International Journal of Engineering & Technology, 7 (2.32) (2018) 253-257

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

A Gabor Wavelet Based Approach for Off-Line Recognition of ODIA Handwritten Numerals

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Abstract

Optical Character Recognition is one of the most interesting and highly motivated areas of research, which has been very much appreciated in different aspect to the area of digitations world. Here in this paper we have suggested a probabilistic approach for developing recognition system for handwritten Odia numerals. To report a good level of recognition of Odia scripts is quite challenging with respect to other Indian scripts .All the procedure are sequentially enclosed to develop an recognition model and report a successful recognition accuracy. Here we have performed the analysis over to standard handwritten numeral database named as IITBBS Odia Numeral Database, which is collected from IIT Bhubaneswar. In the suggestive recognition system we have adopted a 2D-Gabor wavelet transformation approach for selection of feature vector. Apart from it we have also noted down the dimensional reduction to the obtained feature vector by sustaining to PCA. In order to predict high recognition rate we have followed up by RBF Neural Network classifier. In addition to it we have also evaluate different version of RBF like Gaussian and Polynomial. Performing over 400 samples each of 10 categories (400*10) number of Odia numeral images, we have maintained a well-defined training and testing ratio in the clas-sifier and achieved 98.02%, 96.8%.recognition rate for the reported classifiers.

Keywords: *OCR, Gabor Wavelet, Principal Component Analysis (PCA), Radi-al Basis Function (RBF), Neural Network.*

1. Introduction

Optical character has gain popularity for research in recent years, though it has huge application in natural language processing. Here we have to keep track for human activities so as scan the optical character images written by different individuals are converted in machine understandable format. In board aspect character recognition system can developed for both printed and handwritten documents, which are properly scanned through the scanner and processed to develop a robust recognition model for recognition system. As the recognition system usually produces the coded format of the character known as ASCI values, which has implemented in various corner of application of digitations world. From last couple of years some motivational work related to recognition system has listed by various researchers in various regional scripts around the globe [1] such as English, Dutch, French, and Japanese etc. Similarly when it comes about Indian scripts, it seems s to be a challenging task. As Indian scripts contains a wide range of regional languages such as Devangiri, Sanskrit, Hindi, Telgu, Tamil, Odia, Bengali and etc. Recognition system proposed for various Indian regional scripts are listed few in number [2].According to the results analysis of different adopted models by researchers [3] we have concluded that recognition to the printed scripts is quite easy rather in comparison to the offline documents, it causes due to different variation in writing skills, orientation shape of character are equivalent and etc. of individuals. We have noticed up a good in number of initiative techniques has been proposed by researchers for the successful implementation of Indian scripts[4], But still some robust approach have to be followed up in enhance accuracy of the recognition rate over the various scripts.

In this paper we have tried to provide a solution to offline handwritten Odia numeral system. Basically Odia is official language of state Odisha, India and mostly used to seen in the eastern part of India, some south states and also some western parts of India like West Bengal, Hyderabad, and Bangalore etc. This Indian script is big advantage as compare with other Indian regional language [5]. It has a uniqueness feature that it has no concept of lower and upper case concept for letters. While in other hand to perform a good and effective recognition system to handwritten Odia scripts is much difficult due their equivalent in shape, size and orientation. For any robust system the main phase of the model is the feature extraction process and along with the correct classifier used. Every feature set value has to be unique and productive in nature. Here in the proposed work we have put emphasis on the statistical value rather than structural one. As we have various orientation and similar shape of the numeral images of different individuals, to have a proper feature value we have evaluate a 2d-Gabor wavelet transform [6] over all the data images and reported the desired feature vector. In addition to it we have also added a step called dimension reduction of obtained feature vector and termed as the key feature values. All the key feature values are the achieved through implementing PCA [7] over the obtained feature vector from Gabor wavelet transform .In the subsequent stage the reported key feature values are processed forward two the classifier K-NN and RBF neural network and noted down the recognition rate of both the classifiers.

In the proposed system we had also put emphasis on the background related work of the numerals as shown second section. In the third section we have discussed the adopted model for the recognition of numerals. Implementation and Result Analysis of the model was discussed fourth section and fifth section of the paper. And lastly we have discussed the conclusion and future outcomes of depicted OCR in the sixth section of the paper.

2. Survey on Related Work

The entire recognition model have put basic emphasis on the phases like image acquisition, preprocessing, feature extraction, and lastly choosing the correct classifier. But the main phase is to evaluate the feature vectors of the individual image so that how it has been proved depicted by various researchers [2] [4]. Pal et al. in [4] has suggested the recognition model through the curvature feature values of each individual and 94.6% as accuracy over the datasets used for the system. Subsequently analysis of various strokes that may be of horizontal or vertical type that reported by Bhomik et al. in [6]. On partitioning the dataset into proper training and testing ratio they have listed up 95.89%, 90.50% classification accuracy for both training and testing phase. Some work also related to histogram analysis was suggested by Roy et al. in [8] on Odia numerals. They had shown that how the filters like Gaussian and Robert filter are very much effective over the data images and performed the classification through the classifier like neural network and quadratic classifiers .As the outcome they have noted down 90.3%,94.8% recognition rate for the respective classifiers. Numerals can also go transformation based analysis, such transformation related to Fourier based such as discrete cosine transform, and discrete wavelet transform was reported by Mishra et al. in [9] on numeral dataset.

Through the BPNN classifier they have reported 92.7% and 87.5% overall average accuracy. A comparison analysis among the classifiers such as SVM, MNN, and QDA was reported by Pujari et al. in [10]. They have shown the significance of gradient and curvature feature values of the respective numeral images. Subsequently measure the accuracy overall and reported SVM as to best among three with a recognition rate 90.5% and 95.5% for gradient feature along with curvature feature sets. We can also choose variant and invariant data images and it has solved for recognition model was depicted by P.K Patra et al. in [11]. Some moments of the data images such as Zernike, Mellin transformation were used for both the variant and invariant datasets, as an outcome of the recognition system 95.5% was reported for their work. In [12] Dash et al. had also given importance over the transformation analysis over the numeral images. They had listed up the use of transformation like Slantlat and Stockwell transformation over to the respective datasets and reported the statistical feature of the individual image of the numeral database. Beside that they had also shown a comparison of the rated accuracy over the classifier like HMM, SVM, K-NN. Some cross validation to the proposed system was done and suggested 98.8% as highest accuracy rate. A new robust technique was suggested by Ray et al. in [11]. They had basically put emphasis on the conjunct version of Odia characters and all the recognition rate achieved were listed by the help of Recurrent neural network, which is of Deep Bidirectional Long Short Term Memory (LSTM) based approach. Once again Patra et al. in [14] have listed the significance of the pre-processing technique and suggest how it can helpful in the recognition system. Along with some transformation analysis were also reported by them. Cosine function of transformation and Binarization were the productive feature vector were reported and through neural network they had noted down 80%, 90.2% classification rate over the numeral datasets.

3. Proposed Recognition Model

In order to establish a highly productive recognition system, it is very much vital to adopt correct methods step by step to report high recognition rate as well as it will make the model robust in nature. For the same we have listed up of all the used techniques into certain stage and suggest a schematic outline of recognition system and named it as proposed model for recognition of Odia handwritten numerals. Subsequently all the steps that are followed one by one were shown in below fig.1.

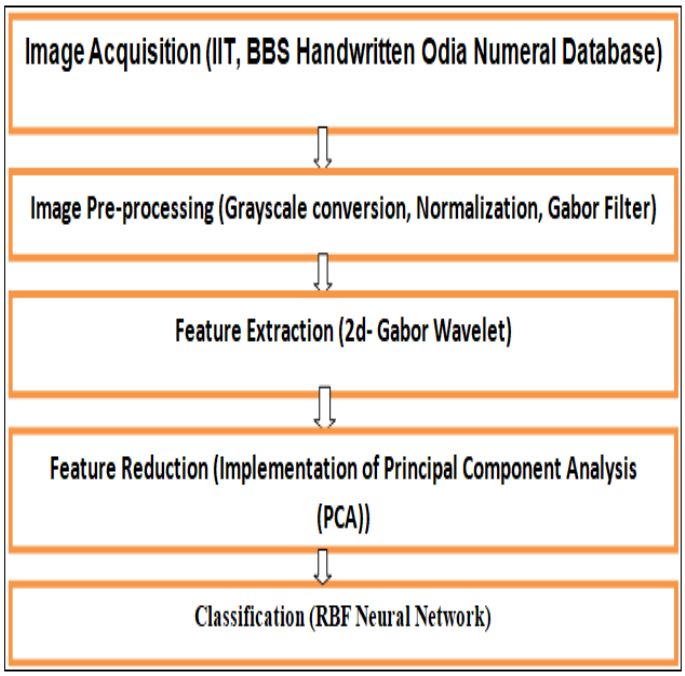

Fig. 1. Adopted Recognition system for Handwritten Numerals

3.1 Image Acquisition

In each recognition model the first criteria is to have good quality of the data images, which are properly scanned or else captured correctly. For the same we have assigned a standard well defined dataset name as IITBBS Odia Handwritten Numeral Dataset proposed by Dash et al. [12] [15].In the acquisition part we have listed of 10 numerals of 400 sample each (400*10) and for proper labeling of the dataset we had numbered the Odia numeral digits from 0 to 9 as shown in below fig.2.

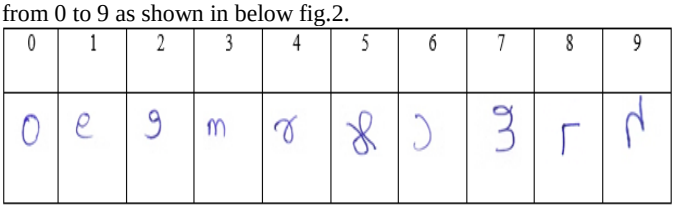

Fig. 2. Sample of IIT BBS Odia Handwritten Numeral Database

3.2Preprocessing of the Numerical Database

Usually preprocessing involves the process of some level of abstraction of some unwanted signal attached with the original image which has to be removed or else suppressed in order to maintain a good quality of image. This phase is considered to be the most primary module of any recognition system to have a proper well-defined quality of the data image that has to be maintained throughout the any system. In this proposed system we have given emphasis on the quality of Odia handwritten numeral images. In order to have promising outcome we have maintained the standard size of the images to 160*160. We have considered the image and converted them to their respective grey scale values and report the normalization matrices. And subsequently we applied a median

filter to each and every image sand remove the unwanted signal attached to it and process them to next phase of feature extraction.

3.3 Feature Extraction Using Gabor Wavelet Transform

In the proposed system after successfully performing preprocessing of numeral images, we forwarded the respective images to the next phase, where all the images are gone through a Gabor function [16]. Basically a Gabor function is very much effective at various frequencies and different orientations. This function always supports Gaussian conditions which are used for evaluating the object at certain changes scales, frequencies and location of orientation etc. The entire preprocessed images are followed up by the 2d-Gabor function. For such nature of the function we have chosen 2D-Gabor wavelet transform [17] [18]. Which is used to predict the feature values of the each images and this is can represented as follows

$$Gw(u,v) = g_{\sigma}(u,v)\, exp(2\Pi j\omega(u\cos\theta + v\sin\theta)) \quad (1)$$

Where

$$g_{\sigma}(u,v) = \left(\frac{1}{\sqrt{2\Pi}\,\sigma_u\,\sigma_v}\right) exp\left(\frac{-1}{2}\left(u^2/\sigma_u^2 + v^2/\sigma_v^2\right)\right) \quad (2)$$

Here $g_{\sigma}(u,v)$ represents the Gaussian function which is sinusoidal in nature. For every function frequency ω is much responsible for evaluating the feature values like σ,θ .If an image $H(u,v)$ process through Gabor Wavelet transform can be depicted as

$$G_{pq}(u,v) = \sum_{u}\sum_{v} H(u-m,v-n)\lambda^{*}_{pq}(m,n) \quad (3)$$

$$\lambda(u,v) = \left(\frac{1}{\sqrt{2\Pi}\,\sigma_u\,\sigma_v}\right) exp\left(\frac{-1}{2}\left(u^2/\sigma_u^2 + v^2/\sigma_v^2\right)\right) exp(2\Pi j\omega u) \quad (4)$$

$$\lambda_{pq}(u,v) = \alpha^{-p}\,\lambda(\bar{u},\bar{v}) \quad (5)$$

Where $\lambda(u,v)$ is the desired 2D-GWT Gabor Wavelet transform which has to be evaluating over p number of scales and q number of orientation. In the subsequent phase we have to also note down the rating at successive different scaling at also different orientation.

3.4 PCA Used in Feature Reduction

After evaluating the desired feature vector by using a 2d-Gabor wavelet we have listed up the vector of having bigger dimension, hence in the next phase we have considered to make compression to the feature vector which is named as dimension reduction. In order to predict a higher rate of recognition we have to trace out the key feature values of the data images and that can achieved through the probabilistic principal component analysis (PCA) [7]. The orthogonal transformation property of the PCA has very much significant to report the variances and report the highest coefficient along with some Eigen values. The key features which is calculated depending upon the highest Eigen values and termed as PC scores. We have listed up all the crucial steps involved in the feature reduction are depicted in algorithm.1.

Algorithm. I: Implementation of PCA

1. Make input of feature matrix $(f \times M)$

f : Number of features, M : Total number of image.

2. Report the mean vector $(f \times l)$.

3. Perform the subtraction of feature values with mean values.

4. Calculate the co-variance matrix $(f \times f)$.

5. Report the n Eigen vectors corresponding to n larger Eigen values $(n \times f)$.

6. Perform the mapping like $(n \times M)$ such that $n < m$.

3.5 Classification Phase

We have processed all the 10 numeral images having 400 samples each by such the total inputted images are of 4000 images successfully and followed up the schematic approach of the proposed model one by one. We have listed up of the key feature vector of respective images at certain frequencies then forwarded to the classifier to perform the classification. In this paper we have considered a RBF neural network [19] as the classifier. As per the nature of neural network with this we have just added some basis function to it and also used predict the behavior of the kernel function associated with the neural network [20]. Here we have taken a three layered neural network such as input, hidden and output layer. Basically it has significance role in classification as an output it provides an optimum solution for the problem by adopting minimum of mean square error. In order to have well defined result we have focused certain parameters like learning rate, epoch, and time values of the network. For the proposed system the equivalent relation for the system are as follows

$$Y_i(x) = \sum_{i=1}^{k} W_{ki}\,\phi_k(\|x_i - \mu_k\|) + W_{oi} \quad (6)$$

In above statement $Y_i(x)$ represents the i[th] processing element at the output and W_{oi} is the respective adjustable weight associated with it. Here we have considered Gaussian and Polynomial kernel function and perform the classification one by one and reported the recognition accuracies.

4. Implementation

For implementation of the suggested techniques we have evaluate each stage of the proposed model step by step. As per the model we have gone through the different phases like acquisition, preprocessing, feature extraction using Gabor wavelet, reduction in feature dimension and last used the RBF Neural network classifier. Besides all we have formed the steps of the model into an algorithm for implementation which is depicted in the algorithm II. In that algorithm we have segmented the algorithm into two halves like offline section and online section.

Algorithm. II. Suggested Offline Reading

1. Consider the standard Offline handwritten numeral database containing 400 samples of 10 categories each.
2. Subsequently processed the images to the pre-processing unit and perform enhancement of the respective images.
3. Report the desired feature vector of the images through implementing the 2d-Gabor wavelet along the numeral dataset.
4. After getting the feature set we have followed up the PCA to perform the dimension reduction of feature set and report the different highest pc scores.
5. The obtained feature set from PCA is termed as primary feature sets. Then onwards we have processed the matrixes of the feature set to the RBF Neural Network for classification.
6. List the recognition rate of numerals at different Pc scores.

On-Line Procedure

1. Ask the user to process the query image.

2. In the next phase proceeds the image to preprocessing section and so on.
3. Evaluate the feature extraction step and report the co-efficient matrix of 2d Gabor wavelet transform.
4. Perform the dimension reduction of feature set and report the primary feature values.
5. Trained and test samples of image and perform the recognition through RBF neural Network.

5. Result Analysis

In the proposed model of recognition system all the implemental setup was done in the environment of MATLAB 2014. We have taken standard database containing 4000 images of handwritten numerals of 10 categories. Then we have followed up the step mentioned in the proposed system of recognition one by one. A Gabor function has been proposed here to report the feature vector at different scaling and orientation. Along with it we have also reported primary feature vector by performing reduction in dimension of feature vector. Principal component analysis was the probabilistic approach that is used to report the highest Eigen values which termed as PC score later on. On reduction to dimension we have listed up different primary feature vector containing 30, 40 and 50 Pc scores that are forwarded to the RBF neural network for recognition. In the section of classification we have given emphasis upon two kernel function one is Gaussian and another is Polynomial kernel. After evaluating the pseudo algorithm II we have listed up good recognition rate that are depicted in the following tables I and table II. Where CC represents number of time correctly classified, MC depicts the number of times miss classified and RR represents recognition rate. Apart from all we have listed up the comparison among the two kernel function of RBF which is presented in the fig. 3 and reported Gaussian function have achieved more accuracy than Polynomial one.

Table 1: Reported Confusion Matrix for Odia Numeral Using Gaussian RBF

SL. No	CC	MC	RR (%)
1	396	4	99
2	392	8	98
3	393	7	98.25
4	396	4	99
5	388	12	97
6	392	8	98
7	388	12	97
8	390	10	97.5
9	394	6	98.5
10	392	8	98
Average Recognition Rate = 98.02			

Table 2: Reported Confusion Matrix for Odia Numeral Using Polynomial RBF

SL. No	CC	MC	RR (%)
1	391	9	97.75
2	388	12	97
3	390	10	97.5
4	384	6	96
5	381	19	95.25
6	386	14	96.5
7	383	17	95.75
8	392	8	98
9	388	12	97
10	392	8	98
Average Recognition Rate = 96.8			

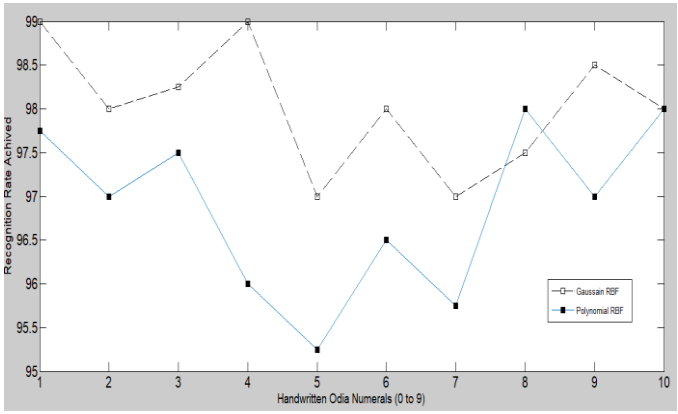

Fig. 3. Reported the individual Handwritten Odia Numeral (0 to 9) Recognition Rate

6. Conclusion & Future Work

Here in this paper we authors have suggested an innovative approach for providing a solution to recognition system for handwritten Odia numerals. For the same we have reported the significance of each step of the proposed model like acquisition, preprocessing, feature extraction, dimension reduction of feature vector and lastly the classification phase. A Gabor wavelet based approach has been evaluated for reporting the feature of the images and also PCA has been projected over the feature values to list up the primary feature vector. It is due to provide the solution of classification problem in less time so we perform dimension reduction to obtained feature vector. The main stage of the model is the classification part, here we have shown how the two kernel based method of RBF has been used. Upon simulation analysis we concluded that the recognition rate achieved in Gaussian RBF is higher than as compared with Polynomial RBF. After result analysis we have noted up overall recognition rate is about 98.02% for Gaussian RBF and 96.8% for Polynomial RBF. In order to have a well-defined OCR system we make an analysis over the various authors reported in paper with the current proposed model as shown in table III. In context to future aspect, still some more robust and probabilistic approach has to be followed up that may be in terms of feature extraction or else classifiers. We can also improve the recognition model by implementing some extreme learning based approach.

Table 3: Comparative analysis with other recognition systems

Reference & Authors	Adopted Feature Extraction Method	Reported Classifier Used for Classification	Over all Recognition Accuracy
Pal et al. in [4]	Curvature Feature values	Modified Quadratic Classifier	94.6 %
Bhomik et al. in [6]	Horizontal and Vertical stroke	Neural Network	95.89%, 90.50%
Mishra et al. in [9]	Cosine and Wavelet Transformation	Support Vector Machine	92% , 87.5 %
Sethy et al. in[16]	Discrete Cosine Transformation & Binarization	Neural Network	80.2%
We Authors	2D-Gabor Wavelet	Gaussian RBF	98.02%
		Polynomial RBF	96.8%

7. Acknowledgement

Here we are sincerely thankful to the Department of CSE, College of Engineering and Technology, Bhubaneswar, India. And we are also thankful to all the authors of references.

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