Arabic (Indian) Numeral Handwritten Recognition Using Angular Radial Transform

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Abstract

In this paper, an Arabic (Indian) numeral handwritten recognition method is presented based on angular radial transform. The angular radial transform is considered as a global features extraction descriptor in order to provide distinct and rotation invariant features about the images of Arabic numeral handwritten. Also, in this, paper the performance of both angular transform and radial transform is investigated and compared. Hellinger distance measure is adopted in the classification stage to compute the distance between the test and training Arabic numeral handwritten images. The extensive experiments indicate that the proposed approach achieved a high recognition rate of 96.74% which is better of recognition rates achieved using its counterpart's angular and radial transforms which achieved 91.34% and 87.10% respectively. Also, they indicated that the performance of angular transforms is outperforms the performance of radial transform. Furthermore, observed that the proposed method is rotation invariant.

Keywords: Numeral handwritten recognition, Angular radial transform, Global features, Rotation invariant features, Hellinger distance measure.

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تمييز الارقام العربية (الهندية) المكتوبة باليد بأستخدام تحويل نصف القطر الزاوي

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الخلاصة

في هذا البحث تم عرض طريقة لتمييز الارقام العربية (الهندية) المكتوبة باليد اعتمادا على تحويل نصف القطر الزاوي. ان تحويل نصف القطر الزاوي اعتمد كمستكشف عام لاستخلاص الصفات من اجل توفير صفات متميزة ولاتتأثر بالتدوير عن صور الارقام العربية (الهندية) المكتوبة بخط اليد. كذالك في هذا البحث تم تدقيق ومقارنة اداء كلا التحويلين الزاوي والنصف قطري. مقياس البعد هيلينجر اعتمد في مرحلة التصنيف لحساب البعد بين صور الاختبار والتدريب للارقام العربية (الهندية) المكتوبة بخط اليد. التجارب المكثفة اشارت الى ان الطريقة المقترحة تنجز معدل تمييز عالي 96.74% وهو أفضل من معدلات التمييز التي تنجز بأستخدام مكوناتها وهي التحويل الزاوي والتحويل النصف قطري التي تنجز 91.34% و87.10% على التوالي. كذالك اشارت الى ان التحويل الزاوي يتفوق على التحويل النصف قطري. كما لوحظ ان الطريقة المقترحة لاتتأثر بالدوران .

الكلمات المفتاحية: تمييز الارقام المكتوبة باليد، تحويل نصف القطر الزاوي،الصفات العامة، الصفات المضادة للتدوير ، مقياس البعد هيلينجر.

Introduction

The writing is a natural process where the brain sends a nerve impulse to the hand, to start writing which means that the handwritten script is differs from person to another as other human features such fingerprints, pinna, and facial expressions [1]. Therefore, handwritten recognition can be used to distinguish between the people. Handwritten recognition can be classified into two types which are on-line and off-line handwritten recognition [2,3]. On-line handwritten recognition means that the system has the ability to recognize the handwritten in real time. On the other hand, in off-line handwritten recognition, the recognition process is achieved indirectly. Numeral handwritten recognition has received more attention in the last years due to its wide applications in different fields such as criminal evidence, office computerization,

collecting data from filled in forms, check verification, bank draft reading, and phone number sorting [4,5]. Handwritten numerals recognition suffer from many challenges such as writing style, size, shape, and slant variations, as well as image noise which leads to change numeral topology [6,7]. Furthermore, the handwritten varies when a person writes the same numeral at different times. The proposed method presented Arabic numeral handwritten recognition approach using Angular Radial Transform (ART) as a global feature extraction technique to extract distinct features from Arabic numeral handwritten images. Furthermore, these features are rotation invariant. In order to compute the distance between the extracted features of the test and training of handwritten numeral images, the Hellinger distains measure has been used. Extensive experiments have been carried out to evaluate the accuracy of the proposed work.

The rest of the paper has been adjusted as follows: Section 2 presented an overview of related work. The ART is discussed in Section 3. Section 4 explained the used similarity measures. The proposed method is given in Section 5. The experimental analysis is presented in Section 6. Section 7 clarifies the conclusions.

Related work

The main challenges in handwritten recognition process are the distortions and enormous variability of these patterns [8] Therefore, any successful handwritten recognition system required an active and accurate feature extraction technique that can provide distinct features which can be used effectively to distinguish between different numeral handwritten images. Also, it required an accurate classifier to compute the exact distance between the feature vectors of the test and database numeral handwritten images. There are numerous numeral handwritten recognition have been existed based on different feature extraction and classifier techniques. Sabri A. Mahmodi and Marwan. Abu-Amara [9] proposed Arabic (Indian) numeral handwritten recognition method based on radon and Fourier transforms. In this work, the Fourier transform is applied on each projection of radon transform for each handwritten to construct feature vectors of the training and test Arabic numeral images. In the classification stage, the researchers consider three types of classifiers which are hidden Markov model classifier,

nearest mean classifier, and K-Nearest neighbor classifier. Mohamed H. Ghaleb et. al. [8] introduced an Arabic (Indian) numeral recognition method, based on centralized moments. In this method the features of numeral images are extracted by estimating the centralized moments for vertical and horizontal. The work in [10] presented by Ouafae et.al. proposed a new handwritten numeral recognition system using Characteristics Loci(CL). In this method each numeral image is divided into four portions, and then the CL derived from each portion of the image. This work adopted two type of the classifiers in the classification stage, which are multilayer perception and k-nearest neighbor's classifiers. Meng Shia et.al. [11] presented a handwritten numeral recognition technique using curvature and gradient transformation. In this work there are three main processes are achieved in order to extract the features of handwritten numeral images, these processes are curvature and gradient calculation, feature vectors generation, and dimensionality reduction. Furthermore, in this paper, the experiments carried out on three standard handwritten numeral databases, namely, IPTP CDROM1, NIST SD3 and SD7. Kathirvalava kumar Thangairulappan and Palaniappan Rathinasamy [12] presented handwritten Arabic numeral classification base on neural network. In this method the image of handwritten numerals are converted into the matrix, then the size of each matrix reduced in half by using logical OR operation. Vikas J. Dongre and Vijay H. Mankar [13] proposed Devnagari numeral recognition method based on geometrical features. Statistical combination classifier utilized to distinguish between the training and test Devnagari Handwritten numeral images. Gita Sinha and Dr. Jitendra kumar [14] presented offline Arabic numeral handwritten recognition techniques using Zone based feature extraction method. In this method, the researchers consider three feature extraction techniques namely, zone centroid zone (ZCZ), image centroid zone (ICZ), and combined feature extraction method consist of ICZ+ ZCZ. In this work the support vector machine classifier is utilizes in the classification stage. F.A. Al-Omari and O. Al-Jarrah [15] presented online Indian numeral handwritten recognition system based on geometric features. In this system, the authors clarified that the proposed system is a rotation, scaling, and translation invariant. The probabilistic neural network is adopted to

distinguish between the training and test Indian numeral handwritten images. The method in [16] proposed by Javad Sadri et.al. presented isolated Arabic – Persian handwritten digits. In this method, the features have been extracted by considering each digit from four views which are left, right, bottom, and top. The distance between extracted features is computed using support vector machines. Md Sohail Siddique and Ayatullah Faruk Molla [17] proposed Arabic and Urdu numerals handwritten recognition based on the digit variations.

Angular radial transform

The ART can be defined in polar coordinates on a unit disc based on complex orthogonal sinusoidal basis functions. The ART can be defined in mathematical form as follows [18]:

$$A_{pq}=\frac{1}{2\pi}\int_0^{2\pi}\int_0^1 f(\rho,\theta)\, V^*_{pq}(\rho,\theta)\rho\, d\rho\, d\,\theta, \qquad (1)$$

where

$$V_{pq}(\rho,\theta)=R_p(\rho)e^{jq\theta}, \qquad (2)$$

Eq.(2) can be divided into separate parts. One is the radial part which is only dependent on the distance from the center and defined in terms of ρ only. This is called the radial part of the basis function. Another part is called as angular part and this is dependent on the angle from the x-axis and defined in terms of θ. The radial part of the basis function is

$$R_p(\rho)=\begin{cases}1 & p=0\\ 2\cos(\pi p\rho) & p>0\end{cases}, \qquad (3)$$

where p is a non negative integer, q is an integer, $\rho = \sqrt{x^2 + y^2}$,

and angular part is defined as $e^{jq\theta}$, where $j = \sqrt{-1}$ and $\theta = \arctan(\frac{y}{x})$.

Distance measure

Hellinger distance measure has been considered to compute the distance between the training and test numeral handwritten images. Hellinger distance measure estimate the deviation between two objects. The resulted values of using Hellinger distance measure are within 0 and 1. It can be defined as follows [19]

$$d^2(T,D) = \frac{1}{2}\sum_{i=0}^{F-1}\left(\sqrt{M_i(T)} - \sqrt{\mathrm{M_i}(D)}\right)^2 \qquad (4)$$

where

T, D refers to the test and training numeral handwritten images respectively, F represent the total number of the features.

Proposed method

The proposed method exploits the ART as a global feature extraction descriptor in order to extract distinct and rotation invariant features from the images of Arabic (Indian) numeral handwritten. The two-dimension histogram has been taken for the resulted ART coefficients in order to reduce their dimensionality which leads to reducing the time required for the classification process. The Hellinger distance measure has been utilized to compute the distance between the query and training Arabic (Indian) handwritten images. The proposed method can be explained as follows:

1- Convert the color numeral handwritten image into grayscale image
2- Perform the binarization process, i.e. the gray scale image is converted into two components which are foreground & background
3- Apply ART on the resulted Arabic (Indian) handwritten images
4- Construct the two-dimensional histogram of ART coefficients. In this stage we have assigned the number 10 for both dimensions of the histogram therefore, the total number of the resulted two-dimension histogram bins is 100. These bins feeds as a distinct feature to the classifier instead of the ART coefficients which leads to reduce the complexity of the classification stage.
5- Compute the distance between the test and training Arabic (Indian) numeral images using Hellinger distance measure.
6- Classify the test Arabic (Indian) numeral image according to the resulted distance value into recognized or unrecognized. Figure 1 presented a block digram of the proposed method

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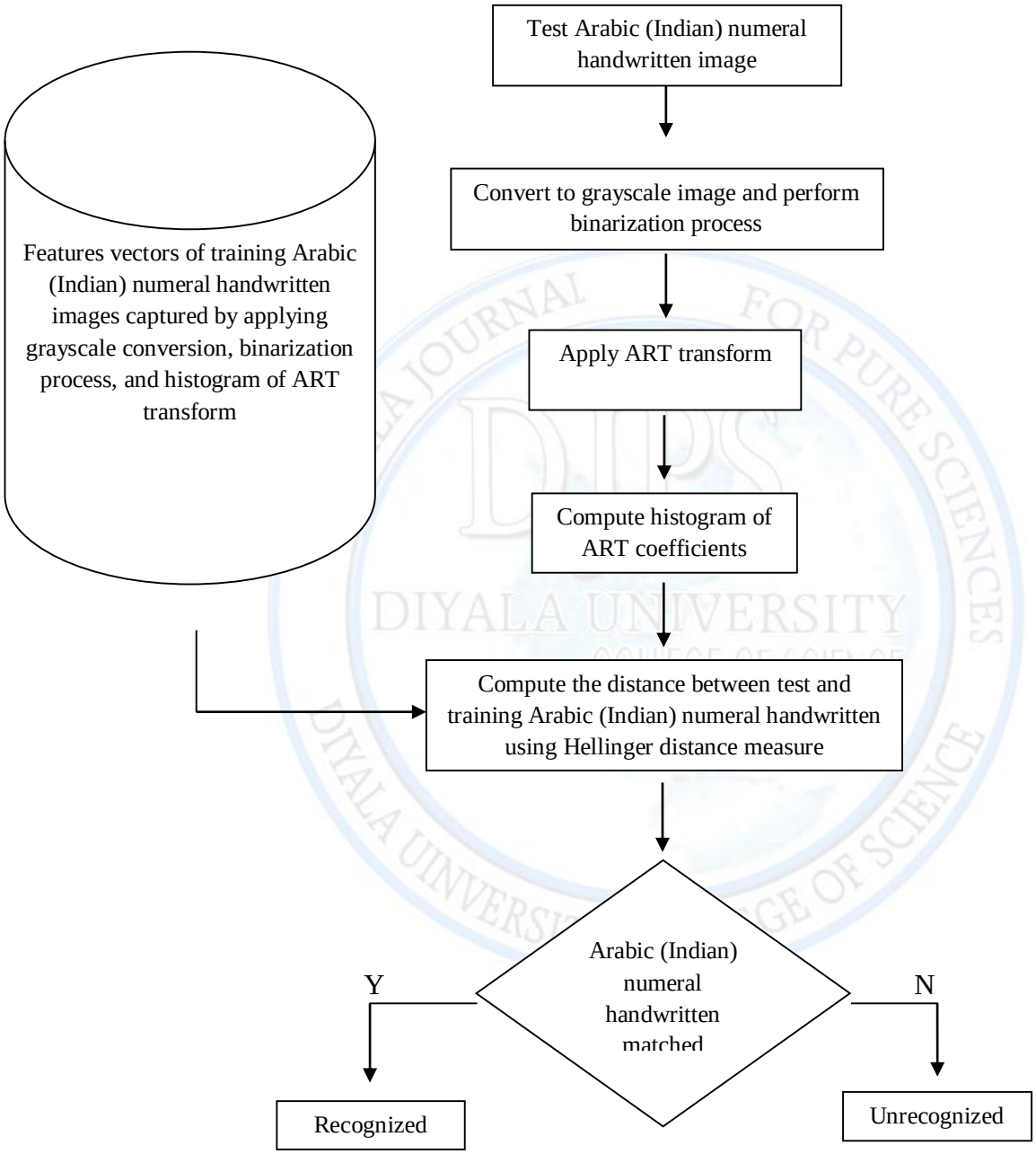

Fig.1.Proposed method's block diagram

Experimental analysis

The accuracy of the proposed method has been assessed by carrying out extensive experiments on our constructed Arabic (Indian) handwritten database. Also, the performance of the proposed method has been compared with the performance of its counterparts which are angular and radial transforms. Furthermore, the rotation invariant trait of the proposed method has been evaluated by conducting experiments on rotation numeral handwritten images. In this work, we have constructed Arabic (Indian) numeral database by taken the Arabic (Indian) numeral handwritten of 100 individuals for different ages at both female and male. Each individual has 20 samples for each Arabic (Indian) numeral digit. Therefore, the total number of database numeral images is 2000. Figure 2 presented a part of the constructed numeral handwritten database. In order to assess the rotation invariant trait of the proposed method, we have carried out additional experiments on the rotated Arabic numeral image by different rotated angles. The proposed method algorithms are implemented using Visual C++ 6.0 while; the Matlab codes used to construct the data sets on a personal computer (PC) has C.P.U with 3.0 GHZ and 2GB RAM.

English	Arabic	Handwritten									
0	0	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠
1	1	١	١	١	١	١	١	١	١	١	١
2	2	٢	٢	٢	٢	٢	٢	٢	٢	٢	٢
3	3	٣	٣	٣	٣	٣	٣	٣	٣	٣	٣
4	4	٤	٤	٤	٤	٤	٤	٤	٤	٤	٤
5	5	٥	٥	٥	٥	٥	٥	٥	٥	٥	٥
6	6	٦	٦	٦	٦	٦	٦	٦	٦	٦	٦
7	7	٧	٧	٧	٧	٧	٧	٧	٧	٧	٧
8	8	٨	٨	٨	٨	٨	٨	٨	٨	٨	٨
9	9	٩	٩	٩	٩	٩	٩	٩	٩	٩	٩

Fig.2. Part of the utilized numeral handwritten database

1. Evaluate the accuracy of the proposed method

To evaluate the accuracy of the proposed method an extensive experiments have been carried out to compare the performance of the proposed approach and its counterparts which are Angular Transform (AT) and Radial Transform (RT). Each one of these transformations is considered as a feature extraction method and compared with the proposed method. The AT coefficients provided by computing the angles between x and p for the handwritten image pixels, while RT coefficients provided by computing p for the handwritten image pixels. One-dimension histogram has been computed for the coefficients of both transformations. In theexperiments of this seaction we have divided the database described in Section 6 into training and test sets. The test dataset is constructed by selecting the first five numeral images of each individual, while, the remains numeral images utilized for training dataset, therefore, the number of the test numeral images is 500, while, it is 1500 for the training numeral images. The results of these experiments are presented in tables 1-4. The tables 1, 2, and 3show the confusion matrix of the proposed method, AT, and RT respectively.

Table1: The confusion matrix of using proposed method

Digits	0	1	2	3	4	5	6	7	8	9
0	99.63									0.37
1		97.33						2.67		
2			99.17	0.83						
3			0.33	99.67						
4		1	1		98					
5	0.07					99.93				
6							85.45			14.55
7		3.01						96.99		
8	1.77								98.23	
9							7			93

Table2: The confusion matrix of using AT

Digits	0	1	2	3	4	5	6	7	8	9
0	95.32									4.68
1		93.28						6.72		
2			95.89	4.11						
3			3.49	96.51						
4		2	4.72		94.28					
5	4.60					95.40				
6							71.15			28.85
7		8.11						91.89		
8	5.77								94.63	
9							14.87			85.13

Table3: The confusion matrix of using RT

Digits	0	1	2	3	4	5	6	7	8	9
0	91.12									6.88
1		89.51						10.49		
2			92.14	7.86						
3			8.85	91.15						
4		3.60	7.30		90.10					
5	8.79					91.21				
6							67.11			32.89
7		13.57						86.43		
8	9.78								90.22	
9							17.96			82.04

Table 4 presented the average of recognition rate achieved using the proposed method and its counterparts (AT and RT). The existing results refer that the proposed method achieved 96.74% recognition rate which is better than 91.34% and 87.10% which achieved by using AT and RT respectively. Also, it observed that the performance of AT is better than the performance of RT.

Table 4: The average of recognition rates achieved using proposed method(ART), AT, and RT

Method	Recognition rate %
ART	96.74
AT	91.34
RT	87.10

2. Evaluate the rotation invariant property of the proposed method

In this section, the rotation invariant trait of the proposed method has been demonstrated through a set of experiments using different rotation angles. For this purpose, we have rotated the numeral test images of the dataset used in Section 6.1 by 30°, $45^{\circ}, 90^{\circ}$, and 180°, while, the training numeral images are taken without rotation angle. Figure 3 shows original Arabic (Indian) numeral image and its rotation version using different rotation angles. Table 5 presented the results of the experiments which carried out in this section. It observed that the recognition rates achieved using rotate test Arabic (Indian) numeral images by angles 30°, 90°, and 180° are close to that achieved without rotation angle, while, the recognition rate

achieved using rotated test Arabic (Indian) numeral images by 45° is slightly less than of that achieved using un-rotated numeral test images. This is because of that the maximum effect of the rotation process occurs at the angle 45°. Therefore, it can be concluded that the proposed method is rotation invariant.

(a) (b) (c) (d) (e)

Fig.3: (a) original handwritten numeral image, (b) original handwritten numeral image rotated by 30°, (c) original handwritten numeral image rotated by 45°, (d) original handwritten numeral image rotated by 90°, (e) original handwritten numeral image rotated by 180°.

Table 5: Averages of recognition rates % achieved using proposed method under rotation variation

Recognition rate % using proposed method without rotation angle	**Recognition rate % achieved using proposed method with different rotation angles**			
96.74	30°	45°	90°	180°
	96.53	**96.2**	**96.66**	**96.74**

Conclusions

The proposed method investigated the performance of ART in Arabic (Indian) numeral handwritten recognition. The extensive experiments carried out using the proposed method and its counterparts indicated the following conclusions:

1- Using ART as a feature extraction method in Arabic (Indian) numeral handwritten recognition leads to provide a distinct feature, as well as it rotation invariant.

2- The performance of the proposed method (ART) outperforms its counterparts (AT and RT).

3- The performance of AT is better than the performance RT.

4- The results of the experiments carried out to test the accuracy of the proposed method under rotation variation referred that the proposed method is rotation invariant.

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