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Offline MODI Character Recognition Using Complex Moments

Kulkarni Sadanand A.[a]*, Borde Prashant L.[b], Manza Ramesh R.[c], Yannawar Pravin L.[d]

[a,b,d] *Vison and Intelligent Ssystem Lab, Department of CS & IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad,(MS) India*
[c] *Bio-Medical Image Processing Lab, Department of CS & IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad,(MS) India*

Abstract

The varying writing style and critical representation of characters in Indian script makes Handwritten Optical Character (HOCR) challenging and has attracted researchers to contribute in this domain. 'MODI' Script had cursive type of writings in Devanagari, Marathi where large amount of historical documents were available and need to be digitally explored. The principal objective of this research work is to describe efficiency of Zernike Complex moments and Zernike moments with different Zoning patterns for offline recognition of handwritten 'MODI' characters. Every character was divided in six zoning patterns with 37 zones. Geometrical shapes were used to create zoning patterns. The work was resulted in 94.92% correct recognition rate was achieved by using Zernike moments and 94.78% by using Zernike complex moments with integrated approach for heterogeneous zones.

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Keywords: MODI Script; Zoning; Zernike Moments; Zernike Complex Moments.

1. Introduction

India speaks 780 languages out of which 220 languages was desuetude in last 50 years and another 150 could vanish [1]. 'MODI' was an ancient script of India and was used for writing 'Devanagari' or 'Marathi' in cursive. In review on recent advances in automatic handwritten 'MODI' script recognition[2] it was marked, that the origin of this script was still ambiguous and 'MODI' alphabets were invented by 'Hemadpant' or 'Hemadri' in 12th Century it was also stated in various alterations occurred in writing styles of 'MODI' script. Total time span where 'MODI' Script

* Kulkarni Sadanand A. Tel.: +91- 9422707468;
E-mail address:sankalpsadanand.georai@gmail.com.

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was utilized for written communication at different stages was about 600 years. Meanwhile 'MODI' became very popular and frequently used for writing purpose till the official adoption of Devanagari script in 19th century[2,3,4,5,6].

The work was organized in six sections, section 2 presents significance of 'MODI' Script, section 3 deals with character set used in 'MODI' Script, section 4 provides scheme for automated feature extraction process, section 5 presents the obtained experimental results and section 6 summarizes with concluding remarks.

2. Significance to MODI script

According to reported work[2,3,4,5] plenty of 'MODI' documents were stored in Tanjawar's Saraswati Mahal, Oriental manuscript section of Chennai's Connemara University, Bharat Itihas Sanshodhan Mandal, Pune (BISM), Rajwade Sanshodhan Mandal, Dhule (MS, India) and historical museums. Many precious records were observed to be degraded due to improper facilities. The places like historical palaces, temples, private libraries contents are available in poor condition. Vagdevata Mandir, Dhule (MS, India) has a treasure house of many historical documents[7] and literatures of 300 Indian saints[8]. There was almost 43,837 manuscripts which holds 550 years historical record written in different languages[8,9]. Tanjawar's Saraswati Mahal library contains another 1342 bundles (Collection of at least 1200 to 1500 papers is known as bundle) of historical 'MODI' documents and tried to be preserved with help of oil[10]. Pune (MS, India), Capital of the Peshwas emperor was a largest storage of 'MODI' documents and contains about four million 'MODI' documents. BISM, Pune archives contains another 15 million documents written in 'MODI' script[11]. State Archive Department, Pune division has colleted rare manuscripts which was wrapped in 39,000 clothbundles[12]. Tamil University has taken steps towards digitization, translation, and publishing 'MODI' documents. Government of India funds for this cataloguing of the records. All these documents were converted into an image or in portable document format (PDF)[13]. This was not a robust solution for the problem, HOCR has to be developed for the recognition of 'MODI' handwritten characters. Very strong efforts are going on in the development of HOCR for Indian languages especially for 'Devanagari' script, where as very less efforts has been done on 'MODI' script[2,3,4,5].

3. Character set of MODI script

'MODI' script was written by using 'Boru', 'lekhan', a pen, created from 'Bambuu', need to lift too often for dipping in the ink[2,3,4,5]. The 'MODI' script includes 46 distinctive letters, of which 36 are consonants and 10 vowels. Before the commencement of writing in 'MODI', horizontal line was drawn across the page. Characters has been written with respect to this horizontal line. No punctuation marks or particular stroke for termination of sentence used in this script [2,4]. The basic characters of 'MODI' are shown in Fig. 1.

Fig. 1. The basic characters of 'MODI'.

Pattern recognition of 'MODI' Character is quite challenging due to inconsistency in the writing style, similarity in the character shapes, presence of modifiers, conjunctions and various other features of 'MODI' scripts[2,3,4,5]. In this work 100 samples of each 46 basic 'MODI' characters has considered to form 4600 character set. Each image further divided in 37 zones to form data set of size 170200 images. Data set was further divided in train and test set with the ratio of 30:70. Train feature set was constructed using average character feature to represents a single character.

4. Theory of feature extraction

Moment based features are a traditional and widely used tool for feature extraction. In this work feature were extracted by Zernike and Zernike Complex moments with zoning for 'MODI' characters. *Jyotsnarani Tripathy*[14] has used orthogonal moments for reconstruction of Oriya Alphabets. Zernike moments are introduced by *Fruits Zernike*

in 1934 based on the theory of Orthogonal Polynomials[15]. Schematic representation of steps involved in recognition system is shown in Fig 2.

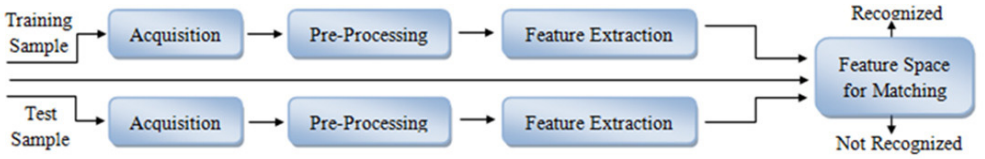

Fig 2: Overview of recognition system

4.1. Data acquisition and preprocessing

In this first step character image has acquired using digital scanner to formulate set of training samples and testing samples. All samples has been written by blue ink. Each character from the data set then pre-processed with foreground and background separation, Morphological operation 'opening' and 'closing' and 'Top Hat' transformation to obtain good discriminating features.

4.2. Zone Creation

Different 37 zones has been extracted with the help of various six geometrical shapes. Circular zones have created by varying the size of radius from 10,13,16,19,22 and 25 as shown in Fig 3a. Square zones in two steps, firstly dividing the character in 4 zones of size 30*30 pixels and an overlapping square zone with size 31*31 pixels as shown in Fig 3b and secondly, the character has divided in 9 zones with four squares of size 15*15 pixels, four rectangles of size 30*15 pixels and one square of size 30*30 pixels as shown in Fig 3c. Rectangular zones have extracted by choosing a rectangular segment of the size 30*60 pixels as shown in Fig 3d. Irregular Hexagonal zones have formed by choosing a hexagonal segment as shown in Fig 3e. Right angle triangular zones have shown in Fig 3f. Isosceles triangular zones have extracted by using two approaches. Only half part has considered in first case as shown in Fig 3g and whole character has considered in second case as shown in Fig 3h. Rhombus zone has formed by choosing a rhombus segment as shown in Fig 3i.

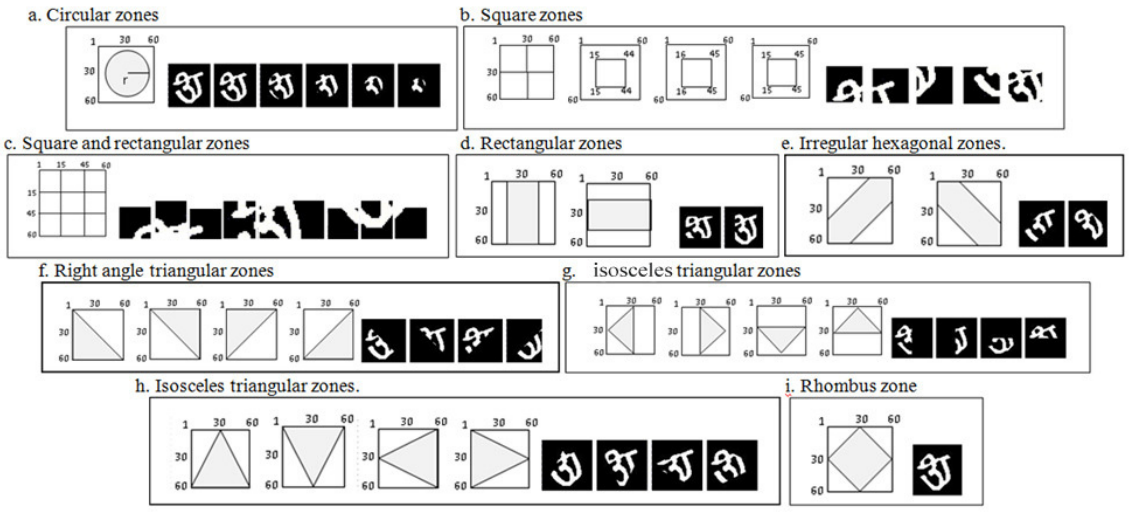

Fig 3a: Circular zones with radius 10, 13, 16, 19, 22 and 25, b. Five square zones, c. Square and rectangular zones total nine zones, d. Two rectangular zones, e. Two Irregular hexagonal zones, f. Four right angle triangular zones of size 1800 pixels, g. Four isosceles triangular zones of size 900 pixels, h. Four isosceles triangular zones, i. One rhombus zone.

4.3. Zone Selection

Using various six geometrical structures different 37 zones has been created. Further, these 37 zones have been further submitted to feature extraction process. Experimental result shows importance of these zones and zoning pattern. Every zone shows exact available amount of data and its importance for recognizing it. More variations has been observed at center part of the character in 'MODI' Script.

Circular zone includes center part of the character in increasing manner. Circular zone with radius 25 occupies maximum possible area which gives 71.81% confidence in recognition rate (CRR) using Zernike moments and 89.63% CRR using Zernike complex moments as compare to other zoning patterns. Square zones was extracted by considering four corners and center part. Inclusion of center part increased CRR in square zones. In rectangular zones more concentration has been done on center part. Triangular and Irregular hexagonal zones partially considers center part of the character. This inclusion of center part shows affect on selection of zones and its importance for recognizing handwritten MODI character.

Experimental result shows considering only one zoning pattern was not sufficient for MODI script. 94.92% CRR has been achieved by using Zernike moments with four zones in three zoning patterns. In case of circular zone with radius 25 only 25% data was available for recognition as shown in Fig 3b, secondly an overlapping square zone occupy 26.69% data as shown in Fig 3b and finally two Isosceles triangular zones has been considered with 25% data for recognition as shown in Fig 3g. an example of zone selection according to zone representation of Fig 3 was shown in Fig 4a where each zone represents available amount of data for recognition.

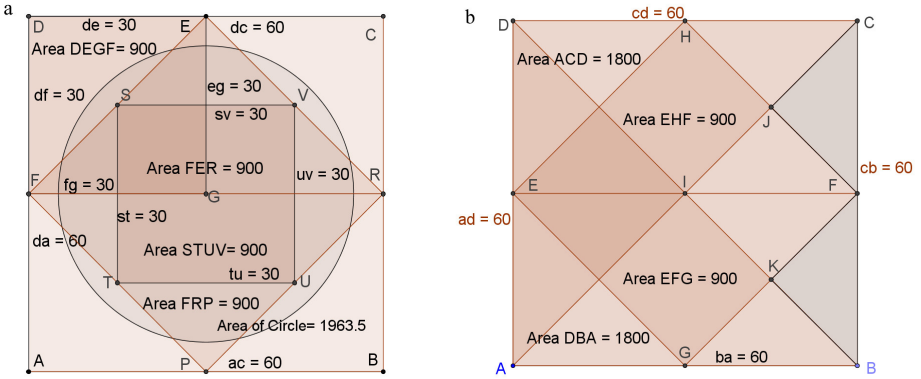

Fig 4:Area of character considered for character recognition, a. Circular zones with radius 25, one square zone and two Isosceles triangular zones, b. Two right angle triangular and two Isosceles triangular zones

Zernike complex moments achieved 94.78% CRR by using with two right angle triangular zones and two Isosceles triangular zones. In case of each right angle triangular zone 50% data was available for consideration as shown in Fig 3f whereas in case of each isosceles triangular zone 25% data was available for recognition as shown in Fig 3g. This work states importance of middle part of each character in handwritten character recognition with special attention to 'MODI' script. So giving importance to the centre part in character various zoning patterns has been selected and observed.

4.4. Zernike Moment

Complex polynomials was used to construct Zernike moments. Complete orthogonal set was formed on the unit disk with $\left(x^2+y^2\right)=1$ as shown in eq.1. Order of moment has defined by m and n and $I(x, y)$. Moment is calculated by using Gray level of the pixel. Zernike polynomials $V_{mn}(x, y)$ expected in polar coordinates as shown in eq.2. Orthogonal radial polynomial $R_{mn}(r)$ is shown in eq.3. Moments Z_{mn} are invariant under rotation and scale.

$$Z_{mn} = \frac{m+1}{\pi} \int\int I(x,y)[V_{mn}(x,y)]dxdy \tag{1}$$

$$V_{mn}(r,\theta) = R_{mn}(r)e^{-jn\theta} \tag{2}$$

$$R_{mn}(r) = \sum_{s=0}^{\frac{m-|n|}{2}} (-1)^s \frac{(m-s)!}{s!\left[\frac{m+|n|}{2}-s\right]!\left[\frac{m-|n|}{2}-s\right]!} r^{m-2s} \tag{3}$$

Zernike Moment represents pixel distribution by using centre of gravity in character, information of boundary points[14] and properties for overall image orientation. Noise present in the image doesn't make any impact on these feature[16]. Zernike moments has been used for recognizing handwritten characters in various scripts for example Tamil script[17], isolated Arabic characters[18], Devanagari compound characters[19] and Farsi characters[20]. In this work Zernike moments have derived up to 9th order.

4.5. Zernike Complex Moment

The Zernike polynomials have been proposed by Zernike[19] and Zernike Complex moments[21] have constructed using a set of complex polynomials. Zernike moment uses complex polynomials as the moment basis set[22]. Zernike Complex moments was implemented for face recognition[23], shape classification[24], printed Arabic character recognition[25], sign language[26], and for Urdu character recognition[27]. Barmak Honarvar[28] stated that image reconstruction has been done by using complex moments (CMs) with perfection and Barmak Honarvar[29] has stated a method to avoid dependencies of Zernike radial polynomials on degree (n) and the azimuthal order (m). This work has used Zernike Complex polynomial for 10th order with two repetitions. Zernike moments, Z_{nm}, of order n with repetition m, are defined in polar coordinates (r, θ) inside the unit circle as shown in eq.4. $R_{nm}(r)$ is the nth order of radial polynomial given in eq.5. The image then reconstructed by using a set of moments through order M as shown in eq.6.

$$Z_{nm} = \frac{n+1}{\pi} \int_0^1 \int_0^{2\pi} R_{nm}(r)e^{-jm\theta} f(r,\theta) r dr d\theta, \; o \le |m| \le n, \; n-|m| \text{ is even} \tag{4}$$

$$R_{nm}(r) = \sum_{k=0}^{(n-|m|)/2} (-1)^k \frac{(n-k)!}{k![(n-2k+|m|)/2]![(n-2k-|m|)/2]} r^{n-2k} \tag{5}$$

$$f(r,\theta) \approx \sum_{n=0}^{M} \sum_{m} Z_{nm} R_{nm}(r) e^{jm\theta} \tag{6}$$

5. Experiment and Result

The recognition of sample has done by features derived from Zernike and Zernike Complex moments. 'Euclidean' distance classifier has used for classification. The 'Euclidean' distance provides information between each pair (one vector from test set and other vector from training set) of observations. Total 4600 samples has been considered for this work. Each image then divided in 37 zones. Further each zone has been considered as distinct image to form test sample set with 51060 zoning images and train sample set with 119140 zoning images.

Performance of Features used to calculate confidence in recognition rate (CRR) as distinct vector for all zones has shown in table 1, 2, 3 and 4. Image was represented in the form of moment vector and used with two approaches for recognition purpose that is in first case of distinct approach selected zones vectors has used separately and each zone treated as a single image. In second case of integrated approach for selected zones moment vectors are integrated and treated a single vector. Homogeneous zoning patterns used only those zones that belongs to same geometrical pattern. Heterogeneous zoning pattern does not consider geographical pattern for zone selection.

Table 1 Performance of Features for each zone.

Sr. No.	Zone and Figure	Zernike moments			Zernike Complex			Sr. No.	Zone and Figure	Zernike moments			Zernike Complex		
		Hit	Miss	CRR	Hit	Miss	CRR			Hit	Miss	CRR	Hit	Miss	CRR
1	Entire Image	1060	320	76.81	1243	137	90.07	20	8th Square of 3c	155	1225	11.23	209	1171	15.14
2	Circle of r=10 of 3a	401	979	29.05	681	699	49.34	21	9th Square of 3c	559	821	40.50	628	752	45.50
3	Circle of r=13 of 3a	571	809	41.37	884	496	64.05	**22**	**Rectangle of.3d**	**338**	**1042**	**24.49**	**390**	**990**	**28.26**
4	Circle of r=16 of 3a	738	642	53.47	1062	318	76.95	23	Rectangle of.3d	966	414	70.00	1204	176	87.24
5	Circle of r=19 of 3a	840	540	60.86	1152	228	83.47	**24**	**Irre. Hexa. of 3e**	**922**	**458**	**66.81**	**1168**	**212**	**84.63**
6	Circle of r=22 of 3a	958	422	69.42	1211	169	87.75	25	Irregular Hexa.of.3e	925	455	67.02	1186	194	85.94
7	**Circle r=25 of 3a**	**991**	**389**	**71.81**	**1237**	**143**	**89.63**	26	Right angle Δ of.3f	875	505	63.40	1127	253	81.66
8	1st square of 3b	847	533	61.37	878	502	63.62	27	Right angle Δ of.3f	850	530	61.59	1116	264	80.86
9	2nd Square of 3b	747	633	54.13	836	544	60.57	28	Right angle Δ of.3f	805	575	58.33	1058	322	76.66
10	3rd Square of 3b	611	769	44.27	732	648	53.04	**29**	**Right angle Δ of.3f**	**928**	**452**	**67.24**	**1141**	**239**	**82.68**
11	4th Square of 3b	765	615	55.43	773	607	56.01	30	Isosceles Δ of 3g	769	611	55.72	1032	348	74.78
12	**5th Square of 3b**	**778**	**602**	**56.37**	**778**	**602**	**56.37**	31	Isosceles Δ of 3g	728	652	52.75	1000	380	72.46
13	1st Square of 3c	1047	333	75.86	1099	281	79.63	**32**	**Isosceles Δ of 3g**	**720**	**660**	**52.17**	**992**	**388**	**71.88**
14	2nd Square of 3c	249	1131	18.04	277	1103	20.07	33	Isosceles Δ of 3g	915	465	66.30	1157	223	83.84
15	3rd Square of 3c	729	651	52.82	756	624	54.78	34	Isosceles Δ of 3h	903	477	65.43	1115	265	80.79
16	4th Square of 3c	329	1051	23.84	375	1005	27.17	35	Isosceles Δ of 3h	957	423	69.34	1147	233	83.11
17	**5th Square of 3c**	**587**	**793**	**42.53**	**652**	**728**	**47.24**	**36**	**Isosceles Δ of 3h**	**883**	**497**	**63.98**	**1144**	**236**	**82.89**
18	6th Square of 3c	836	544	60.57	932	448	67.53	37	Isosceles Δ of 3h	982	398	71.15	1188	192	86.08
19	7th Square of 3c	447	933	32.39	507	873	36.73	**38**	**Rhombus of 3i**	**877**	**503**	**63.55**	**1164**	**216**	**84.34**

Performance and importance of each zone has been evaluated in table 1 and also illustrate important zones like Circular zone with r=25, overlapping 5th square zone of size 31×31, 5th square zone of size 31×31, rectangle zone, irregular hexagonal zone, right angle triangular zone, isosceles triangular zone, isosceles triangular zone, and a rhombus zone and also indicates for whole image CRR was increased from 76.81% to 90.07%.

Table 2 shows 88.33% performance for Zernike Complex moment has achieved in case of four right angle triangular zones and for Zernike moments 82.02% recognition rate has been achieved for five square zones when all zones were used as distinct vectors and also indicates that 92.39% CRR has achieved for four right angle triangular zones using complex moments and in case of Zernike moments 90.94% recognition rate has achieved for two cases using five square zones and using four isosceles triangular zones used with integrated approach.

Table 2 Performance of homogeneous zones used as distinct vector.

Sr. No.	Zone or Figure	Homogeneous zones used as distinct vector						Homogeneous zones used as integrated vector					
		Zernike moments			Zernike Complex Moments			Zernike moments			Zernike Complex Moments		
		Hit	Miss	CRR	Hit	Miss	CRR	Hit	Miss	CRR	Hit	Miss	CRR
1	Six zones of Fig 3a	930	450	67.39	1135	245	82.24	1075	305	77.89	1228	152	88.98
2	Five zones of Fig 3b	1132	248	82.02	1145	235	82.97	1255	125	90.94	1217	163	88.18
3	Nine zones of Fig 3c	936	444	67.82	1002	378	72.60	1246	134	90.28	1237	143	89.63
4	Two zones of Fig 3d	961	419	69.63	1187	193	86.01	1108	272	80.28	1239	141	89.78
5	Two zones of Fig 3e	900	480	65.21	1157	223	83.84	1103	277	79.92	1223	157	88.62
6	Four zones of Fig 3f	1084	296	78.55	1219	161	88.33	1211	169	87.75	1275	105	92.39
7	Four zones of Fig 3g	1068	312	77.39	1204	176	87.24	1255	125	90.94	1274	106	92.31
8	Four zones of Fig 3h	1044	336	75.65	1198	182	86.81	1149	231	83.26	1242	138	90.00

Table 3 Performance of heterogeneous zones used as integrated vector.

Sr No.	Zone or Figure	Zernike moments			Zernike Complex Moments		
		Hit	Miss	CRR	Hit	Miss	CRR
1	Table 1:7,12,17,22, 24,28,32,36,38	991	389	71.81	1264	116	91.59
2	Table 2: 4, 6 ,7, 8	1220	160	88.40	1267	113	91.81
3	Table 2: 3, 4 ,6, 7,8	1231	149	89.20	1267	113	91.81
4	Table 2: 6, 7,8	1233	147	89.34	1272	108	92.17
5	Table 2: 2, 7	1296	84	93.91	1277	103	92.53
6	Table 2: 6,7	1249	131	90.50	1284	96	93.04
7	Table 1: 26,28,32,33	1256	124	91.01	1308	72	94.78
8	Table 1: 8,12,32,33	1310	70	94.92	1285	95	93.11

Table 3 shows 94.92% CRR was achieved using Zernike moments and 94.78% CRR was achieved using Zernike complex moments for four zones with three zoning pattern by integrated approach.

Table 4 Performance of Features.

For all zones **as** distinct vector							For all zones **as i**ntegrated vector					
Zone or Figure	Zernike moments			Zernike Complex Moments			Zernike moments			Zernike Complex Moments		
	Hit	Miss	CRR	Hit	Miss	CRR	Hit	Miss	CRR	Hit	Miss	CRR
All 37 zones	1219	161	88.33	1249	131	90.50	1075	305	77.89	1270	110	92.02

Finally, table 4 shows that performance of Zernike Complex moment was increased from 88.33% to 90.50 % in distinct approach and for Zernike Complex moment has increased confidence in recognition rate (CRR) from 77.89% to 92.02% in integrated approach when all 37 zones have been used.

6. Conclusion

This piece of work mainly focuses on finding efficiency of Zernike complex moments over Zernike moments with new zoning patterns in handwritten character recognition. This work also states efficiency of various zoning patterns with respect recognition of handwritten 'MODI' character. Observations stated in experimental result clearly indicates use of Zernike Complex moments features increases CRR of the system with zoning. This may be applied for recognition of characters from other languages which represents cursive nature and complex representation of characters and for bilingual document analysis.

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