EAR BIOMETRIC SYSTEM: GEOMETRIC FEATURE EXTRACTION USING DISTRIBUTED DATABASE

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***Abstract*— In modern times, the use of biometric technologies has become prevalent in securing and identifying individuals. One such biometric trait is the shape of the ears of the individuals, which changes very little throughout the course of their life. In this paper, our focus will be on the Ear Biometric System, whereby individuals can be recognized through the geometry of their ears and their structure. Mathematical image processing methods will be used to determine important points in the ear and generate feature vectors for comparison purposes. The application of a distributed database approach will be considered to ensure that the recognition process becomes faster for large-scale applications. This is a non-contact method that is convenient and compatible with masks.**

Keywords—Ear Biometrics, Geometric Feature Extraction, Distributed Database, Image Processing, Security System.

I. INTRODUCTION

Security is a very crucial element in the computerized system where traditional approaches through passwords and ID cards do not work. Biometric techniques are better since they are dependent on unique elements of the individual like finger prints, eye scans and voice recognition.

Each of these methods has its limitations. For example, finger prints are prone to degeneration while facial recognition has poor performance in situations where individuals cover their faces. On the other hand, ears are less sensitive in terms of aging and makeup effects; besides being easily accessible from the side.

Basically, the main idea of this research involves developing an application whose foundation lies in identifying an individual through the geometry and mathematical computations of ear structure and characteristics. Furthermore, the use of a distributed database is used in order to enhance processing speeds in case there are lots of records.

Today after the world has already seen a time of complete lockdown due to covid-19 and increasing demand of biometric identification it becomes completely necessary to come up with a method which can make sure that the process of biometric identification doesn't get hindered again if we end up in such situation again. Hence the biometric identification should be unique, universal, permanent (should not change with age/time) and collectability (it should be easy to collect data and then identify without making the person feeling disrespected etc.). As fingerprint recognition has all of these properties and can work properly under all the circumstances that we have faced till now hence it is very much needed in today's time specially for security purposes so that better security can be ensured without harming the dignity of all people needlessly. Every individual on this planet has some uniqueness, some of them are known to us but there are some where enough research is required. One rare uniqueness of human body is its ear, everyone's ear is different from one other, this was found out by a police officer from USA Iannarelli. This idea was further extended to the authentication of people via their ears like we do with fingerprints. French criminologist Bertillon, worked on this method with Iannarelli. They talked about how we can recognize the ears with 2D recognition techniques. In 2D techniques, our focus is on extracting feature vector of ear and storing it for further research. It was found out that as compared to face recognition, ear recognition gave better and effective results. Since features of an ear remain almost same throughout life, it could give us precise details for classification which in turn can increase the efficacy of already established solutions. In 2005 M. Choras did some research on this topic. Choras dealt with the centroid, he was concerned about the position of centroid with respect to the new coordinate system, so he placed the center of system in the centroid which in turn made any changes to orientation of image such as rotation irrelevant for identification. Other needs such as translation and scaling which paved way to RST Inquiries were negated.

The importance of centroid as a reference point is very significant in extraction algorithm and it is a step-wise process, involving two main steps. Moving on to 2007, Choras conducted further research in this area, performed various experiments, and came to conclusion that new research work in ear biometric can give way to development of new models for human recognition systems. According to Choras, in order to achieve success in this area, researchers should opt for a multimodal system for biometric which is one of those systems which are gaining more popularity with the passage of time. This system offers many advantages which are on par with other systems which include facial and ear biometrics as well as fingerprints and eye iris recognition.

The latest research in this area was done by Zhou in 2011 where he explained about the application of color SIFT features for 2D ear recognition. This led to further experiments which enabled the researchers to develop more robust algorithms resulting in higher recognition rates as compared to others known as state-of-the-art methods.

The aim of this research is to develop a biometric system using geometrical feature extraction of the ear that does not require the use of complicated neural networks. It includes two types of feature vectors (FV1 and FV2), which improve the efficiency of the recognition process. Moreover, the system incorporates a distributed database system to improve its recognition speed.

I. LITERATURE REVIEW

Many researchers have looked into ear biometric recognition methods. The authors Chen & Bhanu have used the curvature-based approach which aids in step edge detection and outer/anti helix template matching. The authors Ansari & Gupta utilized edge detection in order to find the convex and concave edges, followed by linking these segments into a maximum ear contour. In their research work, the authors Prakash and Gupta utilized skin segmentation and edge detection hierarchically for more accurate ear localization. The authors Yan & Bowyer have used the conchal region of ear as the anatomical landmark and employed the active contours in order to determine the boundary from the outer contours. The paper entitled 'Anatomical Ear Variations' has been investigated by Slobodan V. Marinkovic et al. These variations have been categorized as oval, round, rectangular and triangular.

TABLE I. VARIOUS RESEARCHES AND THEIR WORKS

Researcher	Work
Chen and Bhanu [1]	Proposed a technique step edge magnitude where they detected image regions having large curvatures after that template matching was performed with typical outer and anti-helix shapes.
Attarchi, S., Faez, K., Rafiei, A. [2]	They took the help of contour lines for ear detection. They worked on location of outer contour of ear first by applying a search method so that connected edge can be found out in ROI.
Ansari, S., Gupta, P [3]	They worked on applying an edge detector which marked edges as convex and concave segments, then they used algorithms which connects contour segments and identifies the figure consisting of largest area and treats it as outer ear contour.
Prakash, S., Gupta, P [4]	They mixed the skin segmentation along with hierarchy edges. After detection of edges in the skin region they are fragmented into edge segments.
Yan, P., Bowyer, K.W.[5]	They developed a recognition method which firstly locates the concha of ear which is used for finding the outer boundary of our ear, here an active contour is being used.
Pflug, A., Winterstein, A., Busch, C.[6]	They mixed depth images and texture which turned out to be a good combination for first step where preprocessing is done where shapes as well as edges are derived from the texture and depth images.
Liu, Y., Zhang, B., Zhang, D.[7]	They came with the concept of ear parotic face angle, which is unique to a person and a novel approach in 3D feature of ear images.
Slobodan V. Marinković1, Svetlana L. Valjarević2, Ivan R. Milić , Irina S. Tomić [8]	According to the shape of their outer rim and lobule, four types of the auricles were distinguished in 66 individuals: the oval (45.5%), round (13.6%), rectangular (9.1%) and triangular (31.8%)

III. ISSUES IN PRESENT TIME

Many studies have been conducted in this area both locally and abroad to develop an effective mechanism to make use of the unique nature of our ears for biometric recognition purposes. The initial breakthrough in this area acknowledging the significance of ears in biometric recognition process was made by a French criminologist named Alphonse Bertillon. Statistical or mathematical proof regarding the findings of the French scientist was provided by an American research scholar named Iannarelli. As mentioned above, there are many advantages associated with using ear recognition technique in comparison to other biometric recognition techniques such as less intrusiveness in comparison to iris or fingerprints, etc.

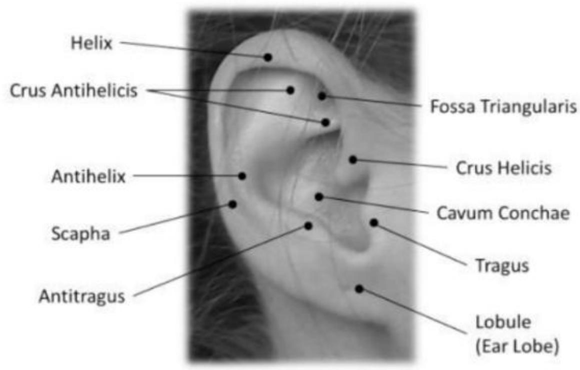

Fig. 1. Ear Anatomy

As stated earlier, considering the unique features that can be found in the human ear, there has been a lot of research done recently in the area of extracting information from the ears. From all of the concepts that have been presented before, one that has been used frequently is the concept of shapes. This model aims to determine certain unique index distributions that can be found on an ear.

IV. RESEARCH METHODOLOY

A. *Vector Extraction Methodology*

Input Image of Ear is used in the program. Firstly, we will use Gaussian filter to reduce noise in the image. Using Canny edge detection algorithm we get edges from gaussian image. We will use dilation to remove errors because of the discontinuity of edges. We will use BFS (Breadth First Search) algorithm to determine the longest edge in the image. We will find a pair of points having the maximum distance between them using O(n^2) approach. The two points are named Umax and Lmax1 respectively. Make 19 points on the line connecting Umax and Lmax1. Draw a perpendicular from each of 19 points to the outer edge of ear. Calculate angle made by a perpendicular and reference line (1). These angles form the first feature vector. Reference point (1) is considered to be the 10th point in Feature Vector 1. Find midpoint of the perpendicular drawn from reference point (1). Draw line from Umax to midpoint until it touches the outer edge. The point is named Lmax2. Make 9 points on the line joining Umax and Lmax2. Draw a perpendicular from 9 points to the outer edge of ear. Calculate angle made by perpendicular and reference line (2).

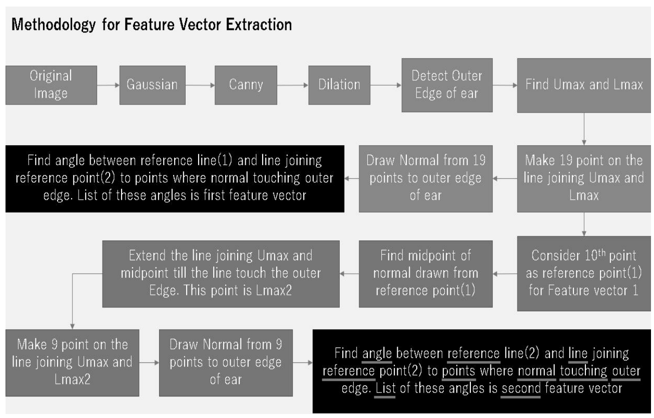

Fig. 2. Methodology for Feature Vector Extraction showing sequential image-processing steps including Gaussian blur, edge detection, feature-point identification and geometric vector generation.

Fig. 3. Original Ear

Fig. 4. Grey and Blur Ear

The initial step will be capturing images in good lighting conditions. The placement of ear should be at a right angle with respect to the camera axis, also the positioning of ear has to be done in such a way that there is no obstruction from any ornaments or jewelry like earrings and the dangle or hoop.

We have performed gaussian filter to remove the noise so that edge detection becomes efficient in next step. We have used the kernel size of 9x9. Convolution basically means using a kernel over the image.

Fig. 5. Canny

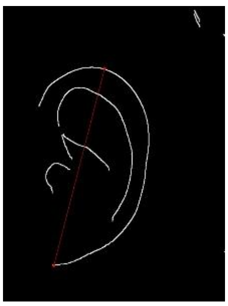

Fig. 6. Umax and Lmax

Later on, we used canny edge detection algorithm to detect the edges in the image. A Canny edge detector is an algorithm that has various steps that detect edges in any image. We then used dilation to correct any unnecessary gaps in the detected edges. In dilating an image, additional pixels are added to the edges of objects whereas in erosion, pixels are removed from the edges of objects. The number of pixels that are added to or removed from objects depends on the structuring element being used.

In step four, we will find the two points with maximum distance between them using an $O(N^2)$ algorithm. $O(N^2)$ is the complexity of an algorithm where its performance is directly proportional to the square of the input size. This is generally quite inefficient: For an input array containing 1 element, 1 operation would be performed, while an input array with 10 elements, 100 operations would be done, etc.

We will name the points Umax and Lmax1 respectively.

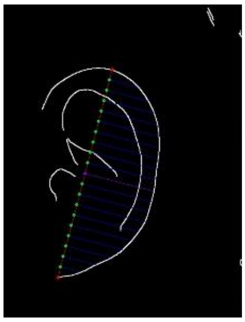

Fig. 7. Normal and Midline

Then we will draw normal from marked 19 points on the line joining Umax and Lmax1 to outer edge of the ear. These 19 points in turn will help us to extract feature vector ahead, these points are very crucial in terms of finding the shape of ear and other details related to the anatomy of ear.

TABLE II. NUMBER OF POINTS IN FV1 VS ACCURACY

Points	Accuracy	Points	Accuracy
3	5.17	19	87.37
5	11.45	21	88.67
7	23.56	23	89.28
9	35.12	25	90.36
11	55.41	27	91.13
13	70.24	29	91.66
15	80.13	31	91.98
17	83.55	33	92.10

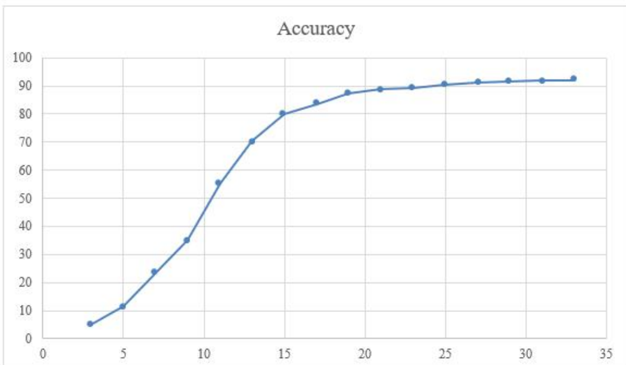

Fig. 8. Number of Points in FV1 vs Accuracy

Then we will find angle between reference line(1) and line joining reference point(2) to points where normal touching outer edge. List of these angles is first feature vector. Consider 10^{th} point as reference point(1) for Feature vector 1. Find midpoint of normal drawn from reference point(1).

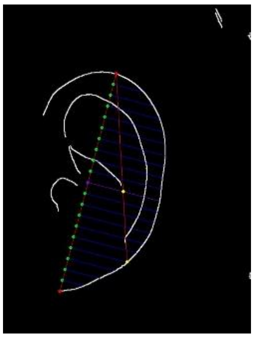

Fig. 9. Lmax2

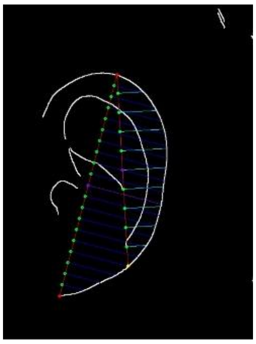

Fig. 10. Feature vector 2

Now, extend the line joining Umax and midpoint of the normal drawn from the middle of the first line till it touches the outer Edge. The intersection point on outer edge is Lmax2. This is further used for finding angles which will be stored in our second feature vector.

Our last step, mark 9 points on the line joining Umax and Lmax2. Draw Normal from these 9 points to outer edge of ear. Find angle between reference line(2) and line joining reference point(2) to points where normal touching outer edge. List of these angles is second feature vector.

TABLE III. NUMBER OF POINTS IN FV2 VS ACCURACY

Points	Accuracy
0	87.371
3	90.451
5	91.752
9	92.752
11	92.853
13	92.859
15	92.861
17	92.861
19	92.861

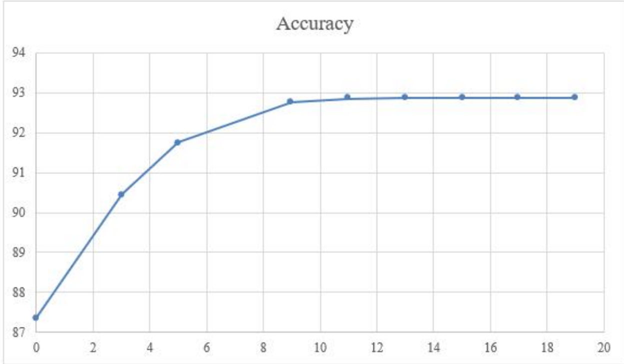

Fig. 11. Number of Points in FV2 vs Accuracy

B. Shape Identification Methodology

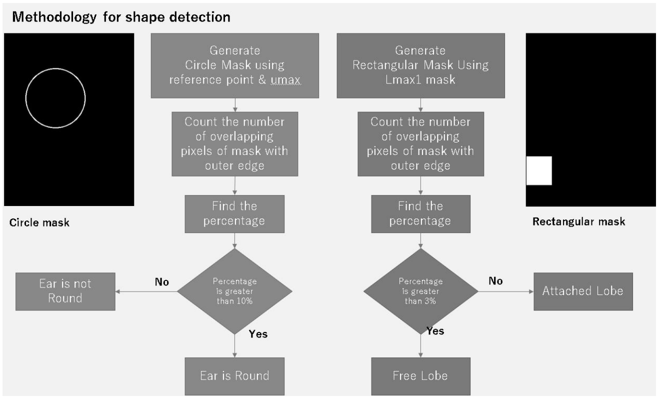

Fig. 12. Methodology for Shape Detection illustrating circular and rectangular mask analysis for classifying ear type and lobe attachment.

To find the shape, we have applied the masking technique. To create the first mask, we have made a circle by taking the midpoint between the reference point and umax. The diameter of the circle is the distance between the reference point and umax.

To create an earlobe mask, we have made a rectangle using lmax. Both masks have been applied to calculate the total number of overlapping pixels, which helped us find the overlapping percentage. The overlap between the circle mask and the earlobe helps us determine if the ear is round or not, while the overlapping region with the rectangle mask determines the shape of the earlobe.

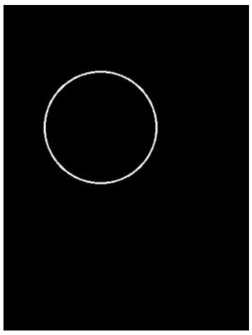

Fig. 13. Cicular ear detection mask

Fig. 14. Free Earlobe detection mask

C. Categories of the ear

TABLE IV. CATEGORIES OF THE EAR

Category	Free Ear Lobe	Round	Narrow
1	*False*	*False*	*False*
2	*False*	*False*	*True*
3	*False*	*True*	*False*
4	*False*	*True*	*True*
5	*True*	*False*	*False*
6	*True*	*False*	*True*
7	*True*	*True*	*False*
8	*True*	*True*	*True*

TABLE V. CATEGORY WISE EAR TYPE

Category	Type of Ear
1	*Attached Ear Lobe* *Square/Pointed* *Not Narrow*
2	*Attached Ear Lobe* *Square/Pointed* *Narrow*
3	*Attached Ear Lobe* *Round* *Not Narrow*
4	*Attached Ear Lobe* *Round* *Narrow*
5	*Free Ear Lobe* *Square/Pointed* *Not Narrow*
6	*Free Ear Lobe* *Square/Pointed* *Narrow*
7	*Free Ear Lobe* *Round* *Not Narrow*
8	*Free Ear Lobe* *Round* *Narrow*

D. Result

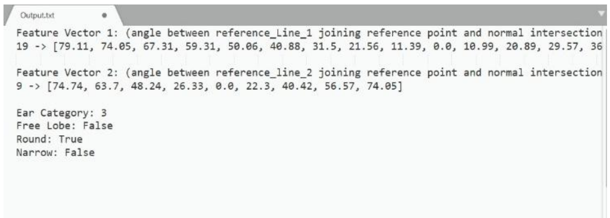

Fig. 15. Program Output

Feature Vector 1- It comprises of the angles that we get in our first feature extraction process for a particular person.
Feature Vector 2 – It stores all the angles that we get during our second feature extraction process for the same person. Ear Category – It tells about the category in which the ear lies, out of 8 above mentioned categories, categories are based on the following three parameters of ear – free earlobe, narrow and round.

TABLE VI. TIME ANALYSIS

Test ID	Time Taken (sec)	
	Combined Database	Distributed Database
1	*0.553*	*0.134*
2	*0.443*	*0.101*
3	*0.345*	*0.096*
4	*0.456*	*0.104*
5	*0.543*	*0.116*
6	*0.345*	*0.067*
7	*0.456*	*0.11*
8	*0.445*	*0.099*
9	*0.567*	*0.148*
10	*0.656*	*0.156*
11	*0.456*	*0.116*
12	*0.564*	*0.141*
13	*0.421*	*0.085*

14	*0.532*	*0.125*
15	*0.671*	*0.165*
16	*0.732*	*0.178*
17	*0.548*	*0.129*
18	*0.478*	*0.11*
19	*0.567*	*0.111*
20	*0.632*	*0.148*
21	*0.691*	*0.167*
22	*0.523*	*0.129*
23	*0.531*	*0.119*
24	*0.323*	*0.111*
25	*0.645*	*0.141*
26	*0.667*	*0.165*
27	*0.467*	*0.112*
28	*0.412*	*0.101*
29	*0.511*	*0.134*
30	*0.498*	*0.156*

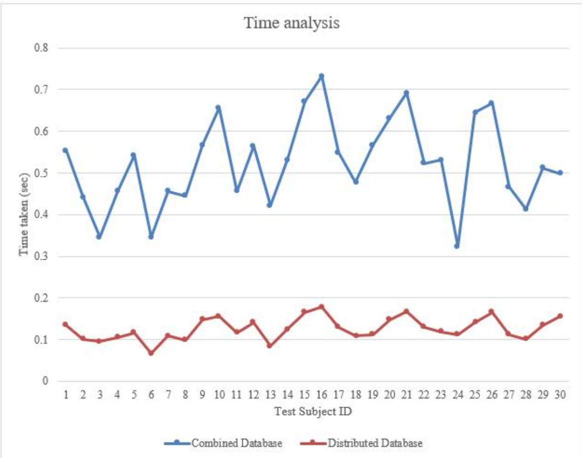

Fig. 1. Time Analysis

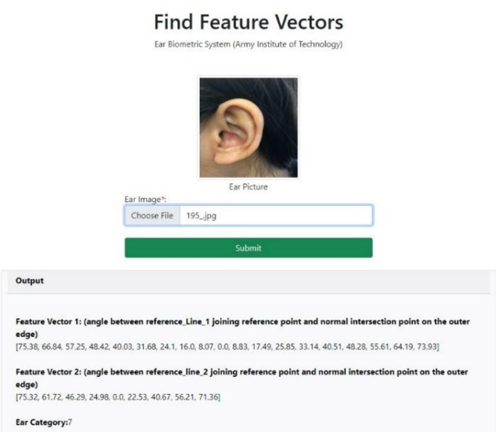

Fig. 16. Feature Vector extraction by GUI

This is a snapshot of our GUI (Graphical User Interface) where the ear image can be uploaded and the respective Feature Vector 1, Feature Vector 2 and ear category (out of above mentioned 8 categories) are obtained in the output pane of the screen.

V. OVERVIEW OF IMPLEMENTATION

Project Implementation:

The methods implemented in this project involve simple mathematical computations as opposed to complicated neural networks that facilitate proper utilization of available resources. This process involves the usage of the following algorithms: sample taking of ear images, Gaussian blurring and edge detection, outer ear contour detection and feature point computation. These processes are efficient at identifying ear contours as well as producing feature vectors.

VI. CONCLUSION

The proposed approach illustrates that the recognition technology for ear biometrics can become an efficient solution that can be used as a contact-free biometric tool. Applying mathematics, including Gaussian blur, and applying the edge detector tool, it is possible to imitate and compare the important ear boundaries. Moreover, the proposed system is not associated with the limitations characteristic of facial and fingerprint recognition and works rather well even if people wear masks.

It would be reasonable to enhance the efficiency of the algorithm by implementing additional datasets and other biometric measures, such as ear biometrics. This project can be seen as a starting point for further research in this field that would help to develop various application solutions for use in attendance systems, security control at airports, and access management systems.

Such an approach can illustrate an efficient use of biometric technology in practice.

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