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An Approach for Telugu Numeral Recognition by Moment Invariants in Wavelet Transform Domain

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ABSTRACT: Optical Character Recognition (OCR) is the task of recognizing the characters which are present in a digital image of text, whose domain can be machine print or handwriting. OCR is one of the most fascinating and challenging areas of pattern recognition with various practical application potentials. The present paper proposes a method for recognizing the Telugu Numerals from zero to nine by using the Moment Invariants. For this, the proposed method uses boundary based shape representation scheme. The input Telugu numeral is decomposed in to one level Haar wavelet transformed sub bands and the Boundary Moment Invariants are measured for each of these four sub bands. The experimental results show the superiority of the proposed method to recognize the Telugu numerals.

Keywords: Boundary, Shape, Wavelet Transform, Feature Vector and Object Recognition.

I. INTRODUCTION

In recent years, the glory of Document Image Analysis and Optical Character Recognition (OCR) has strongly increased since a paper document is still the most dominant medium for exchanging information. The computer is the most appropriate device for processing this information. Most of the works related to OCR are done in English, Chinese, Japanese and Arabic. However, some preliminary work has also been done on Indian scripts. A comprehensive review of the state of the art in the automatic processing of handwriting is reported in [12]. This paper reports many recent advances and changes that have occurred in this field. Various psychophysical aspects of the generation and perception of handwriting are presented to highlight the different sources of variability that make handwriting processing difficult. Major successes and promising applications of both online and offline approaches are indicated. State of the art Analysis and recognition of Asian scripts was reported in [14]. The paper summarizes the research activities of the past decades on the recognition of handwritten scripts used in China, Japan and Korea. It presents the recognition methodologies, features explored, databases used and classification schemes. In addition, it includes a description of the performance of numerous recognition systems found in both academic and industrial research laboratories. A handwritten character magically survives serious distortions in size, orientation and even structure. The general problem of defining the shape of a 2D line diagram, with character as a significant special case is addressed in [2]. The paper argues that the global shape of a character is determined by a set of local shapes. The local shapes, which are few in number, combine variously to give rise to a great diversity of characters. An unconstrained handwritten character recognition based on fuzzy logic is described in [5]. The approach uses the box method for feature extraction. Two recognition strategies are implemented for comparison. The recognition based on fuzzy logic outweighs that using back propagation neural network (BPNN). A hybrid classification system with neural network and decision tree as the classifiers for handwritten numeral recognition is reported in [11]. First, a variety of stable and reliable global features are defined and extracted based on the character geometric structures. A novel floating detector is then proposed to detect segments along the left and right profile of a character image used as local features. Finally, the recognition system consists of a hierarchical coarse classification and fine classification. A distance feature for neural network-based recognition of handwritten characters is described in [10]. Two new features, which are based on distance information, one on distance transformation and another on directional distance distribution, are described. Experimentation has been done on three standard distinct sets of characters (i.e., numerals, English capital letters, and

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Hangul initial sounds). Multiresolution recognition of unconstrained handwritten numerals using wavelet transform and a simple multilayer cluster neural network is reported in [7]. The scheme consists of two stages: a feature extraction stage for extracting multi resolution features with wavelet transform, and a classification stage for classifying unconstrained handwritten numerals with a single multilayer cluster neural network. Work on multi wavelets and neural networks can also be seen in [3]. A MLP Classifier for both printed and handwritten Bangla numeral recognition is proposed in [8]. Pixel-based and shape-based features are chosen for the purpose of recognition. Multi-layer neural network architecture was chosen as classifiers of the mixed class of handwritten and printed numerals. An offline hand printed Bangla numeral recognition scheme using a multistage classifier system comprising of multilayer Perceptron (MLP) neural network is described in [1]. The scheme considers multiresolution features based on wavelet transforms. The recognition scheme is robust to various writing styles and size. Method based on multiresolution analysis for Telugu character recognition can also be seen in [13]. Online handwritten character recognition of Devnagari and Telugu characters using Support Vector Machines is reported in [15]. The input to the recognition system consists of features of the strokes in each written character. The present paper has proposed a method to recognize ten Telugu numerals by using boundary moment invariant descriptors. The proposed method is using Wavelet transform domain for evaluating the feature vector. The organization of the present paper follows as section II gives the methodology, section III gives the results and discussions and section IV gives the conclusions.

II. METHODOLOGY

The character recognition is an important task in the OCR system. The present paper proposes a method to recognize the Telugu numerals from zero to nine. The input object can be represented by using either boundary or region based representations. The present paper uses the boundary based representation approach. On the represented shape of the boundary, the features can be described. The feature description is performed by using the boundary moment invariants (BMI). The size of the feature vector is 7. The BMI1 to BMI7 are given by the Equations (1)-(7).

$$BMI_1 = \eta_{20} + \eta_{02} \tag{1}$$

$$BMI_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2 \tag{2}$$

$$BMI_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2 \tag{3}$$

$$BMI_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2 \tag{4}$$

$$BMI_5 = \begin{pmatrix} (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] \\ + 3(\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \end{pmatrix} \tag{5}$$

$$BMI_6 = (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{11})^2 - (\eta_{21} + \eta_{03})^2] + 4\eta_{11}(\eta_{30} + \eta_{11})(\eta_{21} + \eta_{03}) \tag{6}$$

$$BMI_7 = \begin{pmatrix} (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] \\ + (3\eta_{12} - \eta_{30})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \end{pmatrix} \tag{7}$$

where the normalized central moment of order (p+q) is given by the Equation (8)

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{\frac{p+q+2}{2}}} \tag{8}$$

The central moment of order (p+q) is given by the Equation (9)-(11)

$$\mu_{pq} = \int_{x,y \in c} \int (x - \bar{x})^p (y - \bar{y})^q f(x,y) dxdy \tag{9}$$

$$\bar{x} = \frac{m_{10}}{m_{00}} = \frac{\int\int_{x,y \in c} x f(x,y) dxdy}{\int\int_{x,y \in c} f(x,y) dxdy} \tag{10}$$

$$\bar{y} = \frac{m_{01}}{m_{00}} = \frac{\int\int_{x,y \in c} y f(x,y) dxdy}{\int\int_{x,y \in c} f(x,y) dxdy} \tag{11}$$

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The present paper computes the BMI features in transform domain. The transform domain is achieved by using the Wavelet. A wavelet is a kind of mathematical function used to divide a given function or continuous-time signal into components of different frequency and to study each component with a resolution that matches its scale. A wavelet transform is the representation of a function by wavelets. In the wavelet transform [4, 6, 9] an image signal can be analyzed by passing it through an analysis filter bank followed by a decimation operation. This analysis filter bank consists of a low pass and a high pass filter at each decomposition stage. When the signal passes through these filters it splits into two bands. The low pass filter, which corresponds to an averaging operation, extracts the coarse information of a signal. The high pass filter, which corresponds to a differencing operation, extracts the detail information of the signal. The output of the filtering operations is then decimated by two. A two-dimensional transform can be accomplished by performing two separate one-dimensional transforms. Firstly, the image is filtered along the *x*-dimension using low pass and high pass analysis filters and decimated by two. Low pass filtered coefficients are stored on the left part of the matrix and high pass filtered coefficients are stored in the right part of the matrix. Because of decimation the total size of the transformed image is same as the original image. Then, it is followed by filtering the subimage along the *y*-dimension and decimated by two. Finally, the image splits into four bands denoted by low-low (LL), high-low (HL), low-high (LH) and high-high (HH) after one-level decomposition. Fig. 1 shows one level of filtering. This process of filtering the image is called 'Pyramidal decomposition' of image.

Fig. 1 One Level Wavelet Decomposition of Telugu Numeral six.

III. RESULTS AND DISCUSSIONS

The present paper proposes a method for recognizing the Telugu numerals from zero to nine by using boundary moment invariant (BMI) descriptors. The original images are shown in Fig. 2.

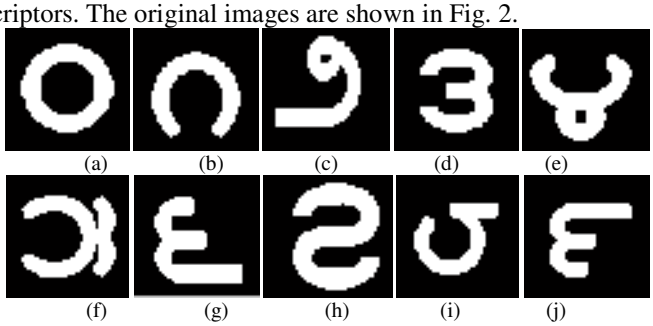

Fig. 2 Original Telugu Numeral Images (a) Zero (b) One (c) Two (d) Three (e) Four (f) Five (g) Six (h) Seven (i) Eight (j) Nine.

The present paper has used boundary based shape representation scheme. By using the Haar Wavelet transform, the original image is decomposed into four sub bands LL, Hl, LH and HH and within each sub band, seven BMI features are calculated and the results are given in Tables I-X. The average value for all these four sub bands is calculated for each numeral. The Table XI gives the average wavelet boundary descriptor for each numeral. The results are plotted on to a graph as shown in Fig. 3 and from this graph, clearly it is visible that each Telugu numeral has its own unique descriptor value i.e. the average value from Table XI. From the Graph shown in Fig. 3, it is clear that the Telugu

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Numeral 0 is having the highest BMI value and Numeral 6 is having the lowest BMI value. The Numeral 1 and 8 BMI values are in high range. The Numeral 7 BMI value is in the low range and the remaining numerals BMI value is in the middle range.

TABLE I
ONE LEVEL WAVELET DECOMPOSED SUB BANDS OF TELUGU NUMERAL ZERO IMAGE BMI DESCRIPTORS

	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
LL	0.9063	4.5106	2.857	2.2503	0.78763	0.32503	0.7314
HL	0.9063	4.5106	2.857	2.2503	0.78763	0.32503	0.7314
LH	0.91247	4.6743	2.2262	2.3523	1.0566	0.11015	0.2591
HH	0.93351	5.3926	2.3322	2.8024	1.2016	0.19193	0.53785
Avg.	0.91465	4.77203	2.5681	2.41383	0.95837	0.23804	0.56494

TABLE II
ONE LEVEL WAVELET DECOMPOSED SUB BANDS OF TELUGU NUMERAL ONE IMAGE BMI DESCRIPTORS

	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
LL	0.83990	5.68160	1.64180	1.49360	0.90977	0.43221	0.54556
HL	0.83990	5.68160	1.64180	1.49360	0.90977	0.43221	0.54556
LH	0.84735	6.08180	1.92320	1.79600	0.93387	0.27390	0.59192
HH	0.84975	6.22920	1.03890	1.02910	0.99058	0.92137	0.54821
Avg.	0.84423	5.91855	1.56143	1.45308	0.93600	0.51492	0.55781

TABLE III
ONE LEVEL WAVELET DECOMPOSED SUB BANDS OF TELUGU NUMERAL TWO IMAGE BMI DESCRIPTORS

	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
LL	0.74108	2.59310	3.43060	2.52190	0.73513	0.25079	0.63247
HL	0.78133	2.85420	1.03360	1.04580	1.01180	0.85478	0.89396
LH	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HH	0.91643	4.78860	2.70910	2.89710	1.06940	0.28595	0.82842
Avg.	0.85971	2.55898	1.79333	1.61620	0.70408	0.34788	0.58871

TABLE IV
AVERAGE BMI DESCRIPTORS OF FOUR SUB BANDS FOR TEN TELUGU NUMERALS

	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
LL	0.95248	6.41000	1.97270	1.80710	0.91606	0.27839	0.50307
HL	0.81130	3.09820	1.52730	1.41220	0.92464	0.46395	0.65522
LH	0.30534	1.37080	1.96490	1.69460	0.86245	0.27112	0.45946
HH	0.32131	1.39530	2.07640	2.33710	1.12560	0.23537	0.55008
Avg.	0.59761	3.06858	1.88533	1.81275	0.95719	0.31221	0.54196

TABLE V
ONE LEVEL WAVELET DECOMPOSED SUB BANDS OF TELUGU NUMERAL FOUR IMAGE BMI DESCRIPTORS

	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
LL	0.74832	2.63570	3.21450	2.86470	0.89117	0.04873	0.13958
HL	0.74832	2.63570	3.21450	2.86470	0.89117	0.04873	0.13958
LH	0.71849	2.47070	2.97190	2.35080	0.79104	0.25349	0.59592
HH	0.78645	2.89230	2.62710	2.31730	0.88207	0.15405	0.35698
Avg.	0.75040	2.65860	3.00700	2.59938	0.86386	0.12625	0.30802

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TABLE VI
ONE LEVEL WAVELET DECOMPOSED SUB BANDS OF TELUGU NUMERAL FIVE IMAGE BMI DESCRIPTORS

	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
LL	0.95042	6.27230	1.14480	1.10780	0.96761	0.79097	0.87620
HL	0.19469	1.21800	1.75180	1.58850	0.90679	0.24869	0.39505
LH	0.94916	6.19170	1.18250	1.13500	0.95977	0.78436	0.89023
HH	0.18639	1.20760	1.53500	1.39400	0.90809	0.25179	0.35098
Avg.	0.57017	3.72240	1.40353	1.30633	0.93557	0.51895	0.62812

TABLE VII
ONE LEVEL WAVELET DECOMPOSED SUB BANDS OF TELUGU NUMERAL SIX IMAGE BMI DESCRIPTORS

	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
LL	0.77007	2.77460	1.81500	1.68090	0.92612	0.26649	0.44794
HL	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
LH	0.27580	1.32730	2.77400	3.82250	1.37800	0.14025	0.53610
HH	0.40219	1.53150	1.36830	1.26570	0.92502	0.05879	0.07441
Avg.	0.36202	1.40835	1.48933	1.69228	0.80729	0.11638	0.26461

TABLE VIII
ONE LEVEL WAVELET DECOMPOSED SUB BANDS OF TELUGU NUMERAL SEVEN IMAGE BMI DESCRIPTORS

	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
LL	0.16004	1.17520	1.07960	1.05950	0.98139	0.19899	0.21083
HL	0.28682	1.34330	1.43980	1.53910	1.06890	0.26048	0.40089
LH	0.58350	1.94980	1.75860	3.24430	1.84480	0.26789	0.86913
HH	0.08142	1.08500	1.70170	1.51270	0.88897	0.16535	0.25013
Avg.	0.27794	1.38833	1.49493	1.83890	1.19602	0.22318	0.43275

TABLE IX
ONE LEVEL WAVELET DECOMPOSED SUB BANDS OF TELUGU NUMERAL EIGHT IMAGE BMI DESCRIPTORS

	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
LL	0.85816	3.61940	1.13860	1.10240	0.96821	0.80065	0.88263
HL	0.17122	1.18880	3.91730	2.78450	0.71083	0.09304	0.25906
LH	0.83739	3.36150	2.43680	3.99050	1.63760	0.21479	0.85714
HH	0.88602	4.06770	1.96870	1.77460	0.90140	0.24337	0.43188
Avg.	0.68820	3.05935	2.36535	2.41300	1.05451	0.33796	0.60768

TABLE X
ONE LEVEL WAVELET DECOMPOSED SUB BANDS OF TELUGU NUMERAL NINE IMAGE BMI DESCRIPTORS

	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
LL	0.82839	3.26410	1.47080	1.34920	0.91733	0.44995	0.60705
HL	0.97206	8.40190	1.88530	1.70170	0.90262	0.33406	0.56846
LH	0.35789	1.45420	2.16520	2.36550	1.09250	0.23637	0.55912
HH	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Avg.	0.53959	3.28005	1.38033	1.35410	0.72811	0.25510	0.43366

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TABLE XI
ONE LEVEL WAVELET DECOMPOSED SUB BANDS OF TELUGU NUMERAL NINE IMAGE BMI DESCRIPTORS

Telugu Numeral	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7	Avg.
0	0.91465	4.77203	2.56810	2.41383	0.95837	0.23804	0.56494	1.77571
1	0.84423	5.91855	1.56143	1.45308	0.93600	0.51492	0.55781	1.68372
2	0.85971	2.55898	1.79333	1.61620	0.70408	0.34788	0.58871	1.20984
3	0.59761	3.06858	1.88533	1.81275	0.95719	0.31221	0.54196	1.31080
4	0.75040	2.65860	3.00700	2.59938	0.86386	0.12625	0.30802	1.47336
5	0.57017	3.72240	1.40353	1.30633	0.93557	0.51895	0.62812	1.29786
6	0.36202	1.40835	1.48933	1.69228	0.80729	0.11638	0.26461	0.87718
7	0.27794	1.38833	1.49493	1.83890	1.19602	0.22318	0.43275	0.97886
8	0.68820	3.05935	2.36535	2.41300	1.05451	0.33796	0.60768	1.50372
9	0.53959	3.28005	1.38033	1.35410	0.72811	0.25510	0.43366	1.13870

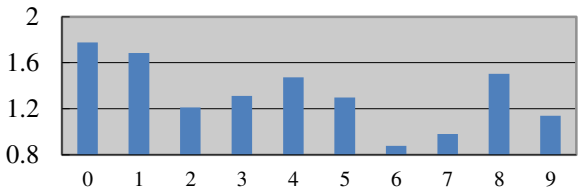

Fig. 3 Graph of Average BMI descriptors for Ten Telugu Numerals.

IV. CONCLUSION

The character recognition plays a vital role in the document image analysis. The present paper proposes an approach to recognize ten Telugu numerals from zero to nine. The proposed method computes seven moment invariant features on the boundary shape representation. The computation of features is further extended to four decomposed sub bands obtained by the Haar Wavelet transform. The average of all these values will yield a unique feature for each of the ten Telugu numerals. From the results, we can conclude that the Telugu numerals which are having the maximum shape as the full/semi circle, those possess the highest feature value where as the numerals which are not having the circle shapes are possess the lowest feature value where the remaining numerals which are having less amount of circle shapes possess the medium feature values. With this approach, the present paper proposed a method for recognizing ten Telugu numerals.

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