Wavepackets in the Recognition of Isolated Handwritten Characters

G. Raju and K. Revathy

Abstract— **This work is to apply wavelet packet transformation for the recognition of isolated handwritten Malayalam (one of the south Indian languages) characters. The key idea is that count of zero crossings of wavelet transform coefficients of an image characterize it. A set of 3000 images of 20 selected characters are used for classification. All images are normalized to have same height, binarized and inverted. Two-level Wavelet packet transformation is applied on each character image. Count of zero-crossings in each of the sixteen subbands together with a structural feature forms the feature vector. Feed forward back propagation network is used for classification. We obtained about 90% accuracy in classification and recognition. Further study by including more characters and more samples is being carried out.**

Index Terms— **Handwritten Character Recognition, Wavelet Packets, Zero crossings of wavelet coefficients, Neural Networks.**

I. Introduction

Offline recognition of handwritten characters is a field where intense research is going on. The major challenge is the large variation in the writing styles of individuals at different times and among different individuals. Also recognition system suitable for one language need not be apt for another. Compared to online character recognition systems, offline systems can use only static information.

Malayalam, one of the South Indian Languages, is the principal language of Kerala, one of the south Indian states. Malayalam character set consists of 73 characters, categories such as Vowels, Consonants, Anuswaram, Visargam, Chardrakala, *Consonant signs*, Chillu, and *Vowel signs*. Recent results on the recognition of isolated Malayalam characters based on structural and statistical features has shown an accuracy of about 85% [1][2][3].

Any hand written character recognition system should address the problems due to variations in writing style, intensity, scale and orientation. To simplify the task, often constraints are imposed on handwriting with respect to tilt, size, relative position, stroke connection etc. [4] [5] [6][7] [8]

Manuscript received February, 2007.

Dr. G. Raju is with the Information Technology Department, Kannur University, Kerala, India. Ph: +91-9446106628. (e-mail: kurupgraju@rediffmail.com)

Dr. K. Revathy is with the Department of Computer Science, University of Kerala, Kerala, India (e-mail: revathy_srp@yahoo.com)

Wavelets are localized basis functions which are translated and dilated versions of some fixed mother wavelet [9] [10]. In the last fifteen years Wavelet and similar transformations became popular for image processing tasks including character recognition. In wavelet analysis, the frequency of the basis function as well as the scale can be changed. Thus it is possible to exploit the fact that high frequency features of a function are localized while low frequency features are spread over time.

The zero-crossings of a wavelet transform provide the locations of the signal sharp variations at different scales [13]. This implies that count of zero crossings of wavelet coefficients in different subbands shall characterize an image. This fact is exploited in this work for the recognition of isolated handwritten characters.

A number of methods relating to application of wavelets in character recognition have been reported [14][15][16][17]. In one of the works reported, images of numerals are decomposed (single level) using Bi-orthogonal wavelets to four sub-images and each sub-image is normalized to the range [0, 1]. The feature vector is formed by these sub-images. Another approach is to get a signature of the character by converting the average image obtained after a three level wavelet transformation into binary image and use it for subsequent classification. Wavelet packets are also used where feature extraction is done by taking the wavelet packet transform of the character image using the best basis algorithm, for a desired number of multiresolution levels.

In this work, we propose a simpler method compared to the earlier methods. Here the count of Zero-crossing of wavelet coefficients is used as a feature for offline recognition of isolated Malayalam characters. One fifty samples each of twenty characters are used for classification. Wavelet packet transformation is applied on each image. The number of zero-crossings in each subbands is used as the main feature. The study shows that zero crossing of wavelet coefficients can be used as a feature for classification.

II. Wavelet Packet Decomposition

The core of the method is Wavelet Packet Transformation. The wavelet packet method is a generalization of wavelet decomposition that offers a richer signal analysis. In the two dimensional orthogonal wavelet decomposition procedures, the generic step splits the approximation coefficients into four parts. After splitting, we obtain a sub-image of smooth (low pass)

coefficients and three sub-images corresponding to detail coefficients along horizontal, vertical and diagonal directions. This is followed by splitting the low pass sub-image while the successive details are never reanalyzed.

In the corresponding wavelet packet situation, each detail coefficient sub-image is also decomposed into four parts using the same approach as in low pass sub-image splitting. The decomposition structure is given in figure 1. The filter used here is Biortho 3.7 and only two levels of decomposition is performed resulting in 16 sub-images (subbands).

III. The Data set

In this work, 20 characters out of 73 in Malayalam language are selected for recognition. For ease of reference each character is given a code. Sample of few characters are given in table I. The samples are collected from different individuals. The individuals selected are from different levels – based on age, qualification and sex. There was no constraint imposed on writing. The samples are scanned at 300dpi and images are stored as 256x256 gray images. We can notice that there are pronounced variations across samples and the samples contain considerable noise

A. Pre-processing

For handwritten character recognition, preprocessing is very crucial for subsequent phases. Preprocessing normally encompasses thresholding and thinning operations. Preprocessing results in noise free single-pixel wide skeleton images. This is followed by cropping of the image so as to fit into a minimum rectangle.

In this work, the preprocessing steps applied are cropping, resizing, binarization and inversion. Resizing is performed as a normalization step, where all characters are fitted into a window of same height. The inversion is done with a purpose to represent background with 0s.

IV. Feature extraction

A. Count of Zero-crossing as a Character Feature

Wavelet transform results in subimages corresponding to smooth component, highpass components in the three directions horizontal, vertical and diagonal. The information content of smooth component and highpass filtered components in the three directions should be a unique feature of an image. This feature can be characterized with number of zero-crossing of wavelet coefficients in each subimage. But for the same character, this count may vary considerably due to variation in writing style, tilt, noise etc.. In spite of this, the count of zero-crossing of each character is found to fall within a range. Though the ranges are found to be overlapping in some cases, the count of zero-crossing in all subimages together shall be used as a character feature.

B. Feature Extraction Method

The following steps are used for feature extraction :

i. For each character image do steps ii to v

ii. Apply two level forward wavelet packet transform using Bior 3.7 filter.

iii. For each subband count the number of zero crossings. Zero crossings are counted row wise.

iv. Record zero-crossing counts against each subband viz L1, H1, V1, D1, L2, H2, V2, D2, L3, H3, V3, D3, L4, H4, V4 and D4. L, H, V and D signifies low pass, Horizontal details, Vertical details and Diagonal details.

v. Find the height to width ratio. (This is used as an additional feature)

The seventeen values (input) together with class identification value (output) are given to the Neural Network for training.

V. Classifier

Feed forward neural network architecture is used for classification. The network is designed with an input layer, one hidden layer and output layer. The number of nodes in input layer is fixed as seventeen and the number of nodes in hidden layer as thirty. The output layer consists of a single node. All the neurons in the input layer are connected to the hidden layer and all the nodes in the hidden layer are connected to the output node. Back propagation is used for training with Mean Squared error as the error function.

VI. Result and Discussion

It is found that the ranges of zerocrossing count for different subbands vary from character to character. Figure 2 shows the variation of average number of zerocrossings for the twenty images. Only subbands L1, H1, V1, D1 and D4 are shown.

Totally 1800 images are used as training set. The trained network was then used for classifying 1200 new images, of which 1074 (89.5%) are recognized correctly. Table II gives details of testing.

VII. Conclusion

We have used the Zero-crossing of wavelet coefficient as a feature for character recognition. The characters are selected from Malayalam, one of the south Indian Languages, with its own morphological features.

The results obtained are promising giving an accuracy of 90% for the recognition of characters. The importance of this

work is that the selected feature VIZ Count of the Zero-crossing of wavelet coefficients is invariant to style, intensity and orientation. Refinement of the method by incorporating preprocessing steps such as thinning may give better results.

The proposed method is to be extended by considering the entire character set as well as using a large database of handwritten character samples.

L1	H1	L2	H2
V1	D1	V2	D2
L3	H3	L4	H4
V3	D3	V4	D4

Figure 1 Decomposition Scheme

Code	Character	Code	Character
A		**B**	
C		**D**	
E		**F**	
G		**H**	
I		**J**	

Table I Character Samples

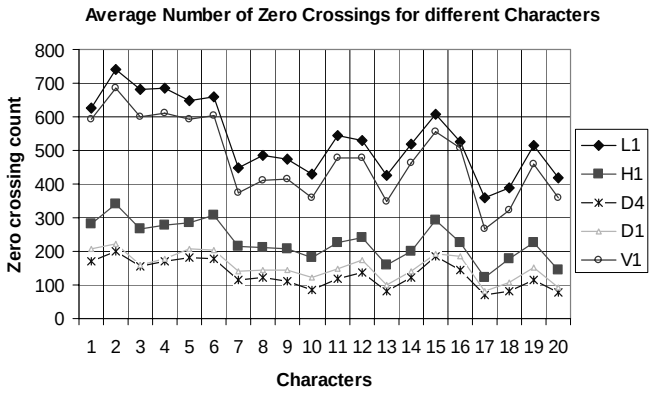

Figure 2 Plot of Average Zerocrossings

Character Code	Number of test samples	Number of successful classification	% of Success
A	60	60	100
B	60	56	93.3
C	50	49	98
D	55	52	94.5
E	62	59	95.1
F	70	61	87.1
G	65	60	92.3
H	60	49	81.7
I	60	56	93.3
J	56	54	96.4
K	60	54	90
L	55	50	90.9
M	58	49	84.4
N	70	62	88.6
O	65	54	83.1
P	62	50	80.6
Q	50	46	92
R	60	48	80
S	60	50	83.3
T	62	55	88.7

Table II Summary of classification with test data set

REFERENCES

[1] Lajish V. L., Suneesh T.K.K. and Narayanan N.K., "Recognition of Isolated Handwritten Character Images using Kolmogrov-Smirnov Statistical Classifier and k-nearest Neighbour classifier", *Proc.of the International Conference on Cognition and Recognition ICCR-05,* Mandya, Karnataka, December, 2005

[2] Lajish V.L., and Narayanan N.K., "Computer Recognition of off-line Handwritten Document analysis – A soft Computing Perspective", *Proc of the National Conference on Geometry, analysis, Fluid Mechanics and Computer Applications*, Kuvempu University, Karnataka, 2004.

[3] Lajish V.L., and Narayanan N.K, "Use of Handwriting Feature Descriptions and Artificial Neural Networks to recognize Isolated Character Images", *Proc of the 6th National conference on Recent Trends in Advanced computing – NCRTAC 2006*, Department of Computer Science & Engg, Manonmaniam Sunderanar University, Tamil Nadu, 2006

[4] H. Bunke and P.S. P. Wang (Editors), Hand Book of Character Recognition and Document Image Analysis, World Scientific, 1997

[5] S. Sasi and J.S. Bedi, "Character Recognition using Fuzzy Logic", *Proc. 37th MWSCS-94*, Lafayette, Lousiana, USA, Aug. 3-6, 1994, pp. 1399-1402

[6] Bortolozzi F., A de S Britto Jr., Oliveria L.S and Morita M., "Recent Advances in Handwriting Recognition", *Proc of the international workshop on Document analysis*, Allied Publishers Pvt Ltd, 2005, pp 1-30

[7] Plamondan R., Sargur N. Srihari, "Online and off-line Handwriting Recognition: A Comprehensive Survey, *IEEE Trans on PAMI, Vol 22*, No 1, 2000, pp 63 – 84

[8] R M K Sinha, Scott D Connell & Anil K Jain, "Recognition of unconstrained online Devanagari Characters" , *Proceedings of the 15th International Conference on Pattern Recognition*, Barcelona, Spain, Sept. 2000, pp. 368-371.

[9] S. Mallat, A Wavelet Tour of Signal Processing, Academic Press, 1999

[10] Antonini M., Barkud M., Muthieu P. and Daubechies I., "Image Coding Using Wavelet Transform", *IEEE Trans on Image Processing, Vol 1*, 1992, pp 205 – 220

[11] Yvette Mallet, Danny Coomans, Jerry Kautsky and Oliver De Vel, "Classification Using Adaptive Wavelets for Feature Extraction", *IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol* 19, No 10, 1997, pp 1058 – 1066

[12] A. Laine, S. Schuler, "Hexagonal wavelet processing of digital mammography", *Medical Imaging 1993, Part of SPIE's Thematic Applied Science and Engineering Series*, Newport Beach, California, February 1993, 14-19.

[13] S. Correia, J. M. Carvalho and R. Sabourin, "On the Performance of Wavelets for Handwritten Numerals Recognition". *In ICPR 2002, Quebec* - Canada, August 2002.

[14]] L. Huang and X. Huang, "Multiresolution Recognition of Offline Handwritten Chinese Characters with Wavelet Transform", *Proc. of Sixth ICDAR*, Seattle, Washington, USA, Sept. 10-13, 2001, pp. 631-634.

[15] S. W. Lee, C.H. Kim, H. Ma and Y. Y. Tang, "Multiresolution Recognition of Unconstrained Handwritten Numerals with Wavelet Transform and Multilayer Cluster Network", *Pattern Recognition, vol. 29*, no. 12, 1996, pp. 1953 - 1961.

[16] P. Wunsch and A. F. Laine, "Wavelet Descriptors for Multiresolution Recognition of Handprinted Characters", *Pattern Recognition, vol. 28*, no. 8,1995, pp. 1237- 1249.

[17] S. E. N. Correia and J. M. Carvalho. "Optimizing the recognition rates of unconstrained handwritten numerals using biorthogonal spline wavelets". *In ICPR 2000, Barcelona* - Espanha, September,2000.