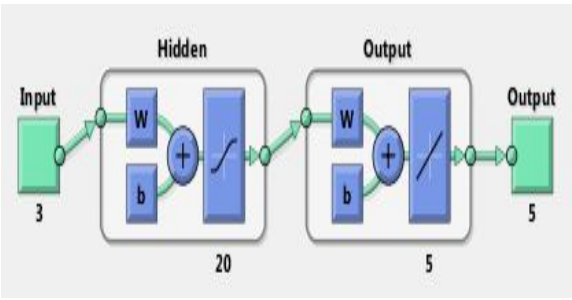

Figure. 4: Neural network training architecture.

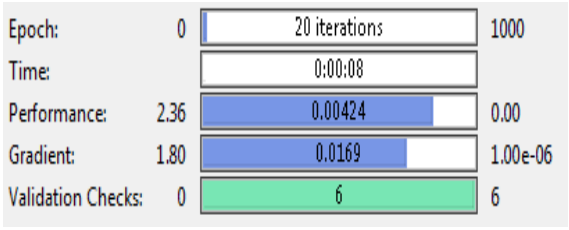

Figure 5: Neural Network Training Progress.

Table: 1: Neural Network Training Parameters

Sl. No.	Parameter	Value/ Type
1	Network Training Function	Scaled Conjugate Gradient
2	Learning Rule	Adaptive LR
3	Time	0:00:08 Sec
3	Network performance Function	Mean Squared Error (MSE)
4	Regression State	Training R: 0.97495 Validation R: 0.92884 Testing R: 0.95806 All R: 0.9548
5 6	Number of Epochs Number of Iteration	1000 20
7	Performance	0.02398 at Epoch 14
8	Gradient	1.00e-06 i. e 0.016867 at Epoch 20
9	Calculations	MEX
10	Data Division	Random

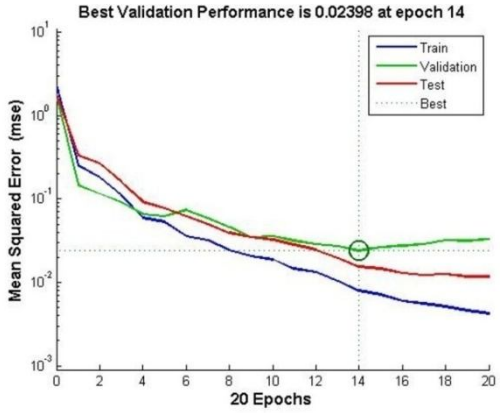

Figure.6: Neural network validation performance.

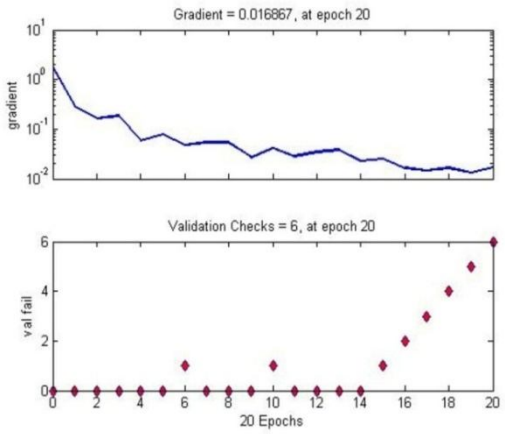

Figure 7: Neural network training state.

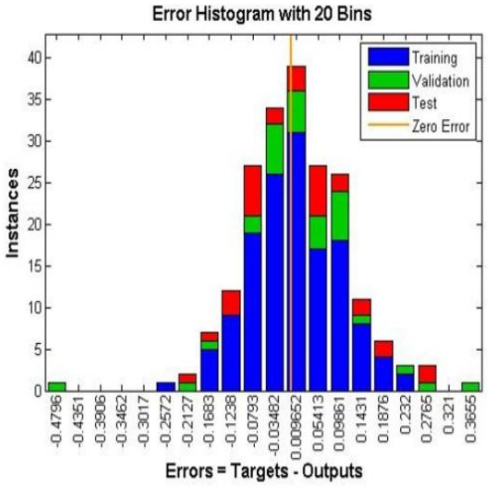

Figure. 8: Neural network error histogram with different instances.

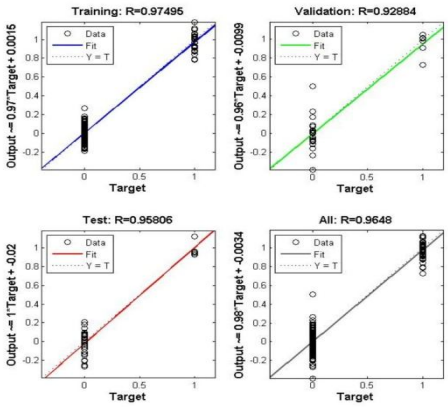

Figure.9: Neural network Regression state.

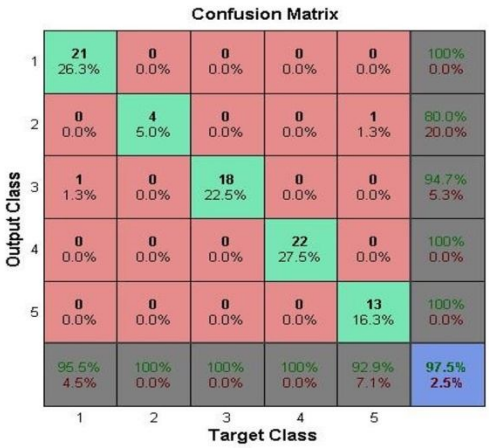

Figure. 10: Confusion Matrix with target class and output class shows accuracy.

Matched Template

$$y[n] = \sum_{k=-\infty}^{\infty} x[k]\, h[n-k]$$

Figure. 11: Matched Template with acquired input image.

CONCLUSIONS

The offline handwritten mathematical equations have been recognized successfully with resolving the local difficulty in the recognition of complex equations. Neural network has been used as a classifier with scale conjugate gradient training. The recognition system has been tested on database collected from various writers and experimental results with simulation have been displayed with 97.5% of accuracy with improvement in throughput. In future, method will be implemented to handle more intricate math equations.

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