TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 18, No. 2, April 2020, pp. 733~739
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i2.14106

Face recognition based on curvelets, invariant moments features and SVM

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Article Info

Article history:

Received Sep 15, 2019
Revised Dec 30, 2019
Accepted Feb 9, 2020

Keywords:

Curvelet
Face recognition
Invariant moment
Support vector machine

ABSTRACT

Recent studies highlighted on face recognition methods. In this paper, a new algorithm is proposed for face recognition by combining Fast Discrete Curvelet Transform (FDCvT) and Invariant Moments with Support vector machine (SVM), which improves rate of face recognition in various situations. The reason of using this approach depends on two things. first, Curvelet transform which is a multi-resolution method, that can efficiently represent image edge discontinuities; Second, the Invariant Moments analysis which is a statistical method that meets with the translation, rotation and scale invariance in the image. Furthermore, SVM is employed to classify the face image based on the extracted features. This process is applied on each of ORL and Yale databases to evaluate the performance of the suggested method. Experimentally, the proposed method results show that our system can compose efficient and reasonable face recognition feature, and obtain useful recognition accuracy, which is able to face and side-face states detection of persons to decrease fault rate of production.

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1. INTRODUCTION

Face recognition represents the modern wave of identity and authentication solutions [1]. This technique has become a broad user acceptance for authentication solutions, getting rid of unsuitable and long passwords. Automatic security system eliminates the need of security man to visually supervise location, performs security checks and monitors security cameras [2, 3]. Currently, the researchers are focusing on face recognition methods. Generally, these methods are consisting of the following steps: image acquiring, preprocessing, features extraction and image classification [4].

The face feature extraction process is a crucial stage in expressing face images that have a great impact on recognition rate. Furthermore, this process has an effect on computation time and storage size [5]. For feature extraction process the curvelet transform represents anisotropic multi-resolution method compared with wavelet. It is having an efficient representation of edge discontinuities in the image of the face [6, 7]. Recently, curvelet transform is used to perform some pattern recognition, such as character recognition [8] and face recognition [9-11].

It is suggested that, most of these proposed methods have directly used the coefficients of curvelet. Actually, curvelet anisotropic characteristic is not used suitably to represent the structure for the face image. Illumination differences are a major source of difficulty for designing a face recognition system, the efficient solution is done by extracting the illumination invariant features using moment invariants [12]. Moment invariants are not affected by the change of scaling, shifting and rotation. A several methods of deriving moment invariants have been proposed. In 1962, Hu proposed the theory of invariant moment by deriving them from algebraic invariants. Li [13] calculated 52 invariant moments, and seven popular invariant moments are approached. In this paper, a novel method for face recognition is proposed, using wavelets at each scale based on curvelet transform and improved Support vector machine (SVM) classifier.

Section 2 of this paper explains the design of the face recognition system, involving curvelet and Invariant Moments method and the principle of SVM as a classification method. Section 3 presents the experimental results that evaluate the adopted techniques performance. Conclusions are reviewed in Section 4.

2. PROPOSED SYSTEM DESIGN

The proposed system is based on decomposition of face image using curvelet transform, and then reducing the dimension of curvelet coefficients to feed the invariant moment algorithm for invariant features extraction. The feature sets produced by curvelet transform and invariant moment are used to train and test the SVM classifier. The flowchart of the proposed algorithm is shown in Figure 1.

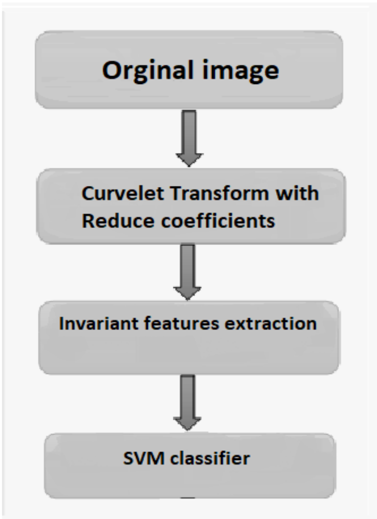

Figure 1. Block diagram of proposed system

3. CURVELET TRANSFORM

The curvelet transform represents one of the multiscale geometric transform family, which was developed to get rid of traditional multiscale representations methods such as wavelets [14, 15]. The curvelet transform solved the problem of isotropic scaling of wavelet, which makes it fit for face features extraction. There are two different implementation methods of curvelet transform:

- Curvelet via unequally spaced fast Fourier transform (USFFT).
- Curvelet via wrapping of specially selected Fourier samples.

Both are shared the same properties of simplicity, fast and less redundant; compare with their earlier generation versions. The first method has been taken in this paper, which is described as follows.

- Apply the 2D FFT and obtain Fourier samples $\hat{f}[n_1,n_2], -\frac{n}{2} \le n_1, n_2 < \frac{n}{2}$.
- For each scale/angle pair (j,l) , resample (or interpolate) $\hat{f}[n_1,n_2]$ to obtain sampled values $\hat{f}[n_1,n_2 - n_1 \tan\theta_l]$for $(n_1,n_2) \in P_j$.
- Multiply the interpolated (or shared) object $\hat{f}$ with the parabolic window $\tilde{U}_j$, effectively localizing $\hat{f}$ near the parallelogram with orientation θ_l, and obtain:

$$\hat{f}_{j,l}[n_1,n_2] = \hat{f}[n_1,n_2 - n_1 \tan\theta_l] * \tilde{U}_j[n_1,n_2]$$

- Apply the inverse 2D FFT to each $\hat{f}_{j,l}$, hence collecting the discrete coefficients $c^D(j,l,k)$.

4. MOMENT INVARIANTS

Moment invariants are invariant under scaling, shifting and rotation. They are widely used in pattern recognition [16, 17]. The derivation details of moment invariants that have been used in face features extraction are discussed by Hu (1962). So that, the general linear transformation is presented below:

$$\omega_1 = \lambda_{20} + \lambda_{02}, \quad (1)$$

$$\omega_2 = (\lambda_{20} - \lambda_{02})^2 + 4\lambda_{11}^2 \quad (2)$$

$$\omega_3 = (\lambda_{30} - 3\lambda_{12})^2 + (3\lambda_{21} - \lambda_{03})^2 \quad (3)$$

$$\omega_4 = (\lambda_{30} + \lambda_{12})^2 + (\lambda_{21} + \lambda_{03})^2 \quad (4)$$

$$\omega_5 = (\lambda_{30} - 3\lambda_{12})(\lambda_{30} + \lambda_{12})[(\lambda_{30} + \lambda_{12})^2 - 3(\lambda_{21} + \lambda_{03})^2] + (3\lambda_{21} - \lambda_{03})(\lambda_{21} + \lambda_{03})[3(\lambda_{30} + \lambda_{12})^2 - (\lambda_{21} + \lambda_{03})^2] \quad (5)$$

$$\omega_6 = (\lambda_{20} - \lambda_{02})[(\lambda_{30} + \lambda_{12})^2 - (\lambda_{21} + \lambda_{03})^2] + 4\lambda_{11}(\lambda_{30} + \lambda_{12})(\lambda_{21} + \lambda_{03}) \quad (6)$$

$$\omega_7 = (3\lambda_{21} - \lambda_{03})(\lambda_{30} + \lambda_{12})[(\lambda_{30} + \lambda_{12})^2 - 3(\lambda_{21} + \lambda_{03})^2] + (3\lambda_{12} - \lambda_{30})(\lambda_{21} + \lambda_{03})[3(\lambda_{30} + \lambda_{12})^2 - (\lambda_{21} + \lambda_{03})^2]. \quad (7)$$

The above formulas are used to calculate the features of face images. Figure 2 shows an example of the extracted features by Curvelet and moment invariants.

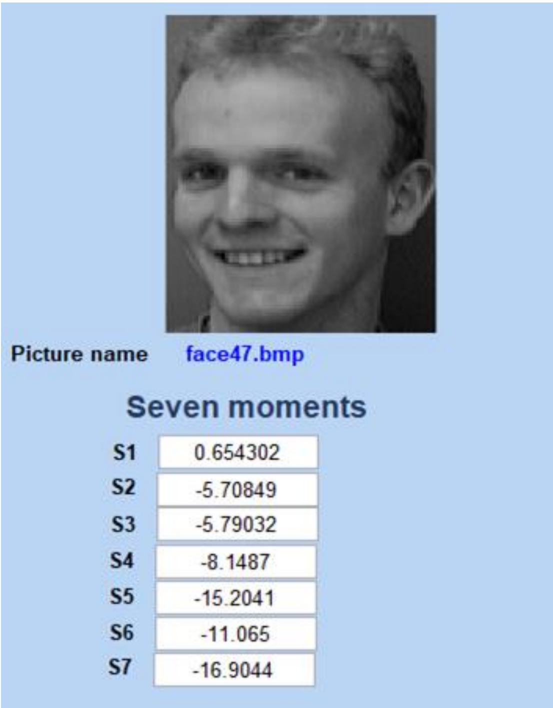

Figure 2. Interface of features extraction

5. CLASSIFICATION

In this paper, support vector machine (SVM) was used for classification of face images [18, 19]. Many kernel functions and different parameters have been considered to enhance the performance of the classifier. The data can be separated by several linear classifiers, but there is only one classifier that can maximize the distance between it and the nearest data point of each class. This linear classifier is named by optimal separating hyper plane [20]. So it is needed to find ω, which represents the coefficient of the hyperplane. The support vector machine SVM is a supervised learning model in the field of machine learning. It is generally used for pattern recognition, classification and regression analysis. The SVM depends on structural risk minimization theory for constructing the optimal hyperplane segmentation in the feature space, making learning editor get the global optimization. Problem description: Assume the training data,

$$(x_1, y_1), \ldots, (x_1, y_1), x \in R^n, y \in \{+1, -1\}$$

This could be projected into a hyper-plane:

$$(\omega . \mathrm{x}) + \mathrm{b} = 0, \omega \in R^n, \mathrm{b} \in R \tag{8}$$

For the normalization:

$$y_i\big((\omega . x_i) + b\big) \geq 1, i = 1, \ldots, l$$

The classification of the interval is equal to: $\frac{2}{||\omega||}$, when the maximum interval is equal to the minimum $||\,\omega||^2$ [21].

6. EXPERIMENTAL RESULTS

To clarify the efficiency of the proposed method, two different databases have been used to test and evaluate the method performance. The first database is called Yale [22]. The second database is called Olivetti-Oracle Research Lab (ORL) [23]. Table 1 summarizes the properties of these datasets [24].

Table 1. The used face databases

Database	No. of subjects	No. of Images per Subject	Total Images per database	Sample image
Yale	15	11	165	
ORL	40	10	400	

Most of the methods attempt to recognize faces from images collected in a highly controlled laboratory with high resolution faces. Accordingly, the system has been tested with images of different resolutions as shown in Table 2. At 30x36 pixels the face becomes not recognized, because of face features turns hard to detect.

Table 2. Results of face recognition at different resolutions.

Face Images				
No. Pixels	92*112	69*84	52*63	30*36
Recognize?	Yes	Yes	Yes	No

In the side face images, there are more features that cannot be detected because of the head turn, which makes part of the eyes and the lips invisible, for that, some examples of a head pose database [25] are used in this method to recognize faces from side view as shown in Table 3. In the other poses image the face is not recognized because of having no enough features. Different number of images are used for training/testing to examine the recognition rate performance. Table 4 shows the recognition rate for the dataset of (ORL and Yale).

Table 3. Results of face recognition at different head poses

Images				
Poses	Side view	Side view	Near frontal	other
Recognize	Yes	Yes	Yes	No

Table 4. The results of system performance

Database	**No. of Testing Images**	**No. of training Images**	**Recognition Rate**
Yale	80	20	96%
ORL	80	20	96.25%

A graphical user interface (GUI) is designed using MATLAB environment, to increase the interactivity and expansibility for users. After training the system with dataset of images, the function of GUI started, as shown in Figure 3. By selecting the test image features extraction will run, and invariant features will be calculated and displayed. To recognize the subject face a click on the recognition process button is needed. If the tested image is for a known person, the system will give a message for person sequence number at the trained database, otherwise, a message of an unknown person will be displayed.

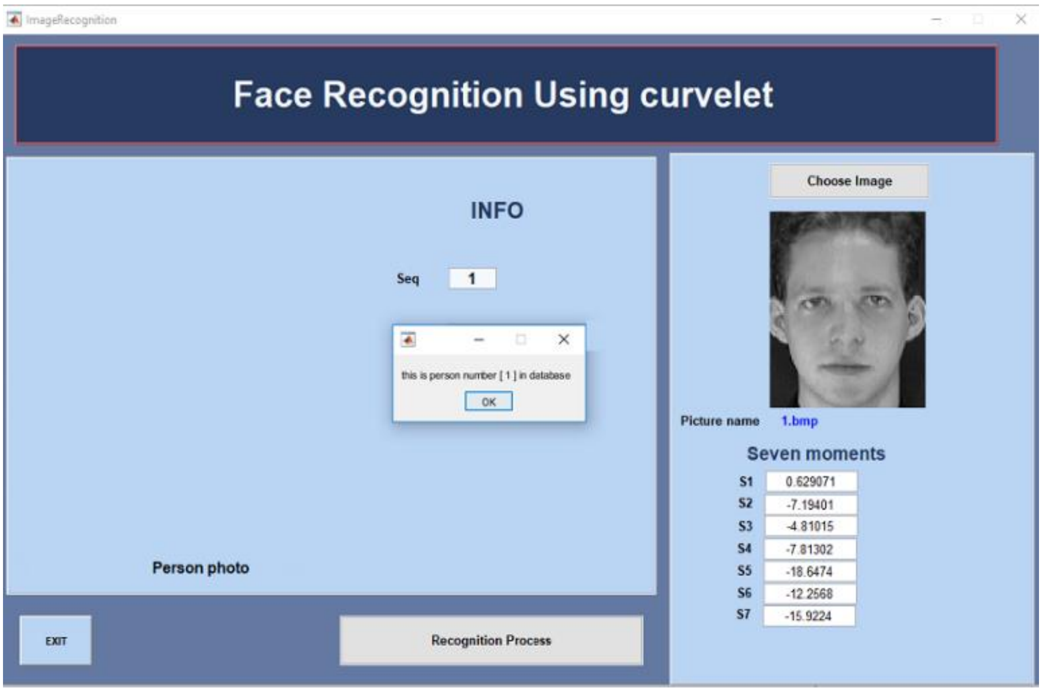

Figure 3. A graphical user interface (GUI) for face recognition system

7. CONCLUSION

In this paper, a new method of face recognition is proposed by using Curvelet transform and invariant moments. Support Vector Machine (SVM) is used as a classifier, many experiments are conducted on (ORL and Yale) face databases, moreover, head pose database is used to evaluate the system performance. The experimental results proved that the use of invariant moments with Curvelet features can improve the recognition rate in different conditions such as different illumination, resolution, and head poses. The system accuracy is achieved up to 96% on the Yale and to 96.25% on the ORL databases. For future studies, it is suggested to apply the proposed method to other face and facial expressions databases to recognize the face regions such as eyes, lips and nose to classify different facial expressions and verify the efficiency of the proposed method.

ACKNOWLEDGEMENTS

This research is funded by cooperation between Northern Technical University and Mosul University in Iraq. Website: For Northern Technical University https://www.ntu.edu.iq, Website: For Mosul University https://www.uomosul.edu.iq.

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