An Ear Recognition Method Based on Rotation Invariant Transformed DCT

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ABSTRACT

Human recognition systems have gained great importance recently in a wide range of applications like access, control, criminal investigation and border security. Ear is an emerging biometric which has rich and stable structure and can potentially be implemented reliably and cost efficiently. Thus human ear recognition has been researched widely and made greatly progress. High recognition rates which are reported in most existing methods can be reached only under closely controlled conditions. Actually a slight amount of rotation and translation which is inescapable would be injurious for system performance. In this paper, a method that uses a transformed type of DCT is implemented to extract meaningful features from ear images. This algorithm is quite robust to ear rotation, translation and illumination. The proposed method is experimented on two popular databases, i.e. USTB II and IIT Delhi II, which achieves significant improvement in the performance in comparison to other methods with good efficiency based on LBP, DSIFT and Gabor. Also because of considering only important coefficients, this method is faster compared to other methods.

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1. INTRODUCTION

Biometrics is the evaluation and analysis of appearance or behavioural specification to recognize identity of a person. Each identification system operates in two separate modes: registration and verification modes. In the registration mode, necessary information and features are extracted from each subject and reserved in database. Then the extracted features of each person are labelled with her or his personality.

In verification mode, the biometric system extracts features from the test subject. Finally an appropriate classifier using the registered features of the claimed identity in the database determines the identity of the subject [1].

The popular stages during registration and verification are image acquisition, object detection, processing, feature extraction and classification. Among all possible biometrics, ear because of its advantages is considered as a reliable biometric. During human life the structure of external ear is almost constant. Also facial expressions and partial face occlusion such as existence of glasses and hair does not affect the efficiency of the ear recognition system. In addition to these advantages if two persons have similar faces, certainly their ears will be different. Furthermore if images of face profile exist, Ear can be extracted from them which makes cost low and time can be saved [2].

In the early weeks of the lifetime, the ear appears with the structure of six separate hillocks.

Starting from the year 1882 there have been many theories, some of them proposed by Streeter [3], Davis [4], I-Chuan [5], Nixon [6], etc. Pursuant to these studies, due to ear's special shape and appearance, it is unique for human recognition.

The growth of ear between 4 months to 8 years old is linear and after that it will be approximately constant and during the lifetime doesn't change [7-14].

Alphonse Bertillon was the first person who used ear as a biometric. He used ear's shape dependence of the lobe and salience and ear height as some of the factors for ear recognition [15]. Alfred Iannarelli [7] provided a database using over 10,000 ear images and by testing, he indicated that ear could be used as a reliable biometric. He designed an ear recognition system based on size, shape and position of ear. At least in 1998, an automated ear recognition system proposed by Burge and Burger using Voronoi diagrams [16].

Totally based on literature, feature extraction is done using various approaches: geometrical and global approach [17].

Some methods which are based on geometrical approach such as: perspective methods [18], geometrical parameters method [19-20], geometrical surface properties [21], etc., and some of them are based on global approach: force field transformation [12], local binary pattern [22], Gabor features [23], etc. Apart from using only 2D images [24-26], [13], A smaller number of researchers have looked at using 3D ear shape [28-31].

In this paper a new ear recognition method based on a modified form of DCT is proposed which is robust to rotation, translation and illumination and compared with other methods. Experimental results emphasis that the proposed method is superior to these methods in uncontrolled conditions.

The rest of this paper is organized as follows: in Section2 databases, pre-processing and normalization is described, Section 3 addresses transformed DCT based ear recognition, Experiments and Results are depicted in Section4 and at the last in Section5 Conclusion is presented.

2. DATA BASES, PRE-PROCESSING AND NORMALIZATION

This paper performs the experiments on USTB II [32] and IIT Delhi II [33] databases. All the images in these databases have been captured by high resolution cameras and under different lighting conditions with various viewing angles. USTB II database contains right ear images from 77 subjects with 4 images from each subject, 308 images in total. The IITD II ear image database contains 793 gray-scale ear images of 221 subjects. At least three ear images are acquired from each subject.

Sample pictures of these databases are shown in Figure 1 and Figure 2. Each row in figures is related to ear images of one person.

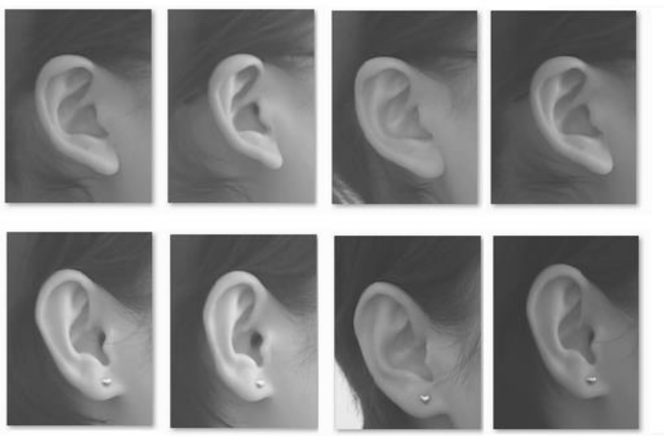


Figure 1. Example images of ear USTB II database

Figure 2. Typical image samples from ear IITD II database

For the methods which are used for ear recognition in this paper we assume that the region of ear has been specified by ear detector. By using the Canny edge detector, edge map of the ear image is obtained, then its mass center which presents the center of a circular region containing the ear is computed. Translation independence of recognition process if misalignment via detector occurs is achieved by calculating mass center of the edge map of ear image as follows [34]:

$$x_c = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} iI(i,j) \qquad (1)$$

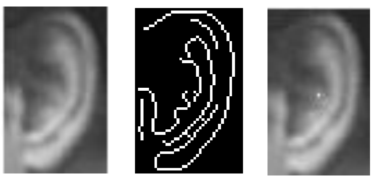
$$y_c = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} jI(i,j) \qquad (2)$$

Where M and N are number of rows and columns of the input image and I is the ear image. By means of the calculated mass center and a suitable radius which experimentally is large enough for the future stages, the region containing the ear has been cropped. Then transition from Cartesian to polar space is performed using the following equations.

$$\rho = \sqrt{(x - x_c)^2 + (y - y_c)^2} \qquad (3)$$

$$\varphi = atan2(\frac{y - y_c}{x - x_c})$$

The reason of this space changing is following in the next section. After this, for decreasing the lighting variation between ear images, histogram equalizing using linear contrast expanding function is performed on polar map of ear image. For GFD and transformed DCT based methods, all steps which are described for normalization are performed. Figure 3 shows the ear image that specified by detector, edge map of it and the location of its mass center. Figure 4 displays histogram equalized polar map of the ear image.



(a) (b) (c)

Figure 3. (a) The Ear image located by detector, (b) Its Canny edge map, (c) Mass center of it

Figure 4. Polar map of the ear after histogram equalization

3. TRANSFORMED DCT BASED EAR RECOGNITION

The presented method for ear recognition in this paper is based on a modified form of discrete cosine transform. This method with dividing the image into different components in terms of visual importance helps to image compressing. In fact by discarding the less important DCT Coefficients related to the considered image, volume and speed calculations can be decreased especially for audio and image compressing applications.

By using modified form of DCT (transformed DCT) on the polar map of image as follows it will be a rotation invariant operator. It can be done with ignoring the phase information of the coefficients and only considering their magnitudes. But slightly translation significantly influences system performances. Even if misplacement occurs via ear detector, it can be reimbursed with calculating the mass center. Therefor transformed DCT is applied on the polar map of normalized ear image. The following equation is related to general 2D DCT for an N by M image:

$$F(u,v) = 4 \times \sum_{i=0}^{N-1}\sum_{j=0}^{M-1} f(i,j) \times \cos\left[\frac{\pi.u}{2.N}(2i+1)\right]\cos\left[\frac{\pi.v}{2.M}(2j+1)\right] \quad (4)$$

Where f(i,j) is the intensity of the pixels in the i-th row and j-th column of image and F(u,v) are the coefficients of DCT in row u and column v of DCT matrix. For most cases compression is achieved by ignoring the small coefficients which are appeared in upper left corner of the DCT matrix so that these changes on audio or image is not sensible. We use a transformed type of DCT by the following equation:

$$\hat{F}(u,v) = 4 \times \sum_{i=0}^{N-1}\sum_{j=0}^{M-1} f(i,j) \times \cos\left[\frac{\pi.u}{2.N}(2i+1)\right]\sin\left[\frac{\pi.v}{2.M}(2j+1)\right] \quad (5)$$

By composing these coefficients with DCT coefficients (in equation (4)) as follows if both of them applied on the polar map of normalized ear image in which i and j related to phase and phase respectively, the phase information will be discarded. Then extracted features in this method are rotation invariant.

$$\bar{F}(u,v) = \sqrt{\hat{F}^2(u,v) + F^2(u,v)} = 4 \times \sum_{i=0}^{N-1}\sum_{j=0}^{M-1} f\ \ (i,j) \times \cos\left[\frac{\pi.u}{2.N}(2i+1)\right] \quad (6)$$

The input image is decomposed to 8×8 sub images and after applying this operator on each array, the resulted coefficients are composed.

4. EXPERIMENTS AND RESULTS

In this procedure, we perform two experiments to evaluate the proposed method. All the experiments are carried out on two popular ear databases i.e. USTB subset II and IIT Delhi subset II. In all methods Principle Component Analysis (PCA) is adopted to enhance the orthogonality between the features' components and 85% of the total data are used for training and the rest is intended for testing. We evaluate the distinctiveness of the proposed method with comparison to the other previous methods with good performance such as the LPB [35], DSIFT [36] and Gabor [37].

In first experiment, system evaluation is carried out based on the method which is defined in [38]. In this method which is named Cumulative Match Score, percentage of correct recognition of the test set is plotted for various ranks as indicated in Figure 4 and Figure 5. In these cases, when feature matrix is built, recognition is done by measuring the Euclidean distance between feature vectors and each class determined vector.

In Figure 5 the operation of systems on USTB II ear database are compared. As this figure shows the transformed DCT starts much better than other methods (92.3% at rank 1). Transformed DCT reaches 100% recognition rate at rank 6 on the first database while LBP, DSIFT and Gabor based methods respectively achieve at rank 15, 13 and 15.

Figure 6 presents systems' performance on IITD II database. All methods are nearly identical in start, but the proposed method has a better start (98.8% at rank1) and reaches 100% recognition rate in lower rank. Therefore the transformed DCT based method result in better performance comparing with other methods on two publicly ear databases especially for rotated probes and under different light condition.

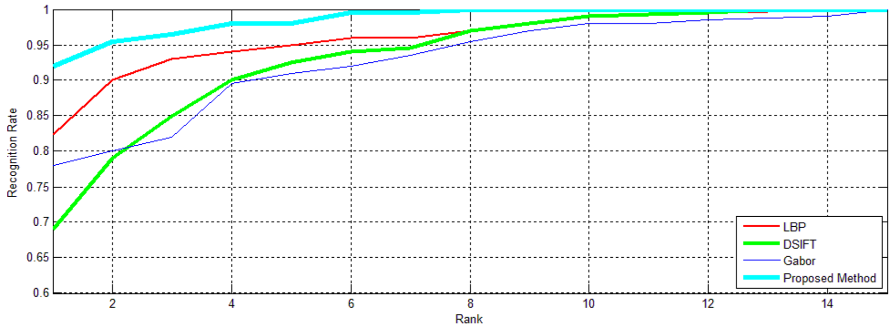


Figure 5. USTB II CMSs

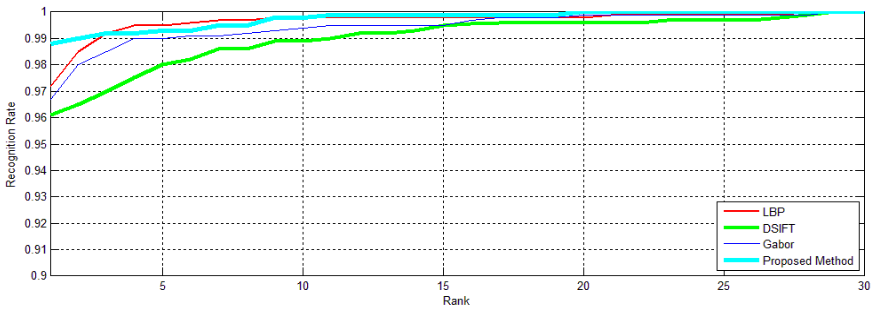


Figure 6. IITD II CMSs

In second experiment, we evaluate the performance of our proposed method in terms of ear recognition. Again, we compare the performance of our proposed method with other methods on two defined databases. The results of applying methods using four different classifiers, which are K-nearest neighbors (K-NN), Linear Support Vector Machine (L-SVM), Radial Basis Function SVM (RBF-SVM), and Sparse Representation Classifier (SRC) on two databases are calculated and averaged. Table 1 summarizes the comparison results of the proposed method with other methods. As shown in Table 1, the proposed method still produces the best identification rate regardless of any classification techniques used. Overall, the best identification result (98.2%) is achieved for the proposed method using K-NN classifier, where K is based on one nearest neighbor.

Table 1. Ear Recognition Results for Various Methods

Method	Classifiers			
	K-NN	L-SVM	RBF-SVM	SRC
LBP[33]	93.5%	89.5%	91.8%	88.7%
DSIFT[34]	79.7%	76.2%	77.3%	75.1%
Gabor[35]	85.6%	82.9%	83.2%	80.1%
Transformed DCT	98.2%	96.7%	97.5%	93.5%

5. CONCLUSION

This paper addresses the ear recognition problem depending on a proposed transformed DCT based method with comparing three existing methods in variant conditions. The proposed method is rotation and translation invariant operator and has acceptable performance under various lightening conditions. Because of these special features, this method is suitable for fully automatic recognition systems. The sensitivity of the proposed method to translations has been omitted by calculating the mass center of the processed ear image, before applying transformed discrete cosine transform. Also because of considering only important coefficients, this method is faster compared to other methods. Experiment results on two databases (USTB II and IITD II) show that proposed method is superior with respect to other methods such as LBP, DSIFT and

Gabor in the condition of image acquiring when there is rotation and translation in ear images and under various lightening conditions.

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