

# Computerized Human Ear Recognition System for Biometric Security

**Abstract**—Biometric authentication for personal identification is very popular now a days. Human ear recognition system is a new technology in this field. The change of appearance with the expression was a major problem in face biometrics but in case of ear biometrics the shape and appearance is fixed. That is why it is advantageous to use it for personal identification. In this paper, we have proposed a new approach for an automated system for human ear identification. Our proposed method consists of three stages. In the first stage, preprocessing of ear image is done for its contrast enhancement and size normalization. In the second stage, features are extracted through Haar wavelets followed by ear identification using fast normalized cross correlation in the third stage. The proposed method is applied on USTB ear image database and IIT Delhi ear image database. Experimental results show that our proposed system achieves an average accuracy of 97.2% and 95.2% on these databases respectively.

**Keywords**- ear recognition; haar wavelet; fast normalized cross correlation; automated system, biometric security

## I. INTRODUCTION

Biometrics deals with identification of individuals on the basis of their physiological and behavioral characteristics. Biometric technology is gaining popularity in this modern era for the purpose of security and other applications.

The new feature in biometrics is human ear which is becoming popular. It has several advantages over other biometric technologies such as iris, fingerprints, face and retinal scans. Ear is large as compared to iris and fingerprint and unlike them, the image acquisition of human ear is very easy as it can be captured from a distance without the cooperation of individual [1]. Human ear contains rich and stable features and it is more reliable than face as the structure of ear is not subject to change with the age and facial expressions. The anatomy of human ear is given in figure 1. It shows the standard features of human ear. It has been found that no two ears are exactly the same even that of identical twins [2] [3]. Therefore it appears that ear biometrics is a good solution for computerized human identification and verification systems. The major application of this technology is crime investigation. Ear features have been used for many years in the forensic sciences for recognition.



Figure 1. Anatomy of Human Ear

There are many approaches in the literature for an automated ear recognition system. Alfred Iannarelli [4] was a pioneer in this field. He classified the ear into eight parts on the basis of 12 measurements. But this method was not suitable because of the difficulty of localization of anatomical points [4]. Burge and Burger [5] proposed that each individual's ear is modeled as a graph of adjacency that can be built using Voronoi diagram of curve segments. For ear recognition, they have proposed graph matching algorithm which was suitable only for passive identification. Moreno also proposed a new method for ear recognition based on outer ear contour's feature points and information that can be obtained from shape and wrinkles present in the ear [6]. In [1], Hurley proposed an approach based on force field transform in which the ear image is considered as an array of Gaussian attractors that act as a source of force field. The ear is described by small channels by using these directional properties of force field. The high order moment invariant based technique was used by Wang to extract ear features [7]. Mu presented a shape and structural feature based ear recognition method for the identification of persons. This edge based ear recognition method includes edge detection, ear description, feature extraction that is followed by ear recognition based on the feature vector which has properties of both outer and inner ear (shape and structure) [8]. The standard PCA algorithm was used by Chang for ear recognition giving a multimodal approach for ear and face biometric recognition [3]. Yazdanpanah et al. proposed an ear recognition system using bi-orthogonal and Gabor wavelet based region covariance matrices approach. They achieved good average accuracy on USTB database [9]. Daramola et al. proposed an automatic ear recognition system using energy

edge density feature and back propagation neural networks [10].

This paper presents the novel technique for automated human ear recognition system. There are three steps of the proposed algorithm. In the first step preprocessing is applied on the ear image which includes its cropping, size normalization and contrast enhancement. In the second step, features of ear are extracted using Haar wavelet. In the third step of proposed system feature matching is done using fast normalized cross correlation (NCC) which gives good results for template matching.

Rest of the paper is organized as follows. In section II proposed ear recognition technology is discussed in detail explaining every step of the system. Experimental results are discussed in section III and conclusion is given in section IV.

## II. PROPOSED SYSTEM

Figure 2 shows the systematic overview of the human ear recognition technology. In the first step image is acquired which is then cropped and enhanced in preprocessing stage. In feature extraction stage, haar wavelet is applied to get the main features of the ear. In the matching stage, fast normalized cross correlation technique is used for the recognition of human ear. Each of the components in this figure is described in detail in this section.

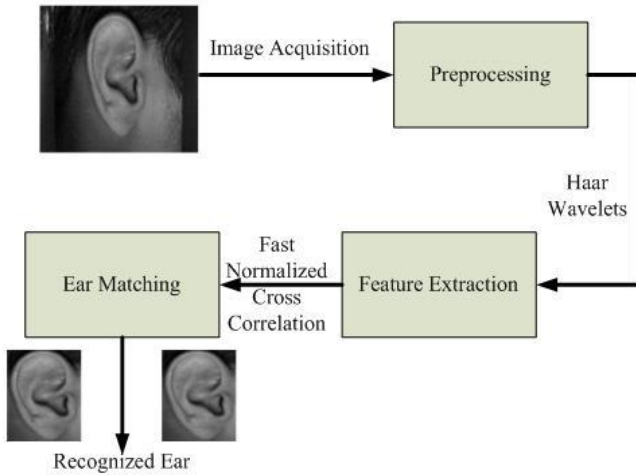


Figure 2: Human Ear Recognition Technology

### A. Preprocessing

Preprocessing of ear image is the first stage in our proposed system. Preprocessing is done to segment out the ear image from the rest of the head portion of a person. Also, size normalization and ear image enhancement is the requirement of our proposed system before feature extraction. Images with ear rings, other artifacts and occluded with hairs have not been processed in this proposed technique. The main steps of preprocessing stage are as below:

- Image is cropped using row and column wise mean based scanning from the head image of the person.

- The cropped images are of different sizes. So size normalization of cropped ear images is done to convert them to a fixed size of 160x120 pixels.
- The resized images are converted to grayscale.
- The contrast enhancement of grayscale image is done using contrast limited adaptive histogram equalization [11]. The main importance of this method is to define a point transformation within a local large template or window assuming that the intensity value within that window is a stoical representation of local distribution of intensity value within a whole ear image. Consider a running subimage  $W(x,y)$  of  $N \times N$  pixels centered on a pixel  $P(i,j)$ , the image is filtered with another subimage  $P(x,y)$  of  $N \times N$  pixels according to equation (1):

$$P_n = 255 \left[ \frac{[\Phi_w(p) - \Phi_w(\min)]}{[\Phi_w(\max) - \Phi_w(\min)]} \right] \quad (1)$$

where  $\Phi_w$  is defined in equation (2):

$$\Phi_w(p) = \left[ 1 + \exp\left(\frac{\mu_w - p}{\sigma_w}\right) \right]^{-1} \quad (2)$$

and min and max are the minimum and maximum intensity values in the whole image respectively.  $\mu_w$  and  $\sigma_w$  are the local window mean and standard deviation respectively and are defined by equation (3) and equation (4) which are as follows:

$$\mu_w = \frac{1}{N^2} \sum_{(i,j) \in (k,l)} p(i,j) \quad (3)$$

$$\sigma_w = \sqrt{\frac{1}{N^2} \sum_{(i,j) \in (k,l)} (p(i,j) - \mu_w)^2} \quad (4)$$

This reduces the noise that may be present in the image. Hence the image becomes clearer after applying this method. Figure 3 shows the preprocessing stage of our proposed system.

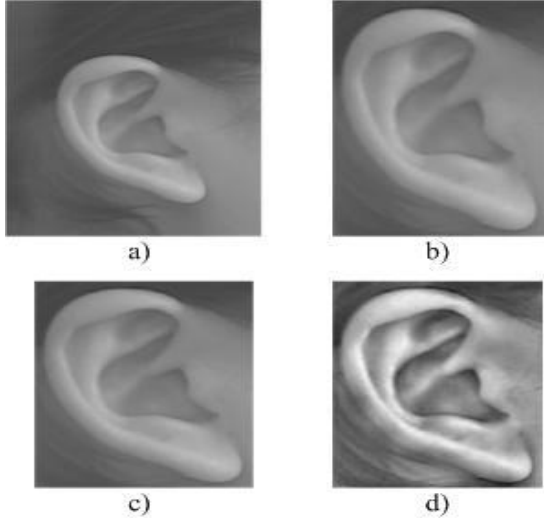


Figure 3. Preprocessing: a)Original Image, b)Cropped Image, c)Resized Image, d)Contrast Enhanced Image

### B. Feature Extraction

After the preprocessing module, the next stage of human ear recognition system is feature extraction. Feature extraction is done using Haar wavelet transform [12]. Haar wavelet is the first known wavelet proposed by Alfred Haar in 1909. Let  $\Psi: \mathbf{R} \rightarrow \mathbf{R}$ , the mother Haar wavelet function is defined by equation (5):

$$\Psi(t) = \begin{cases} 1, & \text{for } t \in [0, \frac{1}{2}), \\ -1, & \text{for } t \in [\frac{1}{2}, 1), \\ 0, & \text{otherwise.} \end{cases} \quad (5)$$

and we can generate any Haar function using equation (6)

$$\Psi_i^j(t) = \sqrt{2^j} \Psi(2^j t - i) \quad (6)$$

Where  $i=0,1,\dots,2^j-1$  and  $j = 0,1,\dots,\log_2 N-1$ . Now two dimensional Haar wavelet transform can be computed using equation (7)

$$S(l, m) = \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} I(x, y) H(l, x) H(m, y) \quad (7)$$

Where  $I(x, y)$  is a  $N \times N$  subimage and  $H(2^j + i, t) = \Psi_i^j(t)$ .

For the proposed system, we have used Haar wavelet of level two on the image for its decomposition. The desired features of the ear are extracted using level two which are then used in the ear matching stage for the recognition of human ear.

Figure 4 shows the feature extraction stage of our proposed system.

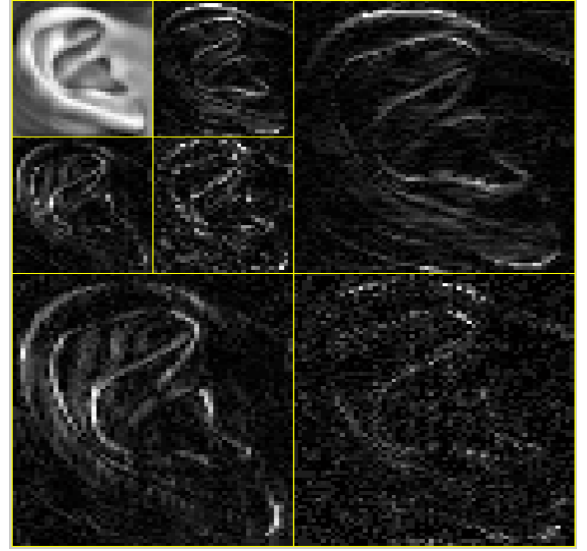


Figure 4: Second level Haar wavelet decomposition of preprocessed ear image

### C. Ear Matching

After extraction of required features from the ear image, matching is done using fast normalized cross correlation. The basic expression for NCC is given in equation (8) [13].

$$\gamma = \frac{\sum_{x,y} (I(x, y) - \bar{I}_{u,v})(t(x-u, y-v) - \bar{t})}{\sqrt{\sum_{x,y} (I(x, y) - \bar{I}_{u,v})^2 \sum_{x,y} (t(x-u, y-v) - \bar{t})^2}} \quad (8)$$

Where  $\bar{I}_{u,v}$  is the mean value of  $I(x, y)$  within the area of template  $t$  shifted to  $(u, v)$ . The simple NCC based technique suffers from many problems since it is not invariant with respect to imaging scale, rotation, and perspective distortions. Hence fast NCC is used by taking all the features from Haar wavelet decomposition in the second stage [13]. A Haar wavelet coefficient based feature vector is computed for a test image and is correlated with the feature vectors saved in database. Fast NCC for ear recognition is very significant as it requires less time for person identification.

## III. EXPERIMENTAL RESULTS

We have tested our proposed algorithm on University of Science and Technology Beijing (USTB) ear image database [14] and Indian Institute of Technology (IIT) Delhi ear image database [15]. USTB ear image database 1 consists of 180 right ear images, three images per person (60 persons). These images are 8 bit gray scale and under different lighting conditions. USTB ear image database 2 consists of total 308 right ear images, 4 images per person (77 persons). Four images per person constitutes of one profile image, two images with angle variation and one image with illumination variation. Each image is 24-bit true color image and 300x400 pixels. The IIT Delhi ear image database is acquired from 125

different subjects and each subject has at least 3 ear images. The resolution of these ear images is 272x204 pixels. Figure 5 shows the sample ear images from both these databases.

Table I shows the recognition rate of our method on these databases. The average accuracy on USTB ear database will be 97.2% while 95.2% on IIT ear image database. Results show that recognition rate on USTB database is good. Table II shows the recognition rate of different matching approaches of ear recognition technology. Fast NCC performs well among several different classifiers in less time. Table III shows the average execution time of different stages of our algorithm. The experiments were carried out on an hp dv-6 workstation with core i-5 (2.24 GHz) and with 4GB RAM. MATLAB 7.8 (R2009a) revised version in windows (64-bits) platform was used for the performance evaluation.



Figure 5. Sample Ear Images: Column a) USTB Ear Database, Column b) IIT Delhi Ear Database

TABLE I. RECOGNITION RATE OF PROPOSED METHOD ON DIFFERENT DATABASES

Database	No. of subjects	Recognized Ear Images	Unrecognized Ear Images	Recognition Rate (%)
USTB DB 1	60	59	1	98.33%
USTB DB 2	77	74	3	96.1%
IIT Ear Database	125	119	6	95.2%

TABLE II. RECOGNITION RATE OF DIFFERENT CLASSIFIERS

Classifiers	No. of subjects	Recognized Ear Images	Unrecognized Ear Images	Recognition Rate (%)
Euclidean distance [16]	262	238	24	90.83%
Back propagation neural network [10]	262	250	12	95.41%
Fast normalized cross correlation	262	252	10	96.18%

TABLE III. AVERAGE PROCESSING TIME OF DIFFERENT STAGES OF OUR METHOD

Database	Preprocessing (secs)	Feature Extraction (secs)	Ear Recognition (secs)
USTB DB 1	0.11	0.03	0.18
USTB DB 2	0.23	0.05	0.21
IIT Delhi Database	0.33	0.04	0.23

These results show the soundness of our algorithm and proved that the proposed system not only provides reliability of the results but also very efficient. Also, our ear matching approach is better than previous methods.

#### IV. CONCLUSION

In this paper, a novel approach is presented for an automated human ear recognition system. The approach consists of three stages such as preprocessing, Haar wavelet based feature extraction and finally fast NCC based ear feature matching. Experimental results on the two databases show that our proposed technique is good and effective as it gives better results than other matching algorithms. The recognition rate is also good than previous approaches for ear recognition. As for future work of this research, ear localization property should be integrated in the preprocessing module.

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