2018 4th International Conference for Convergence in Technology (I2CT)
SDMIT Ujire, Mangalore, India. Oct 27-28, 2018

Rotation Invariance in Transform Features for Handwritten Devanagari Character Recognition

Sushama Shelke
Department of Electronics and Telecommunication
Dr. D. Y. Patil Institute of Engineering, Management & Research
Pune, India
shelke.sushama@gmail.com

Priti Rege
Department of Electronics and Telecommunication
College of Engineering
Pune, India
ppr.extc@coep.ac.in

***Abstract*—Features extracted in any pattern recognition task, need to be invariant to translation, scaling and rotation. Handling translation and scaling in character recognition application is much easy compared to handling rotation in characters. The rotated characters affect the recognition rate. Therefore, it becomes crucial to extract features which are invariant to rotation in order to improve the recognition rate. This paper focuses on transform based features for extracting rotation-invariant features from handwritten Devanagari characters. The results indicate that Convolved Wavelet coefficient features are best at extracting rotation invariant features as compared to other transforms, considered in this work.**

Keywords—handwritten Devanagari characters, feature extraction, rotation invariant, wavelet transform, correlation

I. Introduction

Optical character recognition (OCR) systems convert character images into text. The text output can be stored or edited. Such systems find application for recognizing printed or handwritten characters found in images of postal letters, forms, historical documents, bank cheques, industry parts, vehicle number plates, various official documents, etc.

Although there are several methods for extracting features in a typical character recognition application [1], emphasis is given on those features which are good at handling translation, rotation and scaling. Features can be extracted by several methods and they are application dependant in many instances. There are several classifications of feature extraction techniques found in the literature. In general, features can be divided into following three categories, namely, region based, boundary-based and transform-based features. Firstly, region-based features are those which extract regional characteristics of the object in an image. Secondly, boundary-based features, extract the characteristic features of the boundary. Both region-based and boundary-based methods [2] extract features in spatial domain. Finally, the transform based methods extract the features in transform domain after transforming the spatial image into the frequency domain. The components obtained in this transform domain are called as coefficients.

Devanagari character set consists of 16 vowels and 36 consonants. The script is written from left to right. There are no upper and lower case characters like those found in English script. A Devanagari alphabet consists of various features like strokes, line segments, curves and holes. Every character has a horizontal line at the top called as the shirorekha or header line. This line joins the characters to form a word. The vowels are joined to consonants in various ways forming new shapes. Further, two or more consonants join together forming a complex structure called as the conjunct characters.

Work on Devanagari script recognition started in 1970s, where printed script was used for recognition [3]. The characters in the printed script recognition were classified using the structural characteristics of the characters, such as the occurrence of a vertical line. The characters were further classified based upon the position of the vertical line whether it is at the end or at the middle [4, 5]. This was followed by attempting recognition of handwritten numerals in Devanagari [6]. As the work progressed to handwritten character recognition in Devanagari, attempts were made to find the features that could represent the characters efficiently [7-9]. Extensive research is carried out in finding various features and the classifier combinations to improve the recognition rate [10]. Several researchers also applied multiple features in order to improve the accuracy of the recognition engine. Efforts were also taken on the classifier end so as to meet the challenges posed by the handwritten characters. Since Devanagari dataset is large and there are wide variations in the writing styles of these characters, researchers came up with multiple features and multiple classifiers [11, 12]. Various soft computing techniques like Artificial Neural Networks, Support Vector Machines etc are also implemented to handle handwritten character recognition efficiently.

Different types of transformation are used by various researchers [13, 14] for extracting the features for Devanagari characters so far. It is reported that the transform-based features have good discrimination ability and they are less in number as compared to the other methods, thereby eliminating the need for dimension reduction techniques. Moreover, they are rotation invariant which substantially increases the recognition accuracy. In this paper, transform-based features are extracted and the rotation invariance of these features is quantified and compared to obtain the best method for Devanagari character recognition application.

The next part of the paper is organized as follows: Section II describes the image transforms. Section III presents the proposed system design. Section IV, discusses the results obtained and finally, Section V presents the conclusion.

978-1-5386-5232-9/18/$31.00 ©2018 IEEE

II. IMAGE TRANSFORMS

The images are transformed from spatial domain to frequency domain to obtain the coefficients for several reasons. This is done by multiplying an image with a basis function. This is done for several reasons. Firstly, the images are transformed to compress the image. This is possible since the image can be represented by fewer coefficients in transform domain than the corresponding pixels in the spatial domain, eventually leading to image compression. For example, DCT, DWT are used in image compression standards. Another significance of image transforms is to enhance or denoise an image. For example, Discrete Fourier transform, Discrete Wavelet transform are used for image enhancement. Lastly, the image transforms are applied over an image for extracting the features. Different transforms which are used for feature extraction in this paper, are discussed in further.

A. *Discrete Fourier Transform*

The discrete Fourier transform (DFT) of the image f(x, y) is obtained by equation (1). The resulting Fourier coefficients F (u, v) are extracted which are used as the features.

$$F(u,v) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)e^{-j2\pi(\frac{u}{M}x+\frac{v}{N}y)} \tag{1}$$

where, u = 0, 1, 2,….M-1 and v = 1,2,….N-1.

This transform decomposes signals into sine waves. In case of discrete two-dimensional signal, the transform yields into components those are real and imaginary. The basis function of DFT is symmetric, separable and has complex exponential terms.

B. *Discrete Cosine Transform*

The discrete cosine transform (DCT) applied on an image f(x, y) generates the coefficients F(u, v) as indicated in equation (2). The DCT is a representation of sum of sinusoids at various magnitude and frequency. The energy compaction ability of DCT is very high. Generally, more information lies in low frequency components in an image which is represented by a few coefficients in frequency domain using this transform

$$F(u,v) = \alpha(u)\alpha(v)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)\cos\left[\frac{(2x+1)u\pi}{2M}\right]\cos\left[\frac{(2y+1)v\pi}{2N}\right] \tag{2}$$

Here, M and N are chosen to be equal. The basis function of DCT is orthogonal, symmetric and separable.

C. *Wavelet Transform*

The wavelet transform holds important features like scalability, translatability, separability, multiresolution and orthogonality capability. The two-dimensional discrete wavelet transform of an image *f(x,y)* is given by,

$$F_{\varphi}(j_0,m,n) = \frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)\varphi_{j_0,m,n}(x,y) \tag{3}$$

$$F_{\psi}^{i}(j,m,n) = \frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)\psi^{i}_{j,m,n}(x,y) \tag{4}$$

where,

$$\varphi_{j,m,n}(x,y) = 2^{j/2}\varphi(2^{j}x-m, 2^{j}y-n) \tag{5}$$

and

$$\psi^{i}_{j,m,n}(x,y) = 2^{j/2}\psi^{i}(2^{j}x-m, 2^{j}y-n) \tag{6}$$

are the 2D scaling and wavelet functions respectively. Here, the index '*i*' identifies the directional wavelets that takes the values horizontal, vertical and diagonal details respectively i.e. H, V and D. Generally, $j_0 = 0$ and $M = N = 2^J$ so that j = 0, 1, 2…, J-1 and m, n = 0, 1, 2,…, 2^j-1. The decomposition is done using Daubechies wavelet transform.

The discrete wavelet transform can be implemented using digital filters and down samplers. The high pass or detail component characterizes the image's high-frequency information with vertical orientation; the low-pass, approximation component contains its low-frequency, vertical information. Both sub images are then filtered column wise and down sampled to yield four quarter size output images.

D. *Convolved Transform Coefficients*

The interclass distance can be increased by convolving the feature vector with itself. This operation thus results into increased recognition accuracy. The convolved transform coefficient features are extracted by convolving the feature coefficients obtained by transformation, with themselves. Convolution between the coefficients *F (u, v)* with themselves is given as,

$$F * F' = \sum_{u'=0}^{M-1}\sum_{v'=0}^{N-1} F(u',v')F'(i-u', j-v') \tag{7}$$

III. SYSTEM DESIGN

The proposed system design for finding rotation invariant transform features is indicated in Fig. 1. In this system, the Devanagari character images undergo pre-processing at first. This is then followed by feature extraction and feature matching. The features are matched to reveal the rotation invariance of various feature extraction techniques. The actual algorithms implemented at each stage are discussed further.

A. *Devanagari Characters*

Isolated Devanagari characters with different orientation angles are taken. The characters with various rotation angles are shown in Fig. 2. The character rotation angles are varied from -30 degrees to +30 degrees.

B. *Pre-processing*

The characters are passed through various pre-processing steps before feature extraction. At first, the character image is converted to binary image. If, the image is a color image, it is converted to grayscale and then to binary. A global threshold of 0.85 is used to convert the image from grayscale to binary. It is observed that the character breaks where there is thin edge after thresholding. To tackle this problem, the image is passed through a low pass filter prior to binarization. This bridges small gaps and retains the shape of the character. In order to have all the characters with the same size, the character images are cropped and then inverted to get white object on black background. Finally, the character is resized to a fixed size of 64 x 64. The cropping and resizing operation yields the characters which are invariant to translation and scaling. The invariance to rotation is dependent on feature extraction stage. The characters are now ready for feature extraction.

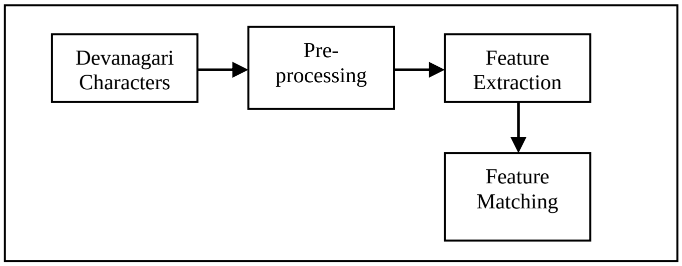

Fig. 1. System design.

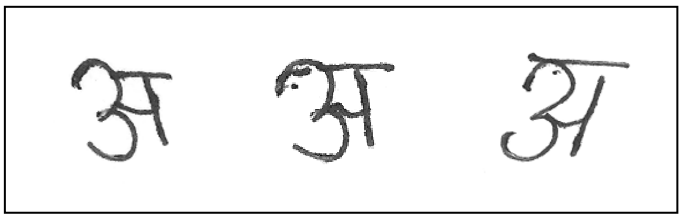

Fig. 2. Sample characters with different rotation angles.

C. Feature extraction

The images are then transformed to frequency domain and the transform coefficients are extracted from the pre-processed characters using various transforms as discussed in previous section. These include, discrete wavelet transform, convolved discrete wavelet transform, discrete cosine transform, convolved discrete cosine transform, discrete Fourier transform and convolved discrete Fourier transform. The discrete Fourier transform coefficients are obtained by implementing fast Fourier transform algorithm.

D. Feature matching

The features are extracted from the characters which exist at various rotation angles. The similarity between the features between the characters in the database and the rotated characters under test is found to check the rotation invariance of the character. Various statistical parameters are calculated to check the invariance. The similarity is checked by obtaining the cross correlation of the features extracted as indicated in (8). The correlation coefficient ‘corr_coeff’ generates a maximum value if the features of the database image and rotated image match. The ‘corr_coeff’ varies between +1 to -1, where +1 indicates exact match and -1 indicates complete mismatch between the two images. The ‘corr_coeff’ is obtained by,

$$\text{corr\_coeff} = \frac{\sum_m \sum_n (f-\bar{f})(g-\bar{g})}{\sqrt{\left(\sum_m \sum_n (f-\bar{f})^2\right)\left(\sum_m \sum_n (g-\bar{g})^2\right)}} \qquad (8)$$

Where, $\bar{f}$ and $\bar{g}$ are the mean of the database character features and the rotated character features respectively.

IV. Results and Discussion

This section presents the results obtained. Fig. 3 shows the pre-processing results. Here, characters images with various rotation angles are seen. These images are 64x64 binary character images which are obtained after applying the algorithms discussed in the previous section.

Fig. 3. Pre-processing results.

Next, transform features are extracted from these characters. The transformation applied and the number of features extracted is indicated in Table I. The transform applied are DWT - discrete wavelet transform, C_DWT - convolved discrete wavelet transform, DCT - discrete cosine transform, C_DCT - convolved discrete cosine transform, FFT - fast Fourier transform and C_FFT - convolved fast Fourier transform. As seen from the table, the numbers of features extracted using discrete wavelet transform are half the number of features extracted by other techniques. This reduces the computations and makes the system faster as compared to other features. Here, 32x32 approximation coefficients are used as features. Same are then convolved to obtain convolved wavelet features.

TABLE I. Feature Extraction Method and Number of Features

Feature extraction	Number of features
DWT	32x32
C_DWT	32x32
DCT	64x64
C_DCT	64x64
FFT	64x64
C_FFT	64x64

Table II indicated the result of matching between the database character features and rotated character features. The correlation coefficients at various rotation angles of the test image are given When the correlation coefficient of the features is obtained by matching with the same character, the correlation coefficient is 1. As the test character is rotated gradually, the correlation coefficients start reducing. But this reduction is less in convolved discrete wavelet features as seen from Table II. Also the values of the correlation coefficients are higher as compared to the other techniques for a particular rotation angle. The standard deviation is calculated for each column to check the variation in the correlation coefficient for a particular character under rotation. As indicated in the table, the standard deviation is least with convolved discrete wavelet coefficient features. This indicates that the variation in correlation coefficient is the least inspite of the rotation of the character from -30 degrees to +30 degrees.

TABLE II. FEATURE MATCHING RATIO

Rotation Angle	Correlation Coefficients					
	DWT	C_DWT	DCT	C_DCT	FFT	C_FFT
-30	0.15	0.59	0.40	-0.03	0.47	0.24
-20	0.34	0.74	0.53	-0.01	0.57	0.27
-10	0.65	0.90	0.73	0.03	0.77	0.42
0	1	1	1	1	1	1
10	0.65	0.90	0.73	0.04	0.77	0.47
20	0.35	0.71	0.53	-0.02	0.57	0.27
20	0.14	0.53	0.40	0.00	0.456	0.14
Standard Deviation	0.31	0.17	0.21	0.37	0.19	0.28

V. CONCLUSION

This paper describes the extraction of rotation invariant feature extraction techniques for handwritten Devanagari characters. Several transform-based feature extraction techniques like discrete cosine transform, discrete Fourier transform and discrete wavelet transform are implemented in this paper. Further, convolved features are also extracted like convolved discrete cosine transform coefficients, convolved discrete Fourier transform coefficients and convolved discrete wavelet transform coefficients. It is found from the results that the convolved discrete wavelet transform coefficient features can handle rotation from -30 degrees to +30 degrees efficiently and result into correct classification of the character.

REFERENCES

[1] Oivind Due Trier, Anil K. Jain and TorfinnTaxt, “Feature Extraction Methods for Character Recognition – A Survey”, Pattern Recognition, vol. 29, pp. 41-62, 1996.

[2] R. Gonzalez and R. Woods, Digital Image Processing, Pearson Education, India, 2006.

[3] R. M. K. Sinha and H. Mahabala, “Machine recognition of Devnagari script,” IEEE Trans. Syst. Man Cybern., vol. 9, no. 8, pp. 435–441, Aug. 1979.

[4] V. Bansal and R. M. K. Sinha, “On How to Describe Shapes of Devanagari Characters and Use them for Recognition”, Proceedings of 5th International Conference on Document Analysis and Recognition, 1999, pp. 410-413.

[5] V. Bansal, R.M.K. Sinha, “Partitioning and Searching Dictionary for Correction of Optically Read Devanagari Character Strings”, Proceedings of 5th International conference on Document Analysis and Recognition, 1999, pp. 653-656.

[6] P. M. Patil and T. R. Sontakke, “Rotation, Scale and Translation Invariant Handwritten Devanagari Numeral Character Recognition using General Fuzzy Neural Network”, Pattern Recognition, vol. 40, no. 7, pp. 2110-2117, 2007.

[7] S. Kumar, “Performance comparison of features on Devanagari handprinted dataset,” Int. J. Recent Trends in Engineering, vol. 1, no. 2, pp. 33–37, 2009.

[8] S. Arora, D. Bhattacharjee, M. Nasipuri, D. K. Basu, M. Kundu, and L. Malik, “Study of different features on handwritten Devanagari character,” in Proc. 2nd Emerging Trends Eng. Technol., 2009, pp. 929–933.

[9] U. Pal, T. Wakabayashi, and F. Kimura, “Comparative study of Devanagari handwritten character recognition using different features and classifiers,” in Proc. 10th Conf. Document Anal. Recognit., 2009, pp. 1111–1115.

[10] S. Arora, D. Bhattacharjee, M. Nasipuri, D. K. Basu, and M. Kundu, “Combining Multiple Feature ExtractionTechniques for Handwritten Devanagari Character Recognition”, in Proc. IEEE Region Colloquium and the Third ICIIS, 2008, pp. 1-6.

[11] G. G. Rajput and S. M. Mali, “Fourier descriptor based isolated Marathi handwritten numeral recognition,” Int. J. Comput. Appl., vol. 3, no. 4, pp. 9–13, 2010.

[12] S. Shelke, and S.Apte, “A Novel Multi-feature Multi-classifier Scheme for Unconstrained Handwritten Devanagari Character Recognition”, in Proc. 12th Int. Conf. Frontiers Handwrit. Recognit., 2010, pp. 215-219.

[13] S.Shelke, and S.Apte, “A Novel Multistage classification and Wavelet based Kernel Generation for Handwritten Marathi Compound Character Recognition”, in Proc. Int. Conf. Communications and Signal Processing, 2011, pp. 193-197.

[14] Minhua Li, Chunheng Wang and Ruwei Dai, “Unconstrained Handwritten Character Recognition Based on WEDF and Multilayer Neural Network”, Proceedings of the 7th World Congress on Intelligent Control and Automation, 2008, pp. 1143-1148.