Handwritten Kannada Numeral Recognition based on the Curvelets and Standard Deviation

Mamatha H.R
Department of ISE, PES Institute of Technology, Bangalore, India
Email: mamatha.bhr@gmail.com

Sucharitha S and Srikanta Murthy K
Department of CSE, PES School of Engineering, Bangalore, India
Email: sucharithaprasad5@gmail.com, srikantamurthy@pes.edu

***Abstract*—A feature extractor is generally used to characterize an object by making numerical measurements of the object. Features whose values are similar for objects belonging to the same class and dissimilar for objects in different classes are considered as good features. In this paper, an attempt is made to develop an algorithm for the recognition of handwritten Kannada numerals using fast discrete curvelet transform. Curvelet coefficients are obtained by applying the curvelet transform with different scales. Standard deviation is applied to the coefficients obtained and the result of this is used as the feature vector. A k-NN classifier is adopted for classification. The proposed algorithm is experimented on 1000 samples of numerals. The system is seen to deliver reasonable recognition accuracies for different scales with 90.5% being the highest for Scale 3.**

***Index Terms*—Curvelets, standard deviation, handwritten kannada numeral recognition, k-NN classifier**

I. Introduction

A character is a system consisting of symbols that are used to represent information of a particular language. A character is represented as a physical entity using a number of writing tools so that the information present can be transmitted to the reader. Character recognition is a topic being studied in depth. Human's ability to recognize characters is being studied in its advanced form and systems are being developed to simulate this ability. Character recognition plays an important role in automating insertion and human-computer interface.

Over the last few years, extensive research is being carried out on Handwritten Character Recognition (HCR) systems in the academic and production fields. A Handwritten Character Recognition system can either be online or offline. The process of finding letters and words present in a digital image of handwritten text is called off-line handwritten recognition. A number of methods of recognition of English, Latin, Arabic, Chinese scripts are excellently reviewed in [1]-[4]. A HCR system has various applications such as being used as a reading aid for the blind, applications involving bank cheques, automatic pin code reading for sorting of postal mail.

A lot of work has been done on the recognition of printed characters of Indian languages. On the other hand, attempts made on the recognition of handwritten characters are few. Most of the research in this area is concentrated on recognition of off-line handwritten characters for Devanagari and Bangla scripts. From the literature survey it is seen that there is a lot of demand for character recognition systems for Indian scripts and an excellent review has been done on the OCR for Indian languages [5]. A Detailed Study and Analysis of OCR Research on South Indian Scripts can be seen in [6].

A proficient method for the recognition of isolated Devanagari handwritten numerals based on Fourier descriptors has been proposed by Rajput and Mali in [7]. Another method proposed in [8] involves computing the zone centroid and further dividing the image into equal zones. The average distance from the zone centroid to each pixel present in the zone is computed. The aforementioned process is repeated for all the zones present in the image of the numeral. At last, n such features are extracted and considered for classification and recognition. F-ratio Based Weighted Feature Extraction for Similar Shape Character Recognition for different scripts like Arabic/Persian, Devnagari English, Bangla, Oriya, Tamil, Kannada, Telugu etc can be seen in [9].

The key factor in achieving high recognition rate in character/numeral recognition systems is the selection of a suitable feature extraction method. A survey on the feature extraction methods for character recognition is reviewed in [10].

Curvelet transform is used as one of the feature extraction methods in [11], [12], and [13]. Here the curvelet transform function is applied on the given image and the coefficients are obtained. The obtained coefficients are used in the feature vector for that particular image.

Literature survey shows that the automatic recognition of handwritten digits has been the subject of intensive research during the last few decades. Digit identification is very important in applications such as interpretation of ID numbers, Vehicle registration numbers, Pin Codes, etc. In

Manuscript received May 6th, 2013; revised July 28, 2013

doi: 10.12720/ijsps.1.1.74-78

Indian context, it is evident that still handwritten numeral recognition research is a fascinating area of research to design a robust optical character recognition (OCR), in particular for handwritten Kannada numeral recognition.

The rest of the paper is organized as follows. Section II describes the Kannada script, section III discusses the proposed methodology, sections IV and V briefly discuss the experimental setup and the results obtained are discussed respectively. Finally in Sections VI and VII, comparative study and conclusions are made.

II. Description of the Kannada Script

Kannada also called as Canarese, is the official language of the state of Karnataka which is present in the southern part of India. Described as 'sirigannada', it is one of the earliest languages evidenced epigraphically in India. The language is spoken by about 50 million people spread over the states of Karnataka, Tamil Nadu, Andhra Pradesh and Maharashtra. The visual form of the Kannada language is the Kannada script. The Kannada script originated from the southern Bramhi Lipi during the period of Ashoka. It underwent a lot of changes from time to time during the reign of Sathavahanas, Kadambas, Gangas, Rastrakutas and Hoysalas [14]. The modern Kannada script emerged in the thirteenth Century. It is also used to write Tulu, Konkani and Kodava languages.

The Kannada script has a large number of structural features which are common with other Indian language scripts. Kannada has 49 basic characters which are classified into three categories: swaras(vowels), vyanjans(consonants) and yogavaahas (part vowel, part consonants). The scripts also include 10 different Kannada numerals of the decimal number system.

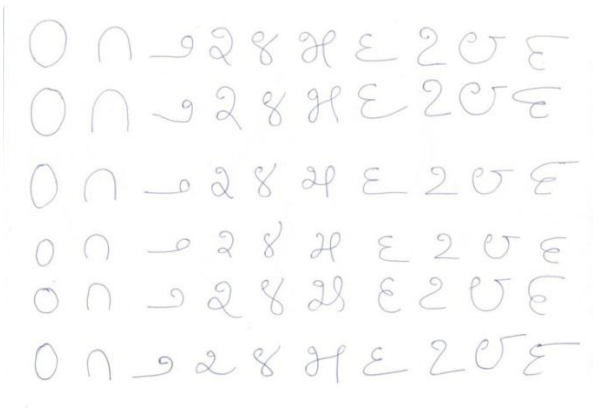


Figure 1. A sample sheet of Kannada Handwritten numerals 0 to 9

One of the challenges faced during the development of an OCR system for Kannada numerals is the distinction of several similar shaped components in the script. Some numerals have very similar variation between them and this leads to recognition complexity and reduces the accuracy rate of the recognition system. Some of the sets of similar numerals are as in Fig. 2.

Numeral 0 and 1		
Numeral 6 and 9		
Numeral 3 and 7		

Figure 2. Examples of some similar shaped numerals

III. Proposed Methodology

A. Data Set and Preprocessing

Kannada lacks a standard test bed of character images for OCR performance evaluation. The dataset of the 10 numerals was created by collecting various handwritten samples. These were scanned through a flat bed HP scanner at 300 dpi. Isolated characters were obtained by manual cropping. Thus 100 different samples of each numeral were created with the total of 1000 samples.

Initially the color images were converted to gray scale and in turn the gray scale images were converted to binary using global threshold method. Thinning is applied on the binary image. Thinning is an image preprocessing operation performed to make the image crisper by reducing the binary-valued image regions to lines that approximate the skeletons of the region. Region labeling is performed on the thinned binary image of the numeral and a minimum rectangle bounding box is inserted over the numeral. The bounding box image would be of variable size due to different style and size of numeral. Hence this image is resized to a 256*256 image and thinning is applied again.

B. The Curvelet Transform

Curvelet Transform is a unique member of the emerging family of multiscale geometric transforms. It was designed to overcome the inherent limitations of traditional multiscale approaches such as wavelets. The curvelet transform can be theoretically described as a multiscale pyramid which has many directions and positions at each length scale. Its elements are needle shaped at fine scales [11]. Curvelet Transform has many variations like Fast Discrete Curvelet Transform based on Wrapping and Unequispaced FFT Transform. Feature extraction method based on Fast Discrete Curvelet Transform using Wrapping can be found in [15].

The input given to the Curvelet Transform based on wrapping of Fourier samples is a 2-D image in the form of a Cartesian array represented as f [m, n] where $0 \leq m < M, 0 \leq n < N$. The algorithm generates the output as number of curvelet coefficients which indexed by a scale j, an orientation l and two spatial location parameters (k1, k2). In order to obtain the curvelet texture descriptor, a number of statistical operations are applied to the coefficients generated as the output. The coefficients of the Discrete Curvelet Transform can be defined by the equation (1) [16]:

$$C^D(j,l,k_1,k_2) = \sum_{\substack{0\le m<M \\ 0\le n<N}} f[m,n]\emptyset^D_{j,l,k_1,k_2}[m,n] \quad (1)$$

Here, each $\emptyset^D_{j,l,k_1,k_2}[m,n]$ is a digital curvelet waveform. If the frequency responses of curvelets at different scales and orientations are combined, a rectangular frequency tiling that covers the whole image in the spectral domain (Fig. 3) is obtained. The curvelet spectra cover the entire frequency plane of the image. Thus there is no loss of information.

C. Feature Extraction

Wrapping based discrete curvelet transform using Curvelab-2.1.2 is applied to find the coefficients and to create feature vectors for every 256*256 image in the database. In this experiment we have used the default orientation and 5 levels of discrete curvelet decomposition. Hence for an image of size 256*256, curvelet coefficients in five different scales are obtained.

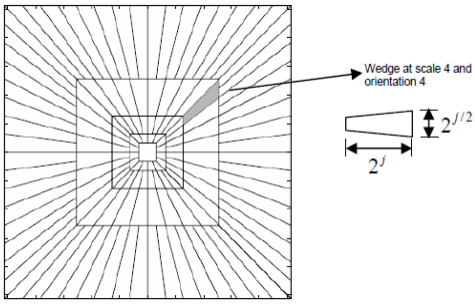


Figure 3. Rectangular frequency tiling of an image with 5 level curvelets.

The curvelet coefficients obtained for each sample are numeric. In this implementation, we have chosen wavelet in the finest level of curvelet transform. This is due to the fact that use of wavelet reduces the redundancy factor [17]. One subband at the coarsest and one subband at the finest level of curvelet decomposition are obtained after the application of curvelet transform on the input. The numbers of subbands obtained at each level for the other levels of curvelet decomposition is different. The number of coefficients obtained after application of curvelet transform is very high. Hence if all the coefficients obtained are used in the feature vector, the size of the feature vector and the time taken for feature vector formation increases drastically. Therefore, for extracting the best features and also decreasing the size of feature vector for each sample, we use standard deviation as the dimension reduction technique. The standard deviation of the coarsest and the finest levels are calculated first using the equation (2). Then, we calculate the standard deviation of the first half of the total subbands at each of the remaining scales. We consider only the first half of the total subbands at a resolution level for feature calculation because; the curvelet at angle θ produces the same coefficients as the curvelet at angle (θ+π) in the frequency domain i.e. these subbands are symmetric in nature. Hence, considering half of the total number of subbands at each scale reduces the total computation time for the feature vector formation without the loss of information of the image. For the finest and the coarsest subbands the standard deviation calculated is used directly in the feature vector but for the other subbands the sum of the standard deviation is calculated and stored in the feature vector. This helps us to reduce 29,241 features obtained in scale 1 to 171, 94,777 features obtained in scale 2 to 426, 1,64,953 features obtained in scale 3 to 348, 1,80,601 features obtained in scale 4 to 322 and 1,84,985 features obtained in scale 5 to 316.

$$s = \left(\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{1/2} \quad (2)$$

where

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

and n is the number of elements in the sample.

D. Classification

The classifier used in the proposed method is the k nearest neighbor classifier [18].The k value indicates the number of neighbors used for classification. In this paper, k=1, k=4, k=7, k=10 and k=13 are chosen and the results are compared to find out the optimum value of k. From the experimental results it is clear that the recognition rate has been independent of the change in the k value of the k-NN classifier. In the k-Nearest neighbor classification, we compute the distance between features of the test sample and the feature of every training sample. Here, Euclidean, Cosine, Cityblock and Correlation measures were used as the distances and nearest as the rule.

Given an mx-by-n data matrix X, which is treated as mx (1-by-n) row vectors x1, x2, ..., xmx, and my-by-n data matrix Y, which is treated as my (1-by-n) row vectors y1, y2, ...,ymy, the various distances between the vector xs and yt are defined as follows[19]:

Euclidean distance

$$d_{8t}^2 = (x_8 - y_t)(x_8 - y_t)' \quad (3)$$

City block metric

$$d_{st} = \sum_{j=1}^{n} \left|x_{8j} - y_{tj}\right| \quad (4)$$

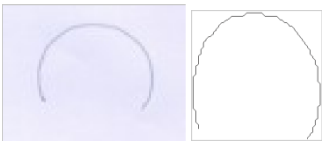
Cosine distance

$$d_{st} = \left(1 - \frac{x_8 y_t'}{\sqrt{(x_8 x_8')(y_t y_t')}}\right) \quad (5)$$

Correlation distance

$$d_{st} = 1 - \frac{(x_8 - \overline{x_8})(y_t - \overline{y_t})'}{\sqrt{(x_8 - \overline{x_8})(x_8 - \overline{x_8})'}\sqrt{(y_t - \overline{y_t})(y_t - \overline{y_t})'}} \quad (6)$$

where $\overline{x_8} = \frac{1}{n}\sum_j x_{8j}$ and $\overline{y_t} = \frac{1}{n}\sum_j y_{tj}$



(a) (b)

Figure 4. An example of Digital Curvelet transform for the numeral ೦

(a) Original image (b) Resized and thinned image

E. Experimental Results

The experiments were carried out in Matlab 7.5.0, on a 64-BIT 2.67 GHz INTEL i5 processor, with 4 GB RAM. The curvelet transformation was done using the Curvelet 2.1.2 toolbox, available from http://www.curvelet.org. The morphological operations were performed using Matlab's Image Processing Toolbox.

The dataset consisted of 1000 samples out of which 800 randomly selected samples were used for training and the remaining 200 samples were used for testing. The classification is done using Euclidean, Cosine, Cityblock and Correlation measures as the distance measures and nearest as the rule. Five different classifiers were used with the K values as 1,4,7,10,13. K value specifies the number of neighbors used for classification.

From the results obtained, we can infer that it is not always necessary to use all the coefficients that are obtained by applying the curvelet transform. Instead we can use the coefficients with larger values to form the feature vector. It can also be noted that the results have been independent of the change in the k value of the KNN classifier.

TABLE I. THE AVERAGE RECOGNITION RATES FOR DIFFERENT SCALES WITH DIFFERENT DISTANCE MEASURES USING THE DEFAULT ORIENTATION

Distance Measure	Scale	Total number of recognized samples	Average recognition rate (%)
Euclidean	1	153	76.5
	2	151	75.55
	3	159	79.5
	4	167	83.5
	5	166	83
Cosine	1	151	75.5
	2	151	75.5
	3	148	74
	4	154	77
	5	154	77
Cityblock	1	163	81.5
	2	166	83
	3	181	90.5
	4	177	88.5
	5	179	89.5
Correlation	1	152	76
	2	154	77
	3	148	74
	4	154	77
	5	153	76.5

According to the Table I, for the testing samples when we use the information of scale 3 for achieving feature vector and Cityblock distance measure in classification, our recognition rate got better.

From the experimental results, we can conclude that the possibility of misclassification is higher among the sets of similar numerals mentioned above in Fig. 2. For example for the scale 3 the numeral ೬ (six) is recognized as ೯ (nine) 5 times and numeral ೯ (nine) is recognized as numeral ೬ (six) 3 times.

As seen from the results, the time used for classification of features is less than a second and this can be attributed to the fact that the entire coefficient set obtained is reduced using standard deviation which results in dimensionality reduction of the feature vector and hence reduces the time taken for recognition.

IV. COMPARITIVE STUDY

The Table II shows the comparison results of existing methods with proposed method. Here an attempt is made to achieve good accuracy using less number of features and thereby improving the time and space complexity. However, the higher recognition rate can be achieved by way of using better classifiers.

TABLE II. COMPARATIVE RESULTS FOR HANDWRITTEN KANNADA NUMERALS WITH OTHER EXISTING METHODS

Authors	No. of samples in data set	Feature extraction method	Classifier	Accuracy (%)
B V Dhandra et al[20]	1512	Structural features	KNN classifer	96.12
Rajashekhara Aaradhya S V et.al[21]	1000	Vertical projection distance with zoning	NN classifier	93
R Sanjeev Kunte et al[22]	2500	Wavelet	Neural classifier	92.3
G G Rajput et al[23]	1000	Image fusion	NN classifier	91.2
V N Manjunath Aaradhya et al[24]	2000	Radon features	NN classifier	91.2
Dinesh Aacharya U et. al[25]	500	Structural features	K-means	90.5
Proposed Method	1000	Curvelet	KNN	90.5

V. CONCLUSION

In this paper, recognition of handwritten numerals of Kannada language using curvelet transform is proposed. In this approach, curvelet coefficients are used to create the feature vector used for recognition. Standard deviation is performed on the coefficients obtained in order to reduce the size of the feature vector. From the results obtained we can conclude that the curvelet transform along with standard deviation for dimensionality reduction can be used effectively for OCR and all the coefficients

obtained need not be used in the construction of the feature vector.

REFERENCES

[1] P. Nagabhushan, S. A. Angadi, and B. S. Anami, "A fuzzy statistical approach to kannada vowel recognition based on invariant moments," in *Proc. NCDAR, PESCE, Mandya*, 2003, pp. 275-285.

[2] B. B. Chaudhuri and U. Pal, "A complete printed bangla OCR system," *Pattern Recognition*, vol. 31, pp. 531–549, 1998.

[3] U. Pal and B. B. Chaudhuri, "Indian script character recognition: A survey," *Pattern Recognition*, vol. 37, pp. 1887-1899, 2004.

[4] M. A. Rahiman and M. S. Rajasree, "A detailed study and analysis of OCR research in south indian scripts," in *Proc. International Conference on Advances in Recent Technologies in Communication and Computing*, 2009, pp. 31-38.

[5] T. V. Ashwin and P. S. Sastry, "A fonts and size-independent OCR system for printed Kannada documents using support vector machines," *Sadhana*, vol. 27, pp. 35-58, 2002.

[6] P. Nagbhushan and M. P. Radhika, "Modified region decomposition method and optimal depth decomposition tree in the recognition of non–uniform sized characters—An experimentation with Kannada characters," *Pattern Recognition Letter*, vol. 20, pp. 1467-1475, 1999.

[7] R. K. Sanjeev and S. Samuel, "Hu's invariant moments & Zernike moments approach for the recognition of basic symbols in printed Kannada text," *Sadhana*, vol. 32, no. 5, pp. 521-533, October 2007.

[8] R. S. Kunte and R. D. S. Samuel, "An OCR system for printed Kannada text using two-stage multi-network classification approach employing wavelet features," in *Proc. International Conference on Computational Intelligence and Multimedia Applications*, 2007, pp. 349-355.

[9] O. D. Trier, A. K. Jain, and T. Taxt, "Feature extraction methods for character recognition—A survey," *Pattern Recognition*, vol. 29, pp. 641–662, 1996.

[10] E. J. Cand`es and D. L. Donoho, "Curvelets–A Surprisingly Effective Nonadaptive Representation for Objects with Edges," in *Curves and Surfaces*, C. Rabut, A. Cohen, and L. L. Schumaker, Ed, Vanderbilt University Press, Nashville, TN, 2000, pp. 105–120.

[11] A. V. N. Murthy, "Kannada lipiya ugama mattu vikasa," *Institute of Kuvempu Kannada Studies Publication*, University of Mysore, 1975.

[12] I. J. Sumana, "Image retrieval using discrete curvelet transform," Master Thesis. Gippsland School of Information Technology, Monash University, Australia, 2008.

[13] J. L. Starck, E. J. Cand`es, and D. L. Donoho, "The curvelet transform for image denoising," *IEEE Trans. Im. Proc.*, vol. 11, no. 6, pp. 670-684, 2002.

[14] H. Douma and M. V. de Hoop, "Wave-character preserving prestack map migration using curvelets". presented at the Society of Exploration Geophysicists, Denver, CO, 2004.

[15] E. Cand`es, L. Demanet, D. Donoho, and L. Ying, "Fast discrete curvelet transforms," *Technical report*, July 2005.

[16] F. M. Kazemi, J. Izadian, R. Moravejian, and E. M. Kazemi, "Numeral recognition using curvelet transform," in *Proc. ACS International Conference on Computer Systems and Application*, 2008, pp. 606-612.

[17] E. J. Candes and D. L. Donoho, "Ridgelets: the key to higher-dimensional intermittency," *Phil.Trans. R. Soc. Lond. A*, vol. 357, pp. 2495–2509, 1999.

[18] M. J. Fadili and J. L. Starck, "Curvelets and ridgelets", *Encyclopedia of Complexity and System Science*, 2007.

[19] S. Theodoridis and K. Koutroumbas, *Pattern Recognition*, Academic Press, New York, 1999.

[20] The Wikipedia website. [Online]. Available: http://www.wikipedia.org/

[21] M. Hangarge, S. Patil, and B. V. Dhandra, "Multi-font/size kannada vowels and numerals recognition based on modified invariant moments," *IJCA Special Issue on Recent Trends in Image Processing and Pattern Recognition*, pp. 126-130, 2010.

[22] U. D. Acharya, N. V. S. Reddy, and Krishnamoorthi, "Hierarchical recognition system for machine printed Kannada characters," *International Journal of Computer Science and Network Security*, vol. 8, no. 11, pp. 44-53, November 2008.

[23] B. V. Dhandra, M. Hangarge, and G. Mukarambi, "Spatial features for multi-font/multi-size Kannada numerals and vowels recognition," in *Proc. International Conference on Communication, Computation, Control and Nanotechnology*, 2010.

[24] K. Sheshadri, P. K. T Ambekar, D. P. Prasad, and Dr. R. P Kumar, "An OCR System for printed Kannada using K-means clustering," in *Proc. IEEE International Conference on Industrial Technology*, 2010, pp. 183-187.

[25] U. D. Acharya, N. V. S. Reddy, and Krishnamurthy, "Isolated handwritten Kannada numeral recognition using structural feature and K-means cluster," in *Proc. IISN-2007*, 2007, pp. 125 – 129.

Mamatha H R received her B E degree in Computer Science and Engineering from the Kuvempu University in 1998 and the M.Tech degree in Computer Networks and Engineering from the Visvesvaraya Technological University in 2006.Since 2008 she has been a Ph.D. student at the Visvesvaraya Technological University. She has 15 years of teaching experience. Currently she is working as an Assistant Professor in the Department of Information Science and Engineering, P E S Institute of Technology. Her current research interests include pattern recognition and image processing. She has published 15 papers in various Journals and Conferences of International repute. She is a life member of Indian Society for Technical Education. She has mentored students for various competitions at international level.

Dr. Srikanta Murthy K received B.E (Electrical & Electronics Engineering). degree in 1986, M.Tech (Power Systems) in 1996 from National Institute of Engineering, University of Mysore and Ph.D. degree in Computer Science from University of Mysore in 2006. He joined the faculty of Electrical Engineering in NIE in 1987 and worked for K V G College of Engineering at various positions from 1991-2004. Presently he is working as Professor and Head, Department of CS&E, P E S School of Engineering, Bangalore, India. He has served as Chairman Board of Examiners in computer science in Mangalore University and also the member of local inspection committee, Mangalore University and Visvesvaraya Technological University. Currently he is guiding 5 candidates towards the doctoral degree and also guided many projects at PG level. His current research interests are computer vision, image processing and pattern recognition. He has published 60+ papers in various Journals and Conferences of International repute. He is a life member of Indian Society for Technical Education, Indian Society of Remote Sensing, Computer Society of India, Society of Statistics and Computer Applications and associate member of Institute of Engineers.

Sucharitha S received her B.E degree in Computer Science and Engineering from Visvesvaraya Technological University in 2012. She is currently pursuing her Master of Science in Computer Science at Indiana University, Bloomington. Her current research interests are pattern recognition and image processing.