A System for Recognition of Offline Handwritten Mathematical Equations using Neural Network with Hybrid Feature Extraction Technique

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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.

Keywords: offline recognition, math Equations, complex semantics, hybrid feature.

Introduction

Mathematics considered as a king of sciences plays a key role in technological development. It is very essential in daily life and for the growth of science and technological development. Availability of mathematical equations systems would help the users to enter math equations into computer system. It is essential to study, to develop and to validate algorithms and methods for recognition of mathematical equations, identification of texts, graphics or notations and the extraction of information. It is a challenging issue in the field of pattern recognition. Mathematical symbols, equations, digits and characters are used in a lot science field. The tools like LATEX, MathML etc are used to accomplish the task of converting mathematical symbols and equations into scientific documents [1]. Moreover in daily life there are different documents are available that contains digits, symbols, characters, images, figures as well as mathematical equations. For good recognition rate, extract the symbols from mathematical equations and analyze the structure of it [2]. Actually handwriting is a friendly interface for inputting mathematical equations to computer [3]. Human being is the best pattern recognizer [4]. Presently computerized document handling systems are more popular. The optical character recognition systems are much accurate in processing the text but failed to process special math symbols, graphics, equations, tables etc. [5]. Two different approaches viz. offline and online are carried out for recognition of math symbols and equations. In online method, data with statistics are captures during writing by using stylus and in offline method; data with statistics are captured after the writing has been completed [6]. Mathematical equation recognition is a synergy of human intelligence and machines [7]. In current scenario of technology special math symbols, various notations can be generated by computers but recognition is tangled [8].

The problem in recognition has been occurred due to variation in writing style, size, pattern of the writer as well as superiority of image. It is a challenging issue to recognize math equations due to intricate semantics and spatial structure of it [9]. The handwritten characters, digits, special symbols and mathematical equation recognition system are useful for blind people to recover information and its comfort [10]. However the trouble with recognition of elements in the mathematical equations is not addressed much as view in the survey. In proposed system, feed forward back propagation neural network has been used and network has been trained with scale conjugate gradient. Height to width ratio, boundary box, zoning density, area of element and counting total elements in the equation are the key features extracted from handwritten math equation. Template matching and confusion matrix shows recognition rate of system.

Literature Survey

The character recognition systems were available in the 1950s. Moreover the technique for the structural analysis of two dimensional mathematical expressions proposed in 1970s with 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].

System Development and Methodology

The flow of proposed system for the recognition of offline handwritten mathematical equation using has been depicted in Fig. 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 stride included in it.

Image Acquisition

In offline method of recognition, image of mathematical equations such as 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.

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.

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. Thresholding segmentation has been done. Actually the accuracy of recognition rate is mostly depends on the segmentation.

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.

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.

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Recognition

The trained classifier has been tested by recognizing various handwritten math equations and accuracy of recognition has been calculated.



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

Experimental Results with Simulation

The system performance has been determined with different types of handwritten mathematical equations viz. convolution sum, quadratic expression, straight line equation and rule of indices. The each and every steps of recognizing the input image of quadratic equation has been explained. Morphological operations have been used for image processing. It deals with forms and structures based on set theory. The main purposes of morphological operations are noise filtering, shape simplification, object marking and segmenting objects from background. The operations like gray conversion, adaptive wiener filtered image and binary image are depicted in Fig. 2 also the filtered binary image, object detection in image. cropped image and mask of equation are depicted in Fig.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 95% accuracy with good recognition speed. The neural network architecture and training with scaled conjugate gradient and performance with mean squared error are depicted in Fig. 4; it shows 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. The training parameters of the network are shown in Table I. The best validation performances 0.0037906 at epoch 76 were depicted in Fig. 5. Training state shows the gradient is 0.0024953 at epoch 82 has been shown in figure 6. Error histogram with training, validation, testing and error has been displayed in Fig. 7 and finally the regression plot of target and output in which training with R = 0.99809, validation with R = 0.9822, Testing with R = 0.8534 and finally all with R = 0.96866 are displayed in Fig. 8. The main key and vital

point is confusion matrix shown in Fig. 9, 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. The mathematical expression recognition, based on the matching the stored prototypes against the expression to be recognized. The matching operation determines the correlation between group of pixels, shapes, curvature etc between two vectors. Finally for simplicity the template matched with the handwritten expression of convolution sum is viewed in Fig. 10.



Figure. 2: Preprocessing of handwritten mathematical expression - quadratic equation



Figure. 3: Quadratic equation with object detection

🗚 Neural Network Training (nntraintool)			
Neural Network			
Hidden Output			
Input 3 20 5 0 0 0 0 0 0 0 0 0 0 0 0 0			
Algorithms			
Data Division: Random (dividerand) Training: Scaled Conjugate Gradient (trainscg) Performance: Mean Squared Error (mse) Calculations: MEX			
Progress			
Epoch: 0 82 iterations 1000			
Time: 0:00:01			
Performance: 1.12 0.000515 0.00			
Gradient: 1.21 0.00250 1.00e-06			
Validation Checks: 0 6 6			
Plots Performance (plotperform) Training State (plottrainstate)			
Error Histogram (ploterrhist)			
Regression (plotregression)			
Plot Interval: 1 epochs			
Validation stop.			
Stop Training Cancel			

Figure. 4: Neural network training architecture

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Sl. No.	Parameter	Value/ Type
1	Network Training Function	Scaled Conjugate Gradient
2	Learning Rule	Adaptive LR
3	Network performance Function	Mean Squared Error (MSE)
4	Overall Training	R: 0.96866
5	Number of Epochs	1000
6	Number of Iteration	82
7	Performance	0.0037906 at Epoch 76
8	Gradient	1.00e-06 i. e 0.0024953 at Epoch 82
9	Calculations	MEX
10	Data Division	Random







Figure.5: Neural network validation performance





Figure 6: Neural network training state







Figure.8: Neural network Regression state



Figure. 9: Confusion Matrix with target class and output class shows accuracy

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Matched Template

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Figure. 10: Matched Template with acquired input image

Conclusions

The improved algorithm has been explained to recognize offline handwritten mathematical equations and resolved local difficulty in the recognition of math 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 98.6% of accuracy with improvement in throughput. The neural network classifier has been trained to capture large variations in shape and size of the large number of symbols that occur in writing math symbol and equations. In future, method will be to handle more intricate math equations.

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