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A Comparative Study using Wavelet and SVM for Devanagri Characters Recognition

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Abstract: This paper presents a wavelet-based approach for recognizing handwritten and printed Devnagari characters. In this paper we have used wavelet for feature extraction of the character. We have developed six handwritten data feature sets and six printed data feature set ,each dataset is divided in four part for our experimentation. We have also used wavelet kernels and regular kernels in SVM classification. Each SVM kernel is applied on total 12 x4=48 feature datasets.

Keywords: Wavelet; MAT; Complex Wavelet; Autocorrelation.

I. INTRODUCTION

Handwritten and printed character & digit recognition is an important topic in OCR applications and pattern classification . There are so many techniques of Pattern Recognition such as Template Matching, Neural Networks, Syntactical Analyses, Wavelet Theory, Hidden Markov Models, Bayesian theory etc have been used to develop efficient OCRs for different languages. OCR work on printed Devanagri script started in early 1970s. Some of the efforts on Devanagri character recognition are due to Sinha [1,7,8] and Mahabala [1]. Sethi and Chatterjee [5] also have done some earlier studies on Devanagri script and presented a Devanagri hand-printed numeral recognition system based on binary decision tree classifier. They [6] also used a similar technique for constrained hand-printed Devanagri character recognition. The first complete OCR system development of printed Devanagri is perhaps due to Palit and Chaudhuri [4] as well as Pal and Chaudhuri [3]. A survey for hand-written recognition of character is proposed [2]. In this paper we are using wavelet theory based feature extraction methods.

II. DATASET

In the present work we have developed printed and handwritten database. For printed we have used different ISM office fonts. and for handwritten we have collect dat from people of different age groups and from different profession . This data were scanned at 600 dpi using a HP flatbed scanner and stored as gray-level images. A few samples from this database are shown in Figure1.

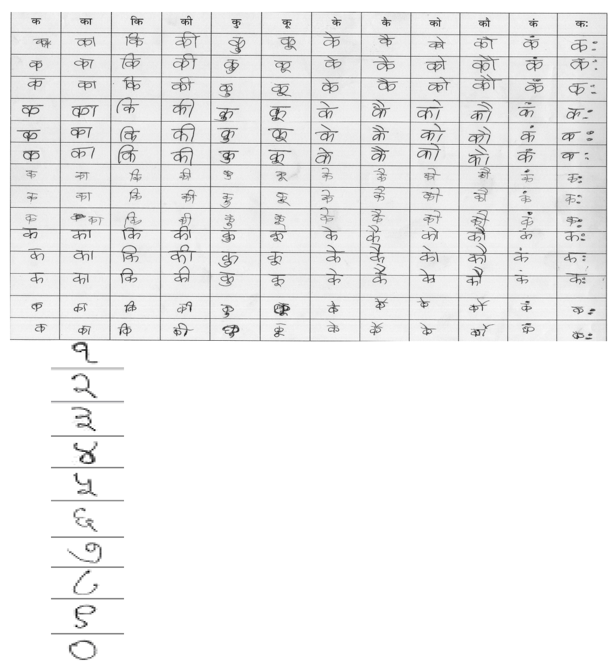

Figure 1.Samples from database of handwritten Devanagari characters and numerial.

The database is exclusively divided into training and test sets. The distribution of samples in these training and test sets over 10 digit classes for numerical data. For Devnagari character has about 11 vowels ('svar') and 33 consonants or ('vyanjan'),and 11 modifiers so we organized data in 55 character classes. The handwritten database is collected from marathi peoples.

III. FEATURE EXTRACTION

A. Wavelet Theory

A character image of size NXN can be decompose into its wavelet cofficents by using Mallat's pyramid algorithm [8]. Mathematically, it can be describes as the following recursive equations [9]:

$$LL^{(K)}(M,N)=[[LL_{rows}^{(k-1)}*\overline{H}]_{2\downarrow 1}*\overline{H}]_{1\downarrow 2}, m=1,...,N|2^{k}; n=1,...,n/2^{k} \quad (1)$$

$$LH^{(k)}(m,n)=[[LL_{rows}^{(k-1)}*\overline{H}]_{2\downarrow 1}*\overline{G}]_{1\downarrow 2}, m=N/2^{k}+1,...,N|2^{k-1}; n=1,...,N/2^{k} \quad (2)$$

$$HL^{(k)}(m,n)=[[LL_{rows}^{(k-1)}*\overline{H}]_{2\downarrow 1}*\overline{H}]_{1\downarrow 2}, m=1,...,N/2^{k}; n=N/2^{k}+1,...,N/2^{k-1} \quad (3)$$

$$HH^{(k)}(m,n)=[[LL_{rows}^{(k-1)}*\overline{G}]_{2\downarrow 1}*\overline{G}]_{1\downarrow 2}, m=N/2^{k}+1,...,N/2^{k-1}; n=N/2^{k}+1,...,N/2^{k-1} \quad (4)$$

Here LL, LH, HL, and HH represent four subimages of the image being decomposed. After wavelet decomposition, the object image energy is distributed in different subbands ,each subband image contains one feature.

B. Feature set S1: Directional – Based Wavelet Features

Kirsch nonlinear edge enhancement algorithm is used to extract statistical features from the characters and then wavelet transform is applied on these statistical features to form original features. Kirsch nonlinear edge enhancement algorithm is applied to an NxN character Image to extract horizontal, Vertical, Right-diagonal and left-diagonal directional features and global features; then 2-D wavelet transform is used to filter out the high frequency components of each directional Feature image and character image, respectively, and to convert the feature matrix into a 4x4 matrix.Apply Daubechies -4 wavelets to four directional feature matrices and the character image, and only keep 4x4 low frequency components of each as features. Total, 16x5=80 features can be extracted from each character, detail can be found in [10][11][12][13][14].

C. Feature Set S2: MAT based Gradient Features

Medial Axial Transformation Algorithm is used to finding a binary image centre skeleton and to converts a binary image into a grayscale image with maximum values on the central skeleton of the character. we can extract MAT Gradient-based features by Normalize the MAT image with its pixel values from $0.0 \sim 1.0$; we use sobel operator to convolute the normalized image to generate the amplitudes and phases of the gradient image. We count the gradient direction of each pixel of the convoluted image with nonzero gradient magnitude values as a direction feature. Finally to get the features each gradient direction is quantized into one of eight directions at $\pi / 4$ intervals. Each normalized gradient image is divided into 16 sub-images. The number in each direction of each sub-image is counted as a feature. The total number of features are 4x4x8=128 detail can be found in[10][11][12][13][14].

D. Feature Set S3: Complex Wavelet Features

A character image of size 28(N)X28(N) is divided into four sub band images : LL, LH,HL,HH at the first level of tree and each of the sub band images has a size of $\frac{N}{2} x \frac{N}{2}$. At each higher level, the decompositions are based on the LL sub band image at the previous level. The feature extraction is conducted at the third level. The number of features = 4X4(for each sub band image) *3 (high frequency sub band image for each tree) *2 (trees) +4X4(for each sub band image) *2(trees)*2(parts: real and imaginary) =160 detail can be found in[10][11][12][13][14].

E. Feature Set S4: Median Filter Gradient Features

For this feature extraction set we convolute a character image by a 2D median filter;weo use Robert operators on the median –filtered image to generate the amplitudes and phases; and finally count the gradient direction of each pixel with nonzero gradient magnitude values as a direction feature. So the total number of features is 128 detail can be found in[10][11][12][13][14].

F. Feature Set S5 : Image Thinning Distance Features

In this feature set, the distance features in both horizontal and vertical directions are extracted firstly, an NxN character image is thinned and the thinned image is scaled into an 8x8 array. The thinned image is scanned both horizontally and vertically respectively. In the horizontal scanning, for each pixel in the 8x8 thinned image, if the value of the pixel is 0 (black), then the distance is 0; otherwise, the distance is set to the distance from that pixel to the nearest black pixel in both horizontal directions on the scanning line. For any pixel, if there are no nearest black pixels in both directions, the distance of the pixel is set to the distance from the pixel to one of two edges, whichever has longer distance to the edge. In the vertical scanning, the same algorithm is applied. In total there are 128 features detail can be found in[10][11][12][13][14].

G. Feature set S6: DCT – Based Wavelet Features

The discrete wavelet transform (DWT), which is based on sub-band coding is found to yield fast computation of wavelet transform .Binarize the image using Otsu method apply morphological thinning, operation.In order to extract local features compute the standard Deviation of the image block. In order to get image bock Apply DCT and divide the magnitude (image) of DCT into 4 equal non-overlapping block,Perform Wavelet (Daubechies 4) decomposition for the magnitude (image) of DCT to obtain approximation ,vertical, horizontal and diagonal coefficients.Compute the Standard Deviation for each frequency bands separately. Store all the computed features in a vector detail can be found in[14][15].

IV. SUPPORT VECTOR MACHINE

The support vector machine (SVM) was first developed by Vapnik and used for classification in many applications such as handwritten digit recognition, image classification, face detection, object detection, text classification etc. [16-20]. Given an training example set $\{(X_{1,} y_1),...,(X_n, y_n)\}$, $where \quad X \in R^N, y \in \{-1,1\}$. The kernel function can map the training examples in input space into a feature space such that the mapped training examples are linearly separable. The problem can be converted to maximize the following dual optimization problem:

$$W(\alpha)=\sum_{i=1}^{n}\alpha_i - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_i y_i \alpha_i y_j K(X_j, X_j), \quad (5)$$

Subject to

$$\sum_{i=1}^{n} \alpha_i y_i = 0$$
$$\alpha_i \in [0, C].$$
$$for \quad i \in [1, n].$$

The decision function becomes

$$f(x) = sign\left(\sum_{i=1}^{n} \alpha_i y_i K(X_i, X_j + b\right), (6)$$

$$b = Y_r - \left(\sum_{i=1}^{l} \alpha_i y_i K(X_r, X_i) + b\right), (7)$$

Where (X_r, y_r) is any training example.
We are using following SVM kernels.

A. *Polynomial*

A polynomial kernel is a popular method for non-linear modeling.

$$K(X, X') = \langle X, X' \rangle^d \quad (7)$$

Where *d* is the degree of the polynomial

B. *Gaussian radial Basis function*

Gaussian radial basis function is defined as

$$K(X, X') = \exp\left(-\frac{\|X - X'\|^2}{2\sigma^2}\right). (8)$$

C. *Exponential radial basis function*

Exponential radial basis function is defined as

$$K(X, X') = \exp\left(-\frac{\|X - X'\|^2}{2\sigma^2}\right). (9)$$

It produces a piecewise linear solution that is attractive when discontinuities are acceptable.

D. *Spline*

A spline kernel is defined as

$$K(X,X') = 1 + \langle X,X' \rangle + \frac{1}{2}\langle X,X' \rangle \min(X,X') - \frac{1}{6}\min(X,X')^3, \quad (10)$$

E. *Wavelet*

The Wavelet kernel is defined as

$$K(X, X') = \prod_{i=1}^{N}\left(\psi\left(\frac{x_1 - x_i'}{a}\right)\right), (11)$$

Where $\psi(x) = \cos(1.75x)\ \exp(-x^2/2), N$ is the dimension of the input feature vector, and a is the scale factor.

F. *Autocorrelation Wavelet kernel*

A Translation invariant kernel $K(X, X') = K(X - X')$ is an admissible support vector (SV) kernel if and only if its Fourier transform is non-negative [21]. This can be satisfied by defining the following auto-correlation wavelet kernel [22]:

$$K(X, X') = \prod_{i=1}^{N}\left(\psi\left(\frac{x_1 - x_i'}{a}\right)\right), (12)$$

Where N is the dimension of the input feature vector and a is the scale factor. It should be mentioned that we can choose any compactly supported wavelet function to construct auto correlation wavelet kernel K(x,x').Details can be found in [23].

V. RESULT AND OBSERVATION

Data used for the present work were collected from different individuals. We considered 15000 basic characters (vowels as well as consonants) and 10000 numerical samples of Devnagari for the experiment of the proposed work.we have collected this data from different writer.The age group of writter is from 5years child to 60 years old man.we have also consider the profession of the writer i.e. student, clerk, officer, lecturer ect.we also formed printed database of ISM office fonts, in which we have used font size of 16 and different fonts.Here we have developed the six feature sets from our data collected and six for printed characters.Each feature set is divided in four parts i.e. vowels ('svar'), consonants ('vyanjan') without modifiers, consonants ('vyanjan') with modifiers, Number.Then we have used SVM with six different kernels. The results are given in following tables for different kernels used with SVM classifier.

Table I. : Result polynomial kernel

polynomial kernel	Feature Set	vowels ('svar') (%)	consonants ('vyanjan') without modifiers(%)	consonants ('vyanjan') with modifiers (%)	Number
Handwritten	S1	85	83	80	89
	S2	84	81	78	90
	S3	82	79	81	87
	S4	81	84	82	88
	S5	83	85	79	90
	S6	84	85	81	89
Printed	S1	90	88	89	89
	S2	89	89	88	91
	S3	91	87	88	92
	S4	90	89	87	90
	S5	92	86	90	91
	S6	90	88	91	92

Table II. Result Gaussian Radial

Gaussian radial	Feature Set	vowels ('svar') (%)	consonants ('vyanjan') without modifiers(%)	consonants ('vyanjan') with modifiers (%)	Number
Handwritten	S1	82	79	81	87
	S2	87	80	80	86
	S3	85	81	83	85
	S4	83	85	79	90
	S5	82	84	81	89
	S6	84	85	84	90
Printed	S1	90	88	87	88
	S2	92	90	85	89
	S3	93	85	86	90
	S4	90	84	88	86
	S5	89	90	82	84
	S6	84	83	85	89

Table III. Result Exponential Radial Basis

Exponential radial basis	Feature Set	vowels ('svar') (%)	consonants ('vyanjan') without modifiers (%)	consonants ('vyanjan') with modifiers (%)	Number
Handwritten	S1	80	78	81	89
	S2	79	82	87	88
	S3	81	85	84	87
	S4	78	88	85	84
	S5	85	87	82	84
	S6	89	86	81	86
Printed	S1	89	89	83	81
	S2	90	87	86	82
	S3	87	89	87	83
	S4	91	88	85	84
	S5	90	89	88	81
	S6	87	88	84	86

Table IV. Result Spline kernel

spline kernel	Feature Set	vowels ('svar') (%)	consonants ('vyanjan') without modifiers (%)	consonants ('vyanjan') with modifiers (%)	Number
Handwritten	S1	87	85	85	89
	S2	88	84	86	87
	S3	85	86	82	88
	S4	87	82	83	87
	S5	85	83	82	89
	S6	87	89	81	90
Printed	S1	90	90	89	90
	S2	88	94	92	91
	S3	89	93	91	92
	S4	91	92	93	93
	S5	92	91	94	94
	S6	89	83	86	87

Table V. Result wavelet kernel

wavelet kernel	Feature Set	vowels ('svar') (%)	consonants ('vyanjan') without modifiers (%)	consonants ('vyanjan') with modifiers (%)	Number
Handwritten	S1	89	89	88	90
	S2	87	88	87	91
	S3	89	85	86	89
	S4	85	86	85	92
	S5	86	87	84	91
	S6	87	87	88	92
Printed	S1	90	91	89	93
	S2	89	89	87	94
	S3	88	91	89	89
	S4	91	88	90	91
	S5	90	92	91	90
	S6	89	88	84	89

Table VI. Result Autocorrelation Wavelet kernel

Autocorrelation Wavelet kernel	Feature Set	vowels ('svar') (%)	consonants ('vyanjan') without modifiers (%)	consonants ('vyanjan') with modifiers (%)	Number
Handwritten	S1	88	87	86	81
	S2	85	86	82	80
	S3	87	84	84	83
	S4	86	82	83	79
	S5	87	85	86	81
	S6	87	81	81	84
Printed	S1	90	90	90	81
	S2	92	93	89	82
	S3	91	91	92	83
	S4	89	92	94	84
	S5	88	89	88	81
	S6	87	87	81	86

VI. CONCLUSION

we can conclude from abov result is that wavelets serve as a good feature set for the character images. The result obtained for recognition of Devnagari characters show that reliable classification is possible using SVMs kernels.

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