LOCAL REGION PSEUDO-ZERNIKE MOMENT- BASED FEATURE EXTRACTION FOR FACIAL RECOGNITION OF IDENTICAL TWINS

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ABSTRACT

In the domain of image processing, face recognition is one of the most well-known research field. When humans have very similar biometric properties, such as identical twins, the face recognition system is considered as a challengeable problem. In this paper, the AdaBoost method is utilized to detect the facial area of input image. After that the facial area is divided into some local regions. Finally, new efficient facial-based identical twins feature extractor based on the geometric moment is applied into local regions of face image. The used feature extractor is Pseudo-Zernike Moment (PZM) which is employed inside the local regions of facial area of identical twins images. To evaluate the proposed method, two datasets, Twins Days Festival and Iranian Twin Society, are collected where the datasets includes scaled and rotated facial images of identical twins in different illuminations. The experimental results demonstrates the ability of proposed method to recognize a pair of identical twins in different situations such as rotation, scaling and changing illumination

KEYWORDS

Face Recognition, Local Regions, Identical Twins, Invariant Moment, Pseudo-Zernike Moment

1. INTRODUCTION

Face is one of the best features to identify people identity from his (her) image. According to this property, identification of facial of identical twins is critical because of the similarity between a pair of twin. To identify identical twins, some important previous works are listed as: in [12], the proposed face detection method contains three levels: (1) overall appearance of the face is constructed; (2) exact geometric and structural embedment of face with differentiating between two similar faces are performed; and (3) the third level consists of process of skin disorders detection such as wounds. Sun et al. [16] utilized Cognitec FaceVACS system to recognize identical twins from CASIA Multimodal Biometrics Database. They obtained true accept rate of approximately 90% at a false accept rate greater than 10%. In [14], the proposed fce detection method includes tree steps: (1) the proposed method marks the face images using normal geometric methods; (2), the Euclidean distance between a pair of markers of test image and images in dataset, are computed and compared; and (3), the algorithm involves finding the strong similarity between the marked regions.

In [15], recognition of identical twins is performed using marks on the face image. Martin et al. [3] employed DNA approach to recognize identical twins. In this paper, the geometric moments is used to extract feature vector from input facial images of twins in order to recognize identical twins.

This paper is organized as follows: in Section 2, feature extraction step of a face recognition system is introduced. In Section 3, the proposed method is demonstrated. In Section 4, experimental results are presented and the paper will be concluded in Section 5.

2. FEATURE EXTRACTION

Each face detection system contains four steps: preprocessing, face localization, feature extraction and classification. Feature extraction is a process which is employed to collect useful information from raw data and so this process is necessary for the pattern recognition problems. Since the feature extraction methods are not public and depend on application, feature extraction step may show different results. There are two different groups for the feature extraction methods: structural features and statistical features [11][19]. In the first group, local structure of input image takes into account where these structural features deal with local data [7].

In the second group, the statistics-based feature extraction methods create a set of feature vector according to the global data of input image. Extraction of irrelevant information from facial image may create unappreciated set of feature vector elements such as hair, shoulders, and background should be regarded in the feature extraction phase [10]. Some of statistics-based feature extraction methods are listed as Principle Component Analysis (PCA), Legendre Moment (LM) [13] and Zernike Moments (ZM) [20], Pseudo-Zernike Moment (PZM) [8]. Legendre functions are Legendre differential equation. It is important that Legendre moments are orthogonal, independent of each other and free of data redundancy.

Zernike Moment (ZM) is a set of orthogonal polynomials which are defined into a unit disk. The ZM technique is independent of scale and rotation of face in image. The Pseudo-Zernike Moment (PZM) is the similar to ZM but the feature vector elements extracted by PZM is more than the feature vector extracted by ZM and so is more suitable than ZM for recognition of identical twins. In this study, PZM is utilized to extract feature vector in order to recognize identical twins. The PZM will be described in the next Section.

3. PROPOSED METHOD

In this paper, the goal is distinguishing of identical twins using facial image. For this purpose, at the first step, a boosting method named AdaBoost [18] technique is employed to localize the facial area of input image and also create subimge. In the next step, the PZM is applied on each subimage to create feature vector elements for each subimage and this step is performed for all images in dataset. In the final step, the feature vectors of test image is compared to feature vectors of all images in dataset and the image of dataset with the minimum distance to the test image is selected as the pair of test image. In the next Section, the processes of face detection and feature extraction will be described in detail.

3.1. Face Detection Method

In the process of identical twins recognition, the second step is face detection. In the proposed method, mixture of successively more complex classifiers in a cascade structure using AdaBoost [18] is applied to detect facial area of input image using a small number of Haar-like features [18]. After finding the facial area, an ellipse will be drowning around the main location of face [8]. The ellipse shape includes five parameters: X_0 and Y_0 are the centers of the ellipse, θ is the orientation, α and β are the minor and the major axes of the ellipse, respectively.

Before the computation of the above mentioned parameters, geometric moments should be described. The geometric moments of order $p+q$ of a digital image are defined as

$$M_{pq} = \sum_x \sum_y f(x,y) x^p y^q \quad (1)$$

where p, q = 0, 1, 2, … and $f(x, y)$ is the grey-scale value of the digital image at x and y location. The translation invariant central moments are achieved by placing origin at the center of the image:

$$\mu_{pq} = \sum_x \sum_y f(x,y)(x-x_0)^p (y-y_0)^q \quad (2)$$

where $x_0 = \frac{M_{10}}{M_{00}}$ and $x_0 = \frac{M_{01}}{M_{00}}$ are the centers of the connected components. Thus, center of gravity of the connected components is utilized as the center of the ellipse. The orientation of the ellipse is calculated according to the least moment of inertia [8].

$$\theta = \frac{1}{2}\arctan\left(\frac{2\mu_{11}}{\mu_{20}-\mu_{02}}\right) \quad (3)$$

where μ_{pq} shows the central moment of the connected components as shown in (2). The length of the major and the minor axes of the best-fit ellipse can also be calculated by analysing the moment of inertia. With the least and the greatest moments of inertia of an ellipse defined as

$$I_{min} = \sum_x \sum_y [(x-x_0)\cos\theta - (y-y_0)\sin\theta]^2 \quad (4)$$

$$I_{max} = \sum_x \sum_y [(x-x_0)\sin\theta - (y-y_0)\cos\theta]^2 \quad (5)$$

Length of the major and the minor axes are calculated from [8] as

$$\alpha = \frac{1}{\pi[I_{max}^3/I_{min}]^{\frac{1}{8}}} \quad (6)$$

$$\beta = \frac{1}{\pi[I_{min}^3/I_{max}]^{\frac{1}{8}}} \quad (7)$$

To determine how well the best-fit ellipse approximates the connected components, a distance measure between the connected components and the best-fit ellipse is obtained as follows [8]

$$\emptyset_i = \frac{P_{inside}}{\mu_{00}} \quad (8)$$

$$\emptyset_o = \frac{P_{outside}}{\mu_{00}} \quad (9)$$

where the P_{inside} is the number of background points located inside the ellipse, $P_{outside}$ is the number of points of the connected components that are located outside the ellipse, and μ_{00} is the size of the connected components. After that, a subimage is made according to the ellipse and finally, the PZM is employed to extract features inside the subimage.

3.2. Pseudo-Zernike Moment (PZM)

PZM is based on the geometric moment and used to create feature vector according to the global data of an image [9]. The advantages of PZM is that its orthogonal moments are shift, rotation, and scale invariants which are suitable for pattern recognition problems [6][5][8][17]. Also, PZM includes several orthogonal sets of complex-valued polynomials defined as

$$V_{nm}(x,y) = R_{nm}(x,y)\exp\left(jm\tan^{-1}\left(\frac{y}{x}\right)\right) \quad (10)$$

where $x^2 + y^2 \leq 1$, $n \geq 0$, $|m| \leq n$, and the radial polynomials $\{R_{nm}\}$ are defined as

$$R_{nm}(x,y) = \sum_{s=0}^{(n-|m|)} D_{n,|m|,s}(x^2+y^2)^{\frac{n-s}{2}} \quad (11)$$

where

$$D_{n,|m|,s} = (-1)^s \frac{(2n+1-s)!}{s!(n-|m|-s)!(n-|m|-s+1)!} \quad (12)$$

The PZM of order n and repetition m is calculate as

$$PZM_{nm} = \frac{n+1}{\pi}\sum_x \sum_y f(x,y)V_{nm}^*(x,y) \quad (13)$$

It is important that PZM is calculated for positive m because $V_{nm}(x,y) = V_{nm}^*(x,y)$. The reason of rotation invariance of PZM is that with the rotation of image, phase of moments in PZM will be varied and so its absolute value remains constant [4]. Therefore, feature is rotation invariance if the absolute value or value of PZM is considered as the feature. In the next Section, the process of feature vector creation using PZM will be described.

3.3 Creating feature vector

In this step, PZM is applied on each subimage to extract feature vector. For this purpose, the feature vector elements are defined as:

$$FV_j = \{PZM_{km} \mid k = j, j+1, \ldots, N\} \quad (14)$$

where j is interval $[1,N-1]$ and so, FV_j includes all PZM from order j to N. In Table 1, samples of feature vector elements is shown for $j = 3$, 5 and 9, and $N = 10$. According to Table 1, number of feature vector elements FV_j is decreased when the value of j is increased.

3.4 Local Regional Pseudo-Zernike Moment (LRPZM)

The main contribution of this paper is focused on applying of PZM in a local area. For this purpose, the obtained subimage from AdaBoost is divided into 13 subregions including an eye and two eyebrow regions (for both the left and right eye); an upper, middle, lower left, and lower right regions of the nose; and the left, middle, and right regions of the mouth. These regions are normalized to attenuate variation in illumination. After that, the PZM is employed in each subregion to extract a feature vector per region.

To find the pair of a twin, a set of feature vectors obtained from regions of input image will be compared with the sets of feature vectors which are produced from the image in the database. In the other words, the distance between the feature vector of a specific region in input image and the feature vector of same region in an image of database (this action is utilized for all regions). If there are 13 regions, then there are 13 distance values. The average value of all distance values is calculated as the distance value between these two images. Finally, the image from database with minimum distance value is considered as the pair of input image. In the next Section, we discuss on the evaluation of the proposed method.

4. EXPERIMENTAL RESULTS

To evaluate the proposed method, two datasets is used: Twins Days Festival [2] and Iranian Twin Society [1] with 520 and 600 pairs of identical twins images, respectively. Both of The datasets includes facial image with different scales, rotation and different illuminations. In Figure 1, subimages of some twin test images are shown.

The results of identical twins recognition of LRPZM is compared with PZM, ZM [20] and LM [13]. Experiments results have been carried out in three steps according to order of moment: (1) order *n* is in interval [1,6]; (2) order *n* is in interval [6,8]; and (3), order *n* is in interval [9,10]. In this paper, *N* is set 10 (N=10) and *j* varies from 1 to 9. The error rate on the classification of all geometric moments (LM, ZM, PZM and LRPZM) is calculated using (15) and the results will be reported in Table 3.

$$Error\ rate = \frac{\text{No. of misclssification}}{\text{No. of total testing patterns}} \quad (15)$$

Table 1. Feature vector elements based on the PZM

***j* value**	FV_j **feature elements (** PZM_{km} **)**		**Number of feature element**
	K	**M**	
4	4	0,1,2,3,4	56
	5	0,1,2,3,4,5	
	6	0,1,2,3,4,5,6	
	7	0,1,2,3,4,5,6,7	
	8	0,1,2,3,4,5,6,7,8	
	9	0,1,2,3,4,5,6,7,8,9	
	10	0,1,2,3,4,5,6,7,8,9,10	
6	6	0,1,2,3,4,5,6	45
	7	0,1,2,3,4,5,6,7	
	8	0,1,2,3,4,5,6,7,8	
	9	0,1,2,3,4,5,6,7,8,9	
	10	0,1,2,3,4,5,6,7,8,9,10	
9	9	0,1,2,3,4,5,6,7,8,9	21
	10	0,1,2,3,4,5,6,7,8,9,10	

Table 2. Feature vector elements produced by geometric moments in each experiment.

Cat.	LM feature elements	ZM feature elements	PZM feature elements
1	*n*=1, *m*=1 *n*=2, *m*=0,2 *n*=3, *m*=1,3 *n*=4, *m*=0,2,4 *n*=5, *m*=1,3,5 *n*=6, *m*=0,2,4,6	*n*=1, *m*=1 *n*=2, *m*=0,2 *n*=3, *m*=1,3 *n*=4, *m*=0,2,4 *n*=5, *m*=1,3,5 *n*=6, *m*=0,2,4,6	*n*=1, *m*=0,1 *n*=2, *m*=0,1,2 *n*=3, *m*=0,1,2,3 *n*=4, *m*=0,1,2,3,4 *n*=5, *m*=0,1,2,3,4,5 *n*=6, *m*=0,1,2,3,4,5,6
2	*n*=6, *m*=0,2,4,6 *n*=7, *m*=1,3,5,7 *n*=8, *m*=0,2,4,6,8	*n*=6, *m*=0,2,4,6 *n*=7, *m*=1,3,5,7 *n*=8, *m*=0,2,4,6,8	*n*=6, *m*=0,1,2,3,4,5,6 *n*=7, *m*=0,1,2,3,4,5,6,7 *n*=8, *m*=0,1,2,3,4,5,6,7,8
3	*n*=9, *m*=1,3,5,7,9 *n*=10, *m*=0,2,4,6,8,10	*n*=9, *m*=1,3,5,7,9 *n*=10, *m*=,0,2,4,6,8,10	*n*=9, *m*=0,1,2,3,4,5,6,7,8,9 *n*=10, *m*=,0,1,2,3,4,5,6,7,8,9,10

Table 3 shows misclassification rates of LM, ZM, PZM and LRPZM. According to the table, higher order moments of the PZM and LRPZM extracts more information for face recognition while low-order moments have no significant effect on the system error. Also, the table shows high misclassification rate of LM because the LM is sensitive to the rotation of input face.

Tables 3 shows the superiority of PZM to ZM because PZM is shift, rotation and scale invariant while the ZM is shift and scale invariant. Also the size of feature vector created by PZM is more than the one extracted by ZM and so, the global information obtained by PZM is sufficient for identical twins recognition. As the both of the PZM and LRPZM have the same feature vector length, the LRPZM takes the first place in Table 3 because the LRPZM analyse the image in small region with more detail. In Figure 2, visual results of LRPZM on pair of identical twins of two mentioned datasets are demonstrated. In this table, the first row shows the results of LRPZM on the Twins Days Festival dataset [2] and second row illustrates the results of LRPZM on the Iranian Twin Society dataset [1].

Table 3. Misclassification rate of each geometric moment in different categories. Following parameters are means as No (Number), FE (Feature Elements) and ER (Error Rate).

Cat.	LM		ZM		PZM		LRPZM	
	No. of FE	ER	No. of FE	ER	No. of FE	ER	No. of FE	ER
n=1,2,…,6	15	10%	15	8.5%	26	4.5%	26	**3.98%**
n=6,7,8	13	9.1%	13	6.5%	24	3%	24	**2.86%**
n=9,10	11	6.1%	11	4%	21	1.3%	21	**0.76%**

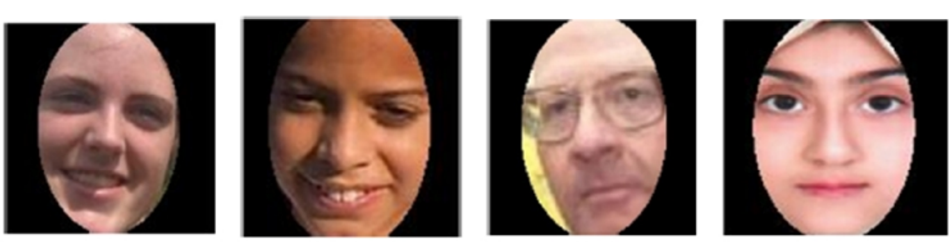

Figure 1. Drawing ellipse around the facial area of input image.

Figure 2. Some of testing identical twins which were correctly classified by LRPZM. The first row refers to the results on the Twins Days Festival dataset [2] and the second row is the results on the Iranian Twin Society dataset [1].

The experimental results prove the ability of LRPZM in extraction of informative feature vector inside the subimages of a pair of identical twins in scaling, rotation and different illumination.

5. CONCLUSIONS

In this paper, a system presented to improve the recognition of a pair of identical twins. The proposed method is based on the Local Region Pseudo-Zernike Moment (LRPZM) as a feature extractor to recognize a pair of identical twins. For the face detection, AdaBoost method is applied on the facial image of twins. After that, the obtained subimage is divided into some local regions and then the PZM is utilized to construct feature vector elements for each region. According to the experimental results, the proposed LRPZM system is able to extract informative feature vector from input image and also is robust to rotation and scaling and changing illumination.

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