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Offline Handwritten Malayalam Word Recognition using Wavelet Transform

Jino P J*[1], Kannan Balakrishnan[2]
*[1]Artificial Intelligence Lab,Department of Computer Applications, Cochin University, Kerala, India
[2]Department of Computer Applications , Cochin University,Kerala ,India

ABSTRACT

Wavelet transforms of malaylam handwritten images are used for the recogntion. A comparative study with Haar, Daubechies wavelets are also performed. Lexicon contains fourteen district names and a total of 736 samples.More than 90 % of recogntion is achieved.Low Frequency components are considered as features. For the classification SVM used with RBF kernel.The Dimensionality of the wavelet coefficients are reduced by Principal Component Analysis(PCA).

Keywords: Offline Handwritten Recognition, Wavelet Transform ,Feature Extraction method, Pattern Recognition.

I. INTRODUCTION

Automatic Recognition of handwritten text documents is a pattern recognition problem, where pattern is the handwritten image. This pattern varies from human to human and it may vary significantly if the same person writes in different situation. The recognition of handwritten documents can be either using analytic or holistic method. In analytic method recognition starts from the basic unit of word , ie. from character level. Holistic method will treat word as a unit and tries to recognize it. Extraction of characters from the handwritten documents is a tedious task, so most often analytic recognition not suitable for certain type of handwriting styles. Handwritten district names will appear in different context for eg : It can be seen in the postal address, Application forms, Bus Boards etc.

Malayalam is the official language in the state of Kerala. Malayalam language has two scripts called old script and new script[1]. People use both in a mixed manner, that is the major hurdle of the researchers to recognize and differentiate script. There are wide variety of applications for offline handwritten recognition which includes converting the official douments in digital format and make necessary changes, Teaching aid for the visually challenged people, Analyze the progress of a paralyzed patient in medical field, Automated answer paper correction written in malayalam.To some extend all these applications lead us to reduce the use of papers and also it will help to retrieve informations in fast and efficient manner.

The lexicon size of handwritten district names is fourteen and our purpose is the recognition of these words in unconstrained manner using wavelet transform. This is the first work for malayalam word recognition using wavelet coefficients. Collaborative research is required to fulfill a proven automatic handwritten recognition mechanism. Wavelet transform has a wide variety of applications in the area of medical images[2],Image compression [3], Image watermarking [4] , Satelite Image processing [5],Pattern Recognition[6]. Classification also plays a vital role in pattern recognition.SVM provides high recognition accuracy when compares with the classfiers like Modified quadratic Descriminant Function(MQDF),Multilayer Perceptron(MLP) and Polynomial Classifier(PC)[7][8].

The paper is organized as follows. Section 2 briefly explains about the related works, Section 3 describes about the selection of wavelet and the proposed works presented in Section 4. Analysis of the Result discussed in Section 5 and the paper is concluded in Section 6.

II. RELATED WORKS

In literature we can find several methods for handwritten recognition. In an attempt Ujjwal et al. [9] propose the recogntion of numeral in three Indian scripts using Daubechies-4 wavelet and MLP(Multi Layer Perceptron) as the classifier.Binu P. et al.[10] proposes a method for malayalam handwritten character recognition using Daubechies,Biorthoganal and symlet wavelets with ELM(Extreme Learning Machine) as the classfier.Best result they produced is for Daubechies-6 wavelet at level6.Haar wavelet is used by Jomy et al. [11] for the recognition of Malayalam handwritten characters.Approximation of wavelet coefficients in the second level reported best result. Zero crossing of wavelet coefficients are used by Raju G et al. [12] for Malayalam handwritten character recognition. Daubechies-4 wavlet with three level decomposition is used for the experiments.Wunsch P et al. [13] propose a method for the recognition of hand printed characters using wavelet descriptors and neural network topology for the recognition. Sushama Shelle et.al [14]propose a method for Marathi handwritten compound character recognition using Daubechies wavelet with level1 decomposition and Artificial Neural Network used for the recognition. For farsi character recognition Saeed Mozaffari et.al[15]use Haar wavelet coefficient at level 3 as features and SVM as the classifier. Patel et.al [16] propose a method for the recognition of handwritten uppercase letters with wavelet co-effients as features and Euclidean distance metric as the classifier. Pasha et.al [17]propose a method for Kannada character recognition with the combination of structural features and symlet wavelet coefficients used as the features and Artificial Neural Network used as the classifier.

III. SELECTION OF WAVELET

A. Wavelet

Wavelet transform is an effective tool to represent images at different levels of resolution. It extracts temporal and spacial information from the image. Mother wavelet, prototype of all other types of wavelets are scaled or shifted as defined as [18]

$$\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}}\,\psi\left(\frac{t-b}{a}\right)$$

Wavelet families include Haar, Daubechies, Symlets, Coiflets, Biorthogonal, Reverse biorthogonal, Meyer, Gaussian, Mexican hat, Morlet, Complex Gaussian, Shannon, Frequency B-Spline and Complex Morlet. Orthogonal and biorthoganal are the two categories of wavelet family.The coefficients of orthoganal filters are real numbers and in case of biorthoganal filters it is real numbers or integers.Selection of a proper mother wavelet is required according to the application to achieve the state of art result.In our experiments, we consider Haar and Daubechies wavelet.

Haar scaling function

$$\phi(x) = \begin{cases} 1\ 0 \le x < 1 \\ 0\ otherwise \end{cases}$$

$$\psi(x) = \begin{cases} 1\ 0 \le x < \frac{1}{2} \\ -1\ \frac{1}{2} \le x < 1 \\ 0\ otherwise \end{cases}$$

The scaling function $\phi(x)$ and the wavelet funtion $\psi(x)$ associated with the scaling filter h_ϕ and the wavelet filter h_ψ are:

$$\phi(x) = \sum_n h_\phi(n)\sqrt{2}\,\phi(2x-n)$$

$$\psi(x) = \sum_n h_\psi(n)\sqrt{2}\,\phi(2x-n)$$

According to Mallat SG et al.[19] The sequences of vector spaces $(V_{2^j})_{j\in\mathbb{Z}}$ form a multi resolution approximation of $L^2(\mathbb{R}^2)$ if and only if $(V_{2^j})_{j\in\mathbb{Z}}$ is a multi resolution approximation of $L^2(\mathbb{R})$. One can then easily show that the scaling function can be written as

$$\phi(x,y) = \phi(x)\phi(y)$$

where $\phi(x)$ is the one dimensional scaling function of the multiresolution approximation $(V_{2^j})_{j\in\mathbb{Z}}$. Relevance is given to the horizontal and vertical directions in the image with a separable multi resolution approximation. This emphasis is apt for many types of images, such as handwritten documents. The orthogonal basis of (V_{2^j}) is then given by, $\forall m,n \in \mathbb{Z}$, $\phi_{2^j}(x - 2^{-j}n, y - 2^{-j}m) = \phi_{2^j}(x - 2^{-j}n)\phi_{2^j}(y - 2^{-j}m)$

The approximation of a signal $f(x,y)$ at a resolution 2^j is therefore characterized by the set of inner products

$$A^d_{2^j} = \langle f(x,y), \phi_{2^j}(x - 2^{-j}n)\phi_{2^j}(y - 2^{-j}m)\rangle$$

Let $(V_{2^j})_{j\in\mathbb{Z}}$ be a separable multi resolution approximation of $L^2(R^2)$, Let $\phi(x)\phi(y)$ be the associated two dimensional scaling function. Let $\psi(x)$ be the one dimensional wavelet associated with the scaling function (x) , then the three "wavelets"

$$\psi^1(x,y) = \phi(x)\psi(y)$$
$$\psi^2(x,y) = \psi(x)\phi(y)$$
$$\psi^3(x,y) = \psi(x)\psi(y)$$

are such that

$$\left(2^{-j}\,\psi^i_{2^j}(x-2^{-j}n, y-2^{-j}m)\right)_{i=1,2,3}$$

is an orthonormal basis of O_{2^j} and is an orthonormal basis of $L^2(\mathbb{R}^2)$. As a conclusion we can define the the decomposition of image $A^d_{2^{j+1}}f$ into $A^d_{2^j}f$ and $D^k_{2^j}f$, where $k \in \{1,2,3\}$

$A^d_{2^j}f$ reperesents low horizontal and vertical frequencies and defined as

$$A^d_{2^j}f = \left(f(x,y) * \phi_{2^j}(-y)\left(2^{-j}n, 2^{-j}m\right)\right)$$

$D^1_{2^j}f$ represents vertical high frequencies and horizontal low frequencies as defined as

$$D^1_{2^j}f = \left(f(x,y) * \phi^j(-x)\psi^j(-y)\left(2^{-j}n, 2^{-j}m\right)\right)$$

$D^2_{2^j}f$ represents vertical low frequencies and horizontal high frequencies as defined as:

$$D^2_{2^j}f = \left(f(x,y) * \psi_{2^j}(-x)\,\phi_{2^j}(-y)\left(2^{-j}n, 2^{-j}m\right)\right)$$

$D^3_{2^j}f$ represents vertical high frequencies and horizontal high frequencies as defined as:

$$D^3_{2^j}f = \left(f(x,y) * \psi_{2^j}(-x)\,\psi_{2^j}(-y)\left(2^{-j}n, 2^{-j}m\right)\right)$$

B. Daubechies Wavelet

According to Ingrid Daubechies et al. [20] Daubechies wavelet is a function $\psi = {}_N\psi \in L^2(\mathbb{R})$ where $N \in \mathbb{N}$ defined by:

$$\psi(x) := \sqrt{2}\sum_{k=0}^{2N-1}(-1)^k h_{2N-1-k}\phi(2x-k)$$

where $h_0, h_1, h_{2N-1} \in \mathbb{R}$ are constant filter co-efficients satisfying the conditions.

$$\sum_{k=0}^{N-1} h_{2k} = \frac{1}{\sqrt{2}} = \sum_{k=0}^{n-1} h_{2k+1}$$

as well as, for l = 0,1, 2,.....N - 1

$$\sum_{k=2l}^{2N-1+2l} h_k h_{k-2l} = \begin{cases} 1 \; if \; l = 0 \\ 0 \; if \; l \neq 0 \end{cases}$$

Scaling Filter coefficients for decomposition of image is shown in Table: 1

TABLE I
Scaling Filter Coefficients

DB4	DB8	DB12	DB16
0.48296291314453	0.23037781330890	0.11154074335011	0.05441584224310
0.83651630373781	0.71484657055292	0.49462389039845	0.31287159091430
0.22414386804201	0.63088076792986	0.75113390802110	0.67563073629729
-0.12940952255126	-0.02798376941686	0.31525035170920	0.58535468365421
	-0.18703481171909	-0.22626469396544	-0.01582910525635
	0.03084138183556	-0.12976686756726	-0.28401554296155
	0.03288301166689	0.09750160558732	0.00047248457391
	-0.01059740178507	0.02752286553031	0.12874742662048
		-0.03158203931749	-0.01736930100181
		0.00055384220116	-0.04408825393079
		0.00477725751095	0.01398102791740
		-0.00107730108531	0.00874609404741
			-0.00487035299345
			-0.00039174037338
			0.00067544940645
			-0.00011747678412

Wavelet Filter Coefficients for the decomposition of image is shown in Table: 2

TABLE II. Wavelet Filter Coefficients

DB4	DB8	DB12	DB16
-0.12940952255126	-0.01059740178507	-0.00107730108531	-0.00011747678412
-0.22414386804201	-0.03288301166689	-0.00477725751095	-0.00067544940645
0.83651630373781	0.03084138183556	0.00055384220116	-0.00039174037338
-0.48296291314453	0.18703481171909	0.03158203931749	0.00487035299345
	-0.02798376941686	0.02752286553031	0.00874609404741
	-0.63088076792986	-0.09750160558732	-0.01398102791740
	0.71484657055292	-0.12976686756726	-0.04408825393079
	-0.23037781330890	0.22626469396544	0.01736930100181
		0.31525035170920	0.12874742662048
		-0.75113390802110	-0.00047248457391
		0.49462389039845	-0.28401554296155
		-0.11154074335011	0.01582910525635
			0.58535468365421
			-0.67563073629729
			0.31287159091430
			-0.05441584224310

IV. PROPOSED METHOD

Proposed method uses wavelet co-efficients as the features and Pricipal Component Analysis for the dimensionality reduction. Block Diagram of the proposed method is shown in Fig:1

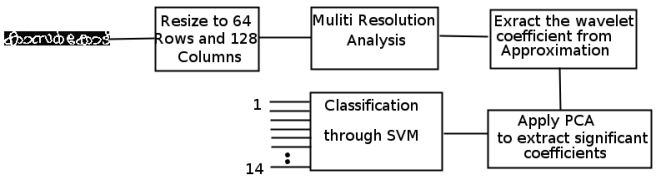

Figure 1. Proposed Method

A. Dataset

Samples collected from 56 writers are used for this experiment. Specially designed forms are used for the

data collection which include the provision for entering Name,Age,Gender and Signature etc. Sample form is given in Fig: 2. All the forms are scanned by using a flatbed scanner in 300 dpi and digitized and stored in tiff format. Words are extracted from the form using horizontal and vertical projection profiles. All the extracted words are arranged folderwise, some of the samples are avoided for the learning process because it contains errors(48 samples). 80 % of the data used for training (588 samples) and 20 % of the data used for testing(148 samples).

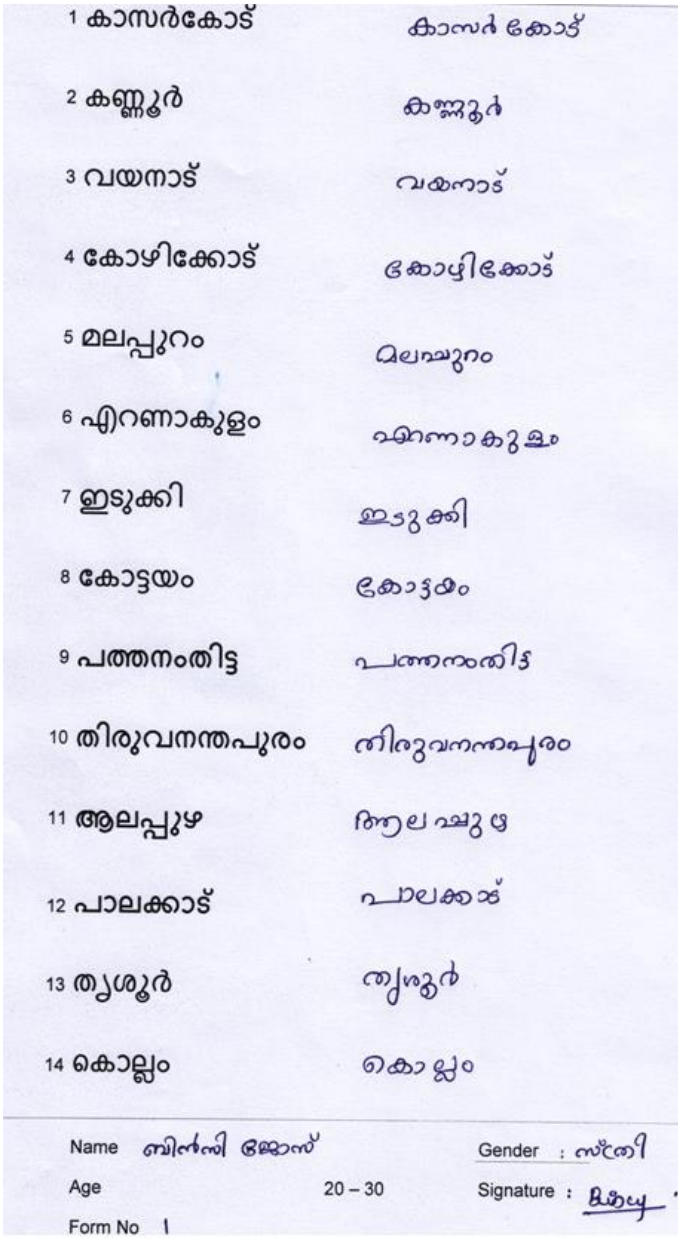

Figure 2. Sample Form

Age wise statistics of the data collection is shown in Table: 3.

TABLE III. Age wise statistics

Age	No.Of Writers
10-20	5
20-30	20
30-40	20
40-50	8
50-60	3

Samples from the dataset is shown in Fig:3

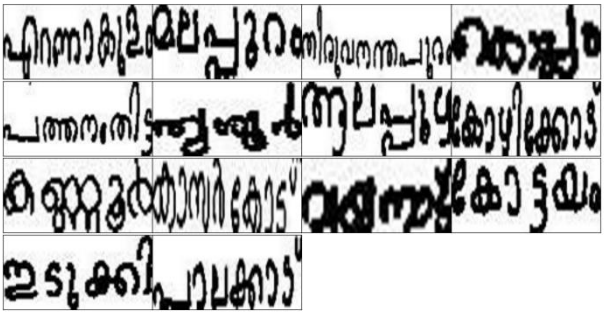

Figure 3. Samples From the Dataset

B. Preprocessing

All the images in the dataset are converted to gray scale. Images are trimmed to avoid whitespaces in the boundary. Finally images are resized to 64 rows and 128 columns using bicubic interpolation method.

C. Feature Extraction

Selection of Features from the dataset is critical for the performance of handwritten recognition system. The resized images are fed for multi resolution analysis. Wavelet transform converts the image in to different resolutions and the approximation level contains higher co-efficients. These low frequency components can be the feature for the recognition of handwritten documents. Significant co-efficients for classification are identified through Principal Component Analysis. In the multi resolution analysis image is decomposed into four subbands LL($A^d_{2^j}f$), HL($D^2_{2^j}f$),LH($D^1_{2^j}f$) and HH ($D^3_{2^j}f$) are approximate,vertical,horizontal and daigonal features respectively.Changes in both horizontal and vertical directions in terms low frequency is represented by approximate features(LL),LH represents low frequency in horizontal and high frequency in vertical directions, HL represents high frequency in horizontal and low frequency in vertical and HH represents high

frequencies in both horizontal and vertical directions. One of the observations after wavelet transform is that wavelet co-efficients are higher in approximation(LL) band. Large wavelet co-efficients are more important than smaller wavelet coefficients.Haar and Daubechis wavelet co-efficients are used as features for our study.In the case of Haar h_ϕ = [0.70710678118655, 0.70710678118655] and h_ψ =[0.70710678118655, -0.70710678118655] , In the case of Daubechis-2 it is h_ϕ =[0.48296291314453, 0.83651630373781, 0.22414386804201, -0.12940952255126] and h_ψ =[-0.12940952255126, -0.22414386804201, 0.83651630373781, -0.48296291314453] as defined in 1 and 2 applied to image. In the level 1 decomposition the approximation features will be 32*64 = 2048 and in level 2, it will be 512. Sample decomposition level-2 of word image of "കൊല്ലം/ kollam" is shown in figure 4

Figure 4. Wavelet decomposition using haar wavelet

Support Vector Machine used as the classifier.The commonly used four kernels in SVM are Linear, Polynomial,RBF and sigmoid. In the present study we use RBFkernel and the parameters are selected using Gridsearch method[21].

Principal Component Analysis is a data reduction technique developed by Hotelling H in 1933. PCA allows as to represent the large dataset to fewer pricipal components thus ensure lower dimension. In our experiments we consider 50 Principal components.

V. RESULTS AND INTERPRETATION

Experiments done with various types of wavelets and their results are exhibited in Table: 4

TABLE IV. Results with Haar and Daubechis

Type of Wavelet	Level	Precision	Recall	F1 Score
DB2	2	0.89	0.89	0.87
DB4	2	0.89	0.87	0.87
DB6	2	0.92	0.90	0.90
DB8	2	0.91	0.89	0.89
DB8	0	0.92	0.90	0.90
haar	2	0.92	0.91	0.91
haar	**1**	**0.94**	**0.93**	**0.93**
DB2	1	0.93	0.91	0.91

Detailed Analysis of Haar Wavelet with level 1 decomposition is shown in Table: 5

TABLE V. Detailed Analysis with Har Wavelet decomposed in level-1

Class	Precision	Recall	F1-Score	Support
1	0.86	1.00	0.92	6
2	1.00	0.92	0.96	13
3	1.00	0.88	0.93	8
4	1.00	0.92	0.96	13
5	0.87	0.93	0.90	14
6	0.77	0.83	0.80	12
7	1.00	1.00	1.00	12
8	0.88	1.00	0.93	7
9	1.00	0.93	0.96	14
10	0.75	1.00	0.86	9
11	0.91	1.00	0.95	10
12	1.00	1.00	1.00	9
13	1.00	0.75	0.86	8
14	1.00	0.85	0.92	13
avg/total	0.94	0.93	0.93	148

Precision(P),Recall(R), F1 Score(F1) are calculated using the following formula

$$P = \frac{t_P}{t_P + f_p} \quad R = \frac{t_P}{t_p + f_n} \quad \text{F1} = 2\frac{P\ X\ R}{P+R}$$

where t_P is true positive , f_p is false positive and f_n is false negative. Result shows that Words like "കാസർകോട്/Kasaragod","ഇടുക്കി/Idukki"," കോട്ടയം/Kottayam",തിരുവനന്തപുരം/Thiruvananthapuram", ആലപ്പുഴ/Alappuzha", "പാലക്കാട്/ Palakkad" recognized with 100 % Accuracy. Confusion matrix is shown in Table:6

Table VI. Confusion Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	6	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	12	0	0	0	0	0	0	0	1	0	0	0	0
3	0	0	7	0	0	0	0	0	0	1	0	0	0	0
4	1	0	0	12	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	13	1	0	0	0	0	0	0	0	0
6	0	0	0	0	1	10	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	12	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	7	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	13	0	1	0	0	0
10	0	0	0	0	0	0	0	0	0	9	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	10	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	9	0	0
13	0	0	0	0	1	1	0	0	0	0	0	0	6	0
14	0	0	0	0	0	1	0	1	0	0	0	0	0	11

VI.CONCLUSION

Handwritten recognition in the word level is successfully implemented and achieved good results. This method is suitable for the recognition of small number of lexicons. Domain specific applications like Place name recogntions,students name recognition in a particular institution can be easily done through this approach.Methods we discussed here in this paper can be implemented without much computational cost.Work can be extended with other wavelts like Symlets,Coiflets etc.Futher various kind of image coding can use as the language specific features for recognition.

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