IJCAT International Journal of Computing and Technology, Volume 1, Issue 7, August 2014
ISSN : 2348 - 6090
www.IJCAT.org

A Survey on Ear Biometrics Revolution

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Abstract - Biometric occupies a vital place in security methods it is one of the most essential security aspects in the modern world. Using ear as a biometric feature is in use for several years. Much research work has been done on this. Ear is an important part of the human body which remains intact for a certain age limit. It consist of large amount of unique features. Since not much changes are observed in the ear, its rich stable structure makes it, very promising to use for identification and authentication. In this paper, a short survey is done about biometrics, why ear is used as a biometric feature and lastly all the different techniques of ear identification is listed.

***Keywords* - PCA, Methods, metrics, FAR, FRR.**

1. Introduction

In general we recognize a person by his/her face. This face recognition is now being used in biometrics where security is concerned. Over the past few decades the use of biometric traits for identification and authentication has taken the spotlight. Data breaches occur all the time, hence new methods for security is continuously evolving. One such method which has been of interest in the past few years is the use of ear for identification and authentication. The possibility of identifying people by the shape of their outer ear was first discovered by the French criminologist Bertillon, and refined by the American police officer Iannarelli, who proposed a first ear recognition system based on only seven features.[1]

1.1 Biometrics

In the current scenario full proof security is in high demand. Methods of using PIN/cards have failed in providing 100% security, hence to overcome this problem the use of Biometrics came into play. **Biometrics** is the science of recognizing the identity of individuals based on their physiological or behavioral features. It refers to the quantifiable data related to human characteristics and traits. Features are used to label and describe individuals.

The various biometric modalities or features can be categorized into two types

1. Physical (or passive)
2. Behavioral (or active)

Physical: a biological biometric trait is "based primarily on an anatomical or physiological characteristics, rather than a learned behavior"[14].It involves taking bodily measurement. When an input sample is to be compared against samples stored in the database, the use of physical characteristics is most relevant.
Examples include fingerprints, face, iris, and ear.

Behavioral: A behavioral trait is "learned and acquire over time rather than based on biology."[14].Such traits require the subject to be active and perform certain activity in front of the camera. Behavioral characteristics are more vulnerable to change in the user's emotional and physical state. Examples include signature, voice and keystroke dynamics.

1.2 Basic Process in Biometric System

Biometrics process can be broadly divided into 4 stages:

1. ***Capture:*** In this stage the sample of the biometrics feature is collected.

2. ***Extraction***: The data is extracted from the captured data and the template is stored.

3. ***Comparisons***: The template is then compared with a new sample.

4. ***Matching***: Now the sample and the template has matched or not is decided.

The process of biometrics is as below:

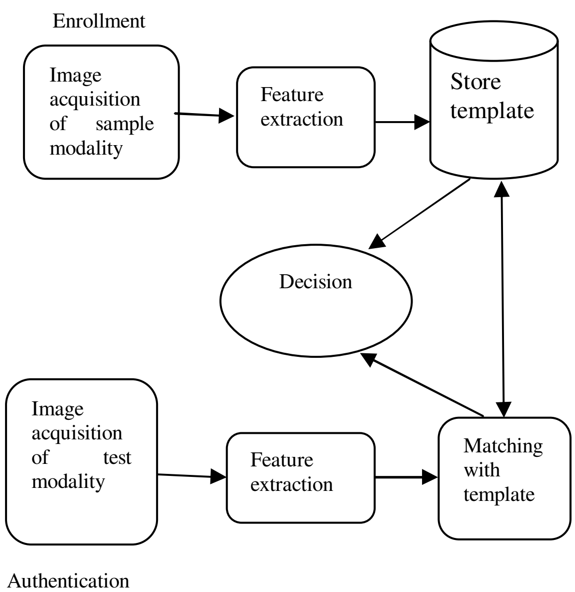

Figure 1: Biometric Process

Different Performance metrics for biometric system

1. **False acceptance rate or false match rate (FAR) :** It is the probability that the system incorrectly matches the input pattern to a non-matching template in the database. It measures the percent of invalid inputs which are incorrectly accepted. In case of similarity scale, if the person is an imposter in reality, but the matching score is higher than the threshold, then he is treated as genuine. This increases the FAR, which thus also depends upon the threshold value

2. **False rejection rate or false non-match rate (FRR):** It is the probability that the system fails to detect a match between the input pattern and a matching template in the database. It measures the percent of valid inputs which are incorrectly rejected.

3. **Receiver operating characteristic or relative operating characteristic (ROC):** The ROC plot is a visual characterization of the trade-off between the FAR and the FRR.In general, the matching algorithm performs a decision based on a threshold which determines how close to a template the input needs to be for it to be considered a match.If the threshold is reduced, there will be fewer false non-matches but more false accepts. Conversely, a higher threshold will reduce the FAR but increase the FRR. A common variation is the *Detection error trade-off (DET),* which is obtained using normal deviation scales on both axes.

4. Equal error rate or crossover error rate (EER): It is the rate at which both acceptance and rejection errors are equal. The value of the EER can be easily obtained from the ROC curve.The EER is a quick way to compare the accuracy of devices with different ROC curves.In general, the device with the lowest EER is the most accurate

.

1.3. Types of Biometrics

1. **DNA Matching:** Genes make up 5 percent of the human genome. The other 95 percent are non-coding sequences, which used to be called junk DNA. In non-coding regions there are identical repeat sequences of DNA, which can be repeated anywhere from one to 30 times in a row. These regions are called variable number tandem repeats (VNTRs).It is used in individual identification.

2. **Ear:** The identification of an individual using the shape of the ear.

3. **Iris recognition:** Is the process of recognizing a person by analyzing the random pattern of the iris. The automated method of iris recognition is relatively young, existing in patent since only 1994. The iris is a muscle within the eye that regulates the size of the pupil, controlling the amount of light that enters the eye. It is the colored portion of the eye, based on the amount of melatonin pigment within the muscle.

4. **Face Recognition: Human often uses face to recognize** individuals, and advancements in computing capability over the past few decades now enable similar recognitions automatically. Early facial recognition algorithms used simple geometric models, but the recognition process has now matured into a science of sophisticated

mathematical representations and matching processes.

5. **Fingerprint Recognition:** Fingerprint identification is one of the most well-known and publicized biometrics. Because of their uniqueness and consistency over time, fingerprints have been used for identification for more than a century, more recently becoming automated due to advancements in computing capabilities.

6. **Gait:** The use of an individual's walking style or gait to determine identity.

7. **Hand Geometry Recognition:** Palm print recognition inherently implements many of the same matching characteristics that have allowed fingerprint recognition to be one of the most well-known and best publicized biometrics. Both palm and finger biometrics are represented by the information presented in a friction ridge impression.

8. **Signature Recognition:** The authentication of an individual by the analysis of handwriting style, in particular the signature.

9. **Typing Recognition:** The use of the unique characteristics of a person's typing for establishing identity.

10. **Vein Recognition:** Vein recognition is a type of biometrics that can be used to identify individuals based on the vein patterns in the human finger or palm.

11. **Voice / Speaker Recognition:** Speaker, or voice, recognition is a biometric modality that uses an individual's voice for recognition purposes. It is a different technology than "speech recognition," which recognizes words as they are articulated, which is not a biometric. The speaker recognition process relies on features influenced by both the physical structure of an individual's vocal tract and the individual's behavioral characteristics.

2. Ear as a Biometric Feature

"The ear, thanks to these multiple small valleys and hills which furrow across it, is the most significant factor from the point of view of identification. Immutable in its form since birth, resistant to the influences of environment and education, this organ remains during the entire life, like the intangible legacy of heredity and of the intrauterine life.
A.Bertillon, 1890

Researchers have done extensive study on different types of biometrics, but research on ear as a biometric feature is new in the field. Ear features has been used for many years in the forensic science for recognition. It has certain advantages over face and fingerprints. The ear is a stable structure with rich features that does not change much with age and with facial expressions. It retains its shape till a certain age. It is also larger compared to fingerprints but smaller compared to the face and hence it can be easily captured from a distance. It is more reliable in verifying the identity of a person. Ear has all the biometric trait properties like uniqueness, universality, permanence and collectability. Because of these qualities, the interest in ear recognition systems has grown significantly in recent years After decades of research Iannarelli have found that no two ears are alike , even in the case of twins, triplets and quadruplets

2.1 External Parts of a Human Ear

The structure of the ear includes the outer rim or helix, the ridge or antihelix that runs inside and parallel to the helix, the lobe, and the distinctive u-shaped notch known as the intertragic notch between the ear hole (meatus) and the lobe. The antihelix splits into two branches at the upper which forms triangular fossa. See Figure 2.

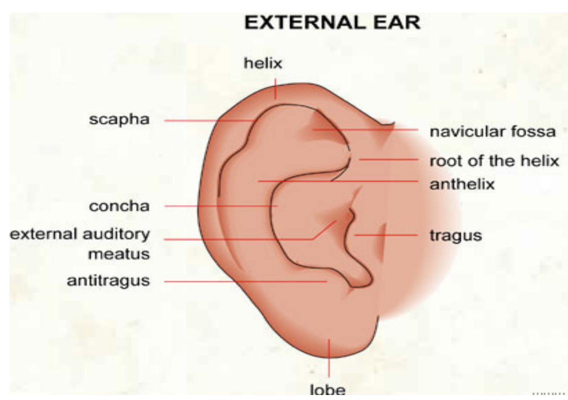

Figure 2: External structure of the ear

The lower of the two branches and the inner helix form the top and left side of the concha. The shape of the ear also includes the crus of helix where the helix intersects with the lower branch of the antihelix. Figure 2 shows the external structure of the ear.

3. Literature Review

When compared to face recognition, ear recognition is found to give better result. Different approaches have been proposed for ear recognition. Iannarelli[2] claims that the ear is unique feature of an individual. He divides the ear into eight parts. It is based upon the twelve measurements taken around the ear as shown in the figure 3.They are measured by placing a compass over an enlarged picture of the ear. The transparent compass has eight spokes at equal intervals. The reference line should be such that the top touches the innermost point on the tragus. The picture should be enlarged until the second reference line exactly spans the concha from top to bottom.

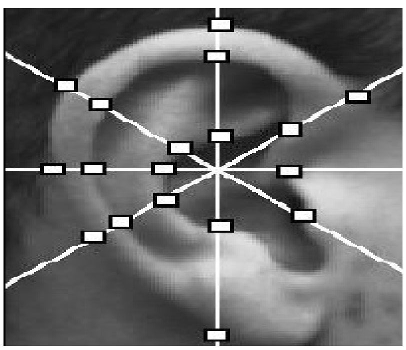

Figure 3: Ear divided in eight parts [1]

Choras (2005) [3] proposed a method for identification featuring human ear images, since they are considered to be unchanging over time and could provide more precise features that are available for classification. The method used by Choras was based on placing the center of the new coordinate system in the centroid, making any rotation of the image irrelevant for the purposes of identification, as well as negating the need for translation and scaling, which will allow RST inquiries. The centroid is a key reference point in the feature extraction algorithm, which is divided into two steps.

Later, Choras (2007) added additional experiments to expand on the earlier study, and determined that emerging ear biometric methods can be useful in the field of automated computer vision human identification systems. In particular, Choras recommended using multimodal (hybrid) biometrics systems a process that is receiving more attention as time goes on. Due to its advantages over other methods, including facial recognition, ear biometrics could provide additional support to the more well-known methods such as iris, fingerprint or face identification [4]

After Iannarelli's classification there have become different, more scientific methods for ear identification. Victor et al. (2002) and Chang et al. (2003) have used principal component analysis (PCA) and FERET evaluation protocol for their research about the ears.

Hurley and Carter [5] presented multiple identification method, which combines the results from several neural classifiers using feature outer ear points, information obtained from ear shape and wrinkles, and macro features extracted by compression network. They also introduce three different classification techniques for outer ear or auricle identifying. Hurley, Nixon and Carter (2000a, 2000b) have used force field transformations for ear recognition. The image is treated as an array of Gaussian attractors that act as the source of the force field. According to the researchers this feature extraction technique is robust and reliable and it possesses good noise tolerance.

Middendorff *et al*. (2007)[9] carried out a review of the existing literature in the field of biometrics related to identification which indicated the use of multi-modal biometrics can improve performance of a recognition system. On the other hand, a consensus does not exist on what features should be used, how they should be acquired, or even how they should be combined. Therefore, Middendorff *et al*. emphasized the importance of considering the type of data to be acquired (e.g. 2D or 3D), the type of recognition algorithm performed on each data element (PCA or ICP), the output of that algorithm (the distance or error metric), the type of fusion to be performed to combine them, and the level at which it should be performed.

The most recent research in ear biometrics includes Zhou *et al*. (2011) [12] who offered a robust technique for 2D ear recognition using color SIFT features. Based on the experiments conducted by the researchers, these methods attain better recognition rates than other methods that are typically viewed as state-of-the-art on the same datasets.

Kisku *et al*. (2009) put forward a multi-modal biometric system that included ear biometrics and featured Scale Invariant Feature Transform (SIFT) descriptor based feature sets taken from fingerprints and ears, and fused them. The results of this study indicated noteworthy upgrading when compared to the individual matching performance of fingerprint and ear biometrics in addition to an existing feature level fusion scheme which have used SIFT as feature descriptor.[7] Similarly, Rahim *et al*. (2012) [11] presented a novel local features and global features extraction approach to identify ear biometrics. In this study, the ear was divided into specific sections so as to highlight specific local features followed by extraction of the eigenvector from each section. Following this initial process, a number of areas of the ear were identified using ear biometrics. Using a popular classifier, the researchers classified these images using extraction features. In addition, performance analysis was carried out and compared among recognition rates of those features. The proposed region-based features were tested using the well-known benchmark database from the University of Science and Technology Beijing (USTB). Some extracted regions were reported to have low accuracy but, on the whole, the proposed method achieved promising results.

Zhang et al. [6] proposed a hybrid system for classifying ear images. In their system they combined Independent Component Analysis (ICA) and a Radial Basis Function (RBF) network. The method was divided into three stages: preprocessing, feature extraction, and identification. In the preprocessing stage, the grey-scale ear images were transformed into 64×40 pixel resolution. Training and probe data were filtered by using a Wiener filter which achieved the best results. Finally histogram equalization was applied to the filtered image.

Yan et al. [10] presented approaches to speed up the ICP algorithm and improve the performance of ICP registration to recognise 3D ear images. Two approaches were considered to make the ICP algorithm faster. One was to control the number of iterations, and the other was to use appropriate data structures to shrink the running time for each iteration by using *k-d* tree instead of Octree. The time for traversing a tree is the most expensive stage of the ICP algorithm. The smaller the number of cells, the faster the traversal time. The number of cells in the *k-d* tree were smaller than the number of cells in Octree. Therefore, the ICP algorithm with k-d tree was much faster than with Octree. The approaches were considered to improve the performance included noise removal, outlier elimination and using point-to-triangle error metric. They achieved a 98.8% recognition rate on their database which consisted 302 subjects, one image for each subject.

4. Classification Of Different Ear Recognition Methods

There are three major methods for ear identification: First, taking a photo of an ear, second, taking "earmarks" by pushing ear against a flat glass and lastly, taking thermogram pictures of the ear.

Taking Photograph: The most commonly used research method in ear identification is taking the photo of the ear. The photo taken, is compared with previous taken photos that are stored in the database, for identifying a person.

Earmarks: For taking the earmarks the ear can be pressed against some material, e.g. glass, and the 'earmark' can be used as a biometric.

Thermogram pictures: In case the ear is partially covered hair or cap, it can be masked out of the image by using thermogram pictures. In the thermogram pictures different colors and textures are used to find different parts of hear. The ear is quite easy to detect and localizable using thermogram imagery by searching high temperature areas.[13]

4.1 Techniques for Ear Recognition

The ear recognition techniques can be broadly classified into 3 types

1. Taking Photograph
2. Earmarks
3. Thermogram pictures

Taking Photograph: This technique includes four methods

1. Hybrid based
   - Markov Random
2. Model based
   - 3D Morphobic Model
   - Active appearance model
3. Feature Based
   - Dynamic Link
   - Elastic Bunch graph matching
4. Holistic Method
   - Traditional Clustering method
   - ICP (Independent Component Analysis)
   - PCA (Principal Component Analysis)
   - LDA (Linear discriminant analysis)
5. Haar Based
6. Force field Based
7. 2D ear curve geometry
8. Fourier Descriptors
9. Wavelet Transformation
10. Gobar Filters
11. Scale Invariant Feature Transform (SIFT)

5. Conclusion

First of all this paper explains the biometrics, its different types and the benefit of using ear as a biometric feature. It also summarizes the different techniques that can be used for ear recognition. However more research is needed to examine the validity of uniqueness that has been claimed in the past. Ear recognition technique has huge benefit, but it is yet to be realized, but in future it will give huge output. Lastly, to enhance the security ear can be clubbed with other biometric modality like face, iris etc.

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