Person Authentication Using Hough Transform in Ear Biometrics

Annapurani .K[#1], Vishaka B Sekar [*2], A.K.Sadiq[#3],Malathy .C[*4]
[#1] Department of Computer Science, SRM University, Kattankulathur, Chennai 603203 Tamil Nadu, India
[*2] Department of Computer Science, SRM University, Kattankulathur, Chennai 603203 Tamil Nadu, India
[#3] Department of Information Technology, College of Applied Sciences, Sohar
[*4] Department of Computer Science, SRM University, Kattankulathur, Chennai 603203 Tamil Nadu, India
[1] annapoorani.k@ktr.srmuniv.ac.in
[2] vishakabsekar@gmail.com
[3]a_k_sadiq@yahoo.com
[4] malathyc03@gmail.com

Abstract- Biometrics refers to the recognition of individuals based on their physiological and behavioral traits. The ear is one such biometric cue because it is found to be unique even among twins. The proposed technique authenticates, a person using the ear as a biometric by exploiting its inherent geometric and structural details and is rotation and scale invariant. This paper aims at developing a modular, robust, biometric authentication system which utilizes an ear profile, by the use of Hough Transform. The Hough Transform maps the curved features of the ear onto straight lines .This makes it accurate in detecting connected components in outer ear images which have been captured under different environmental conditions like illumination or noise. Due to such variations curved edges are often only partially detected as broken edges. Hough Transform detects the contours of such outer ear images effectively. The curved edges of the outer ear are mapped onto straight lines called Hough Line. The length of the longest Hough Line, called max-line, is used for matching. Matching is done using Manhattan Distance between the max-lines of two images. This system has produced an accuracy of 98.26% when tested on the IIT Delhi database, which is greater than accuracy achieved by other edge based mapping techniques.

Keywords: Geometric, Hough Transform, Curved Edges, Hough Line, Manhattan, Accuracy

I. INTRODUCTION

A biometric system is essentially a pattern recognition system which makes a personal identification by determining the authenticity of a specific physiological or behavioral characteristic possessed by the user. Identity management is the process of creating (linking the attributes to a physical person), maintaining and destroying identities of individuals in a population. An important issue in designing a practical system is to determine how an individual is identified [13].

One of the critical tasks in identity management is person authentication, where the goal is to either determine the previously established identity of an individual or verify an individual's identity claim. Authentication attempts to provide an accurate answer to “Is the individual who he claims to be? “.

This can be accomplished by three methods. The two conventional methods of authentication are based on a person’s exclusive possession of a token (e.g., ID card or key) or knowledge of a secret (e.g., password). The third method, called biometric recognition, authenticates a person based on his biological and behavioral (biometric) traits. Biometrics form a strong link between the person and his identity as the person has to be physically present at the time of authentication [13].

The forensic science literature reports that growth of ear is highly linear after the first 4 months of birth [2]. During the period from eight years to around the age of seventy, the ear structure remains constant for a person, after which it again increases. The proposed ear authentication system uses the outer ear profile for authentication.

The advantages of an ear recognition system can be summarized as follows:

- Less variation of ear structure because of ageing when compared with face
- High stability of the ear pattern throughout a person’s life
- Uniqueness of outer ear shape that do not change because of emotion etc.
- Limited surface of the ear allows faster processing compared with face
- Lack of expressive variation (as in face) reduces the intra-class variations
- Easy to capture ear even at a distance and the process is non-invasive and
- Appearance of the ear is not altered by facial make-up, spectacles or beards

II. RELATED WORK

The potential of the human ear for personal identification was recognized and advocated as early as 1890 by the French criminologist Alphonse Bertillon. Bertillon made use of the description and some measurements of the ear as part of the Bertillonage system that was used to identify prisoners [3].

In his studies regarding personal recognition using the outer ear in 1906, Richard Imhofer needed only four different characteristics to distinguish between 500 different ears [5].

In 1949, the American police officer Alfred Iannarelli [4] conducted the first large scale study on the discriminative potential of the outer ear. He collected more than 10,000 ear images and determined 12 characteristics needed to unambiguously identify a person. Figure 1 show the measurement used in this approach.

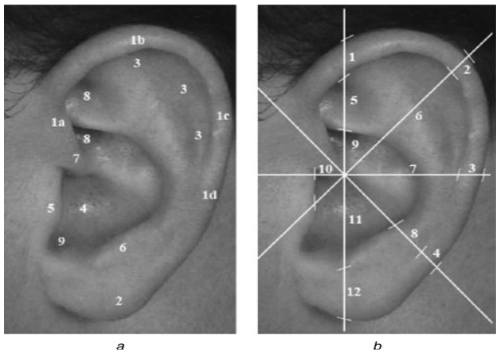

Fig 1. a. Ear anatomy: (1) helix rim, (2) lobule, (3) anti-helix, (4) concha, (5) tragus, (6) anti tragus, (7) crux of Helix, (8) triangular fosse and (9) incisor (10)intertragica b. 12 Measurements used

The problem is to detect the presence of groups of collinear or almost collinear figure points in the ear image. It is clear that the problem can be solved to any desired degree of accuracy by testing the lines formed by all pairs of points. However, the computation required for n points is approximately proportional to n^2, and may be prohibitive for large n.

Also due to imperfections in either the image data or the edge detector, however, there may be missing points or pixels on the desired curves as well as spatial deviations between the ideal line and the noisy edge points as they are obtained from the edge detector.

Hough proposed an interesting and computationally efficient procedure for detecting lines in images. Hough Transform exploited the point-line duality to identify the supporting lines of sets of collinear pixels in images. The Hough transform (HT) is a used for line detection due to its robustness to noise and missing data.

Duda and Hart [13] explored the fact that any line on the x-y plane can be described in terms of ρ and θ. Hence vertical lines which do not have a slope intercept equation can also be represented. In this representation, ρ is the normal distance and θ is the normal angle of a straight line. Applying the Hough Transform to a set of edge points (x_i, y_i) results in an 2D function $C(\rho,\theta)$ that represents the number of edge points satisfying the linear equation $\rho = x \cos \theta + y \sin \theta$. The local maxima of $C(\rho, \theta)$ are to detect straight line segments passing through edge points. It also shows how the method can be used for more general curve fitting.

A method based on reduced Hough transform was proposed by Banafshe Arbab-Zavar and Mark S. Nixon [2] .It proposes the use of the Hough Transform (HT), which can extract shapes with properties equivalent to template matching and is tolerant of noise and occlusion. It finds the elliptical shapes in 2D face profile images to locate the ear regions by using a Hough transform to gather votes for putative ellipse centers in an accumulator, which will go through a refinement process that will eliminate some of the erroneous votes; the location of the peak in this accumulator gives the coordinates of the best matching ellipse. It achieved 91% enrollment success.

Liu [12] performed ear segmentation using histogram based K-means clustering and Hough transformation for ear detection without using training dataset .The clustering is directly applied on to the 2D images.

Pflug et al [1] presented a survey on the approaches in 2D and 3D ear biometrics, covering ear detection and ear recognition systems, discussed their characteristics and reported their performance. The Table I summarizes [1].

TABLE I
Summary of Automatic ear detection methods for 2D and 3D images

Authors	**Detection Method**	**No. of Images and Type**	**Performance**
Prakash & Gupta[12]	Connectivity graph	1604- 3D	99.38%
Arbab-Zavar & Nixon[2]	Hough Transform	942 - 2D	91%
Ansari & Gupta [7]	Edge detection & curvature Estimation	700- 3D	93.34%
Liu & Liu[12]	Adaboost and skin color filtering	50-2D	96%

Suryaprakash, Gupta. P et al [12].The proposed technique is based on connected component analysis of a graph constructed using the edge map of the side face image .Ear localization then builds the edge connectivity graph, and subsequently uses it in finding the connected components in the graph for ear localization purpose. The components having the maximum connectivity are found to form the ear boundary. It produces a maximum success rate of 95% on dataset of 1070 images. The Figure 2 shows the geometric ear recognition performed in [12].

Fig 2. Geometric ear recognition (a) Original edge image, (b) Edge image after approximating edges with line segments

Vyas et al [9] presented a survey of the ear detection methods.14 methods for 2D images and 3 methods for 3D images were discussed with their characteristics and reported their performance.

The results found in [9] are tabulated in Table II.

TABLE II
Accuracy of various ear detection methods

S.No	Technique	Database Used	No. of Images	Accuracy
1.	Deformable contour based	N/A	N/A	N/A
2.	Outer Helix Curve Based	IITK	700	~93%
3.	Template Matching	N/A	103	N/A
4.	Genetic Local Search	N/A	110	N/A
5.	Morphological Operations Based Method	WVU	376	90%
7.	Shape of low level Features	XM2VTS	252	99.6%
8.	Skin Color and Template Based	IITK	150	94%
9.	Distance Transform And Template matching	IITK	150	95.2%
10.	Active Contour Based	N/A	N/A	N/A
11.	Adaboost	UND	203	100%
12.	Shape based	UND	142	100%
13.	Method based on Reduced Hough Transform	XM2VTS	252	91%
14.	Histogram based K-means Clustering and Hough Transform	CVL	180	90%

III. EAR AUTHENTICATION SYSTEM

This paper primarily aims at developing an ear based biometric system which can be used for authenticating people. The increasing variety of biometrics applications in everyday identification and authorization problems urges the development of easily applicable methods.

Therefore rather than use specialized 3D equipment, the focus is for generic deployment via planar images derived from digital cameras. The ear is largely a planar shape and 3D must penetrate the intricate inner ear, which restricts deployment potential. In the case of 2D recognition, detecting ears from cropped side face 2D images is a challenging problem due to the fact that ear images can vary in appearance under different viewing and illumination conditions [9].A suitable way of finding the features of ear images under various environmental conditions by the use of the Hough transform on ear images is proposed here which is tolerant to rotation and illumination variation. This ear authentication system comprises three stages namely

- Image Acquisition and Preprocessing,
- Localization and Feature extraction using Hough Transform
- Matching

In the preprocessing stage, the ear image is normalized and standardized to a common format. Then the feature extraction algorithm is applied on the ear image. Originally the edges belonging to ear are curved [12].But the Hough Transform (HT) breaks every edge of the outer ear into a set of line segments called Hough Lines. This makes it more compact for further processing. The HT arrives at a distance score. The users are assigned a unique secret code each .The distance scores generated and the secret codes are combined to form a feature vector for matching. The block diagram of the proposed ear authentication system is shown in the Figure 3.The authentication proceeds in two phases: Enrollment phase and Verification phase

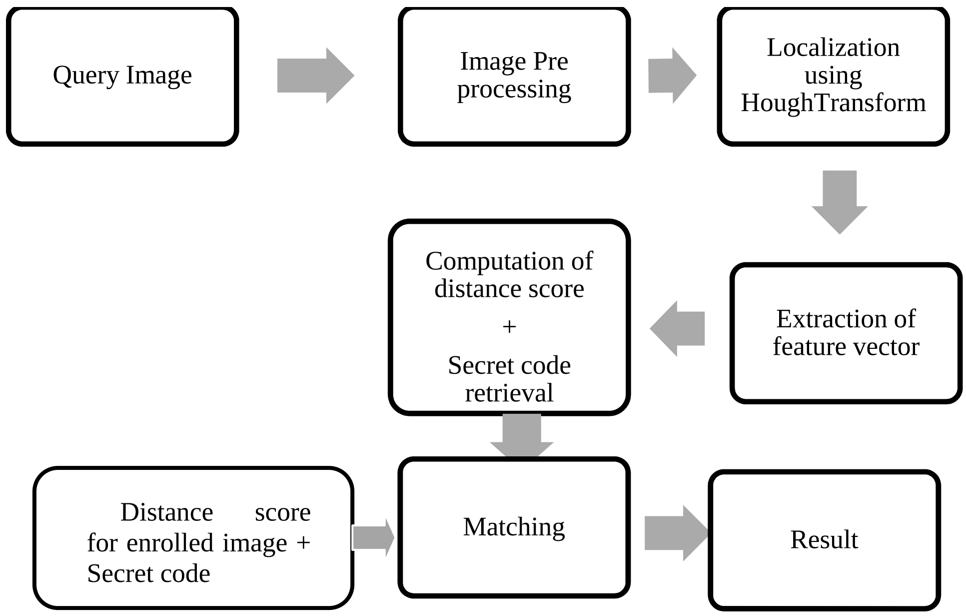

Fig 3. Block Diagram of the ear authentication system

A. Enrollment phase

Enrolment (or registration) in an automatic biometric system is the process of detecting and isolating the area of interest [2] .The enrolment data record comprises one or multiple biometric references and other non-biometric data such as a unique password. In subsequent uses, biometric information is detected and compared with the information stored at the time of enrollment.

It consists of the three steps: Image acquisition, pre processing and Localization using Hough transform.

B. Verification Phase

First, in verification (or authentication) mode the system performs a one-to-one comparison of a captured ear image with a specific template stored in a biometric database in order to verify the individual is the person they claim to be.

Two steps are involved in the verification of a person:.feature extraction and matching. In the first step, the images are subject to feature extraction to produce a feature vector. The feature vectors of enrolled image and query image are then matched. If the distance is less than a threshold, the person is authenticated.

IV. ENROLLMENT PROCESS

A total of 104 ear images of 26 individuals are enrolled, with each individual having 4 images captured under varying environmental conditions. One of the 4 images is the training image. The system is tested against the other three.

A. Image Acquisition

The side face images are acquired using touch less imaging set up under indoor conditions with illumination changes and at varying angles of rotation. All the images are taken from the right side of the face with a distance of approximately 20-25 cm between the face and the camera. The images have been stored in JPEG format.

B. Pre Processing

In this approach the ear part is manually cropped from the side face image and the portions of the image which do not constitute the ear are colored black leaving only the ear. But due to the noise in the image noisy edges may be detected only partially. Low pass filtering, otherwise known as "smoothing", is employed to remove high spatial frequency noise from a digital image is performed using the Wiener filter. The median filter is later applied to restore blurred edges and to remove the strong vertical edges which are part of image borders. They are created when the region containing the ear is cropped from the side face image. The edges of ear image are represented in white and the remaining area is made black by image binarization. Edge detection is performed using the Sobel operator [13].

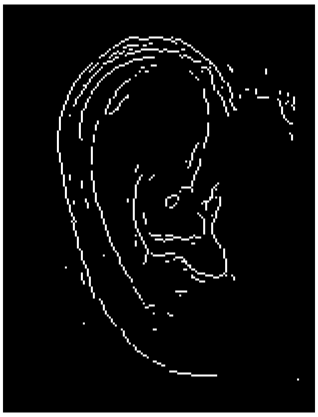

Fig 4. Edge detected image

It can be seen that from Fig 4 the Sobel operator works best for the image as the edges are preserved and are not approximated to form a smooth curve.The outliers are removed properly. The edge detector has detected both horizontal and vertical edges in the ear image.

C. Localization and Feature Extraction Using Hough Transform

This approach proposes the use of the Hough Transform (HT), which can extract shapes with properties equivalent to template matching and is tolerant of noise and occlusion, to find the elliptical shape of the ears in 2D head-profile images. The feature extraction stage prepares an acquired sample for matching and authentication by separating the object of interest from the background. It is an important step for any automatic biometric authentication system.

The algorithm finds the elliptical shapes in cropped 2D side face images by using a Hough transform to gather votes for the region. The regions having maximum votes are plotted as edges. Such curved edges are fitted to straight lines forming a connected edge map. The problem therefore is decomposed into several constrained sub problems i.e. Hough lines .The smaller edges which do not form the boundary are removed leaving only the location of the outer boundary of the ear. Thus the problem of detecting collinear points can be converted to the problem of finding concurrent curves [13].

D. Ear Localization and Approximation of Edges Using Line Segments

Ear localization first builds the edge map, and uses it in finding the collinear points in the map for ear localization purpose.

Hough transform is performed on an edge detected ear image. Each white pixel on the edge detected binary image is represented as a coordinate pair in parameter space (ρ,θ) .For each edge point (x_i,y_i), the value of ρ is calculated as $x_i \cos\theta + y_i \cos\theta = \rho$, $\rho \, \epsilon [-90, +90]$. The ρ-θ plane is partitioned into cells. The spacing between each such cell along the theta axis is 1 degree and 1 degree along θ axis. A 2D array called accumulator A (ρ, θ) is used to store the value of ρ and θ for all edge points in a cell. A voting procedure is then carried out in the parameter space on A. For each edge point the accumulator is incremented

$$\mathrm{A}(\rho, \theta) = \mathrm{A}(\rho, \theta) + 1$$

At the end of this procedure, $\mathrm{A}(\rho, \theta) = \mathrm{P}$, means there are P points in this edge. A graph is plotted for the values of the accumulator bin,$A(\rho, \theta)$.

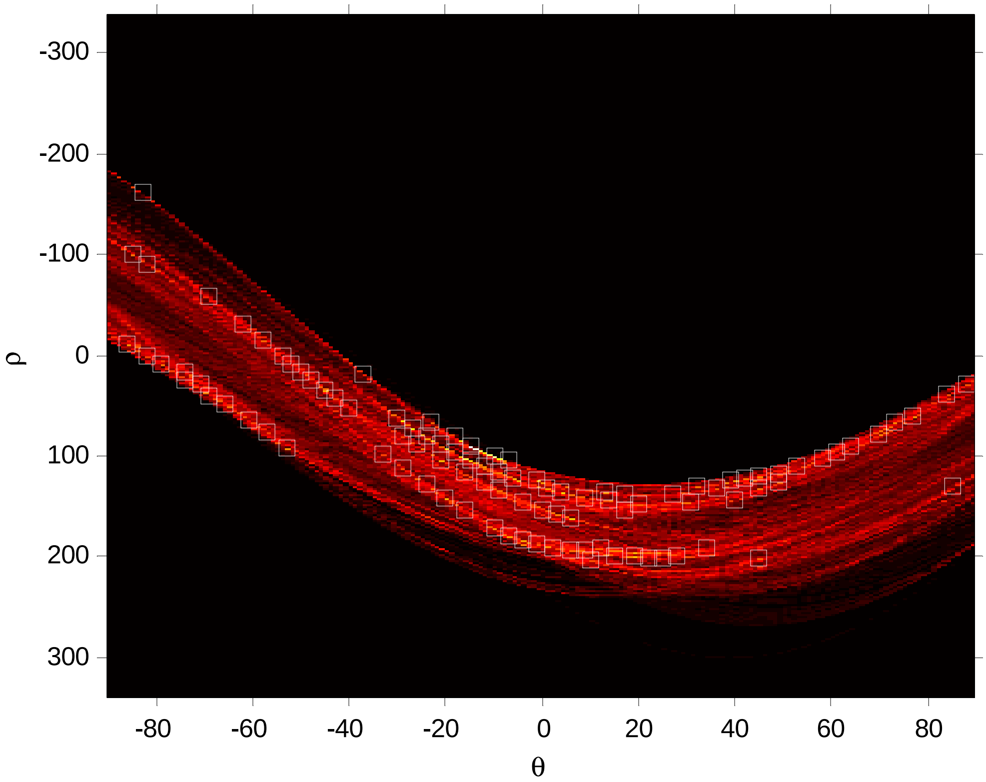

Fig 5. Sinusoidal curves in parametric form

The Figure 5 shows the plot for the values of A. These are plotted for the lines with rotation -90 to +90 degrees. The point of intersection of these sinusoidal curves represents point of intersection of the lines in coordinate space. But they are mostly parallel corresponding to non intersecting lines on the ear boundary. The white boxes in the figure 5 show the peaks of the curves, which are the maxima of the curves. The maxima is found by thresholding the accumulator $A[\rho, \theta]$ .A threshold of 50% is used. The values above the threshold are considered as peaks. These peaks correspond to the strong lines in the image.

V. VERIFICATION PROCESS

The straight lines thus found are fitted to the curvature of the outer ear forming an edge map as shown in Figure 6. The edges which are linear (or almost linear) need only two points for their representation after line segment fitting. In this manner the curved edges are broken down into a set of straight lines called Hough Lines. The Hough Lines are plotted on the binary ear image. The lines are green in color. Their endpoints are depicted in red and yellow Let the set of Hough lines of an image be χ.

A. Extraction of Distance Score

The Euclidean distance between end points of each Hough Line segment in χ is calculated .Let the distances so obtained be Υ. The distance score is defined as

$$\beta = \max(\Upsilon)$$

The line is highlighted in blue in Figure 6 .The above procedure was performed for all the test images in the gray scale format and the result set stored for further matching and comparison.

B. Matching

First, in matching mode the system performs a one-to-one comparison of captured ear image with a specific template stored in an ear image database in order to verify the individual is the person they claim to be. It is a simple algorithm which can be used in security systems.

1)Ear Image Database: It contains the ear images of different people taken in advance. Images of 26 subjects having a resolution of 204x272 are taken with each subject having 4 images of varying rotation, intensity or illumination are taken and stored.

2)Secret code: Both the images are placed in separate folders with their names as a unique secret code assigned to every individual. Two images of the same individual have the same code. One of these is used as sample input and the other as reference image.

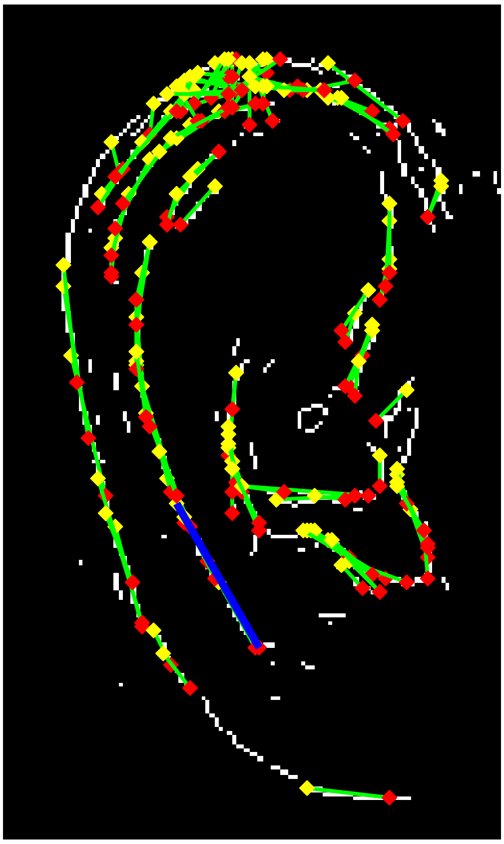

Fig.6 Result of Hough lines in MATLAB

C. Security & Two Part Matching

Firstly the secret code is submitted at the time of comparison. Any user cannot access the system without the knowledge of the secret code. This prevents fake login attempts.

Let the secret code for a particular subject be β_1.Let the distance score for the ear image be β_2.The distance score and the secret code form a feature vector $\alpha = [\beta_1, \beta_2]$where α is the feature vector of the query image .

Let the feature vector of the reference image be, $\alpha' = [\beta'_1, \beta'_2]$ where β'_1 is the secret code and β'_2 is the corresponding distance score Now the reference image submitted by the user during the enrollment phase, having secret code $\beta'_1$is fetched.

The distance D between the two feature vectors is calculated as the Manhattan distance between the two distance scores, $\beta_2$and β'_2 as

$$D = |\beta_2 - \beta'_2| \text{ where } \beta_1 = \beta'_1$$

The distance D is calculated as the distance between the max-lines provided their secret codes $\beta_1$and β1' are identical, i.e.; the distance is found between the enrolled image of a particular user and the test image of a user who claims to be a legitimate user.

D. *Authentication*

If D is less than a threshold then a match is found. A threshold of 70% is used. If the distance D between two images is less than 70%, then the images are said to be matched. The person is verified to be who he/she claims to be. The results of the matching procedure are stored for further analysis.

VI. RESULTS AND DISCUSSION

This technique is tested against the IIT Delhi Ear database, with 26 enrolled users. Each subject has 4 images taken under different angles and illumination. Total of 104 images are enrolled. One image per subject is used as the training image and the test dataset contains three images per subject. The system prompts for the secret code and then the ear image.

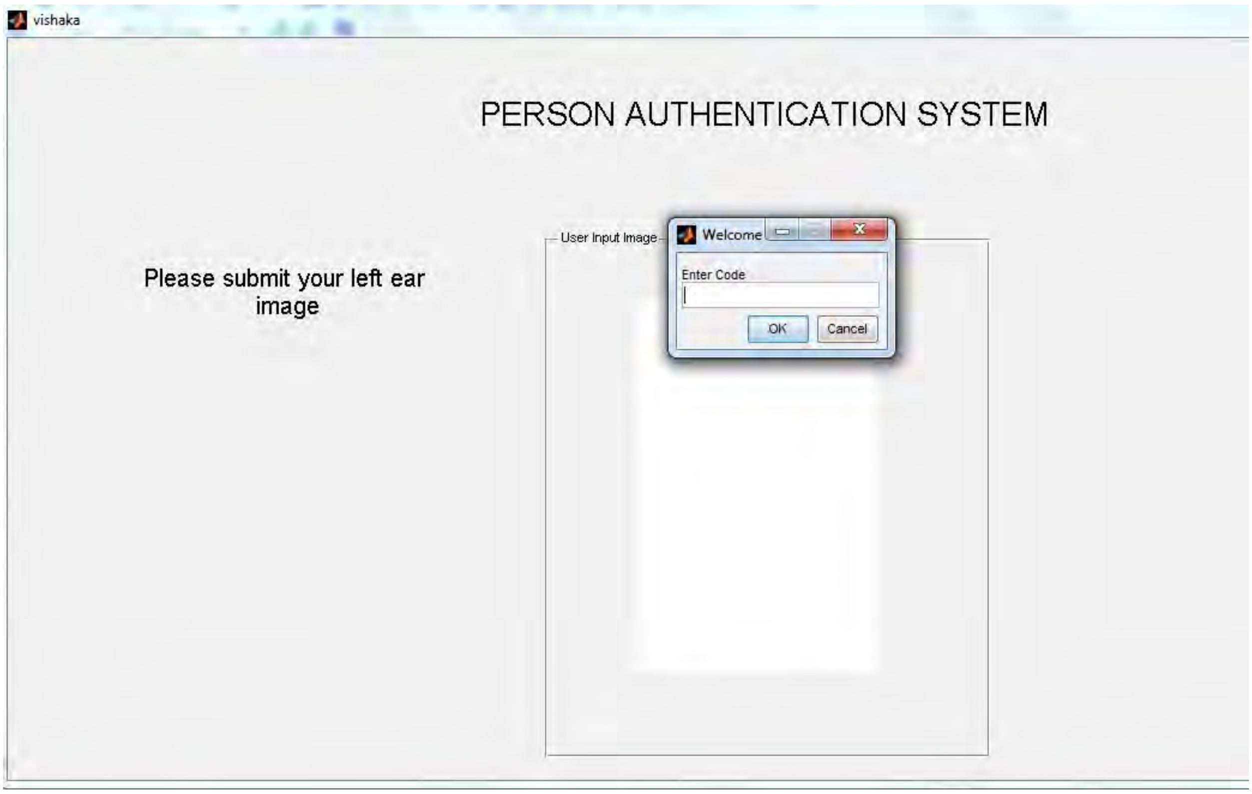

Fig 7- Prompt for secret code

The secret code assigned during the enrollment phase is submitted by the user.

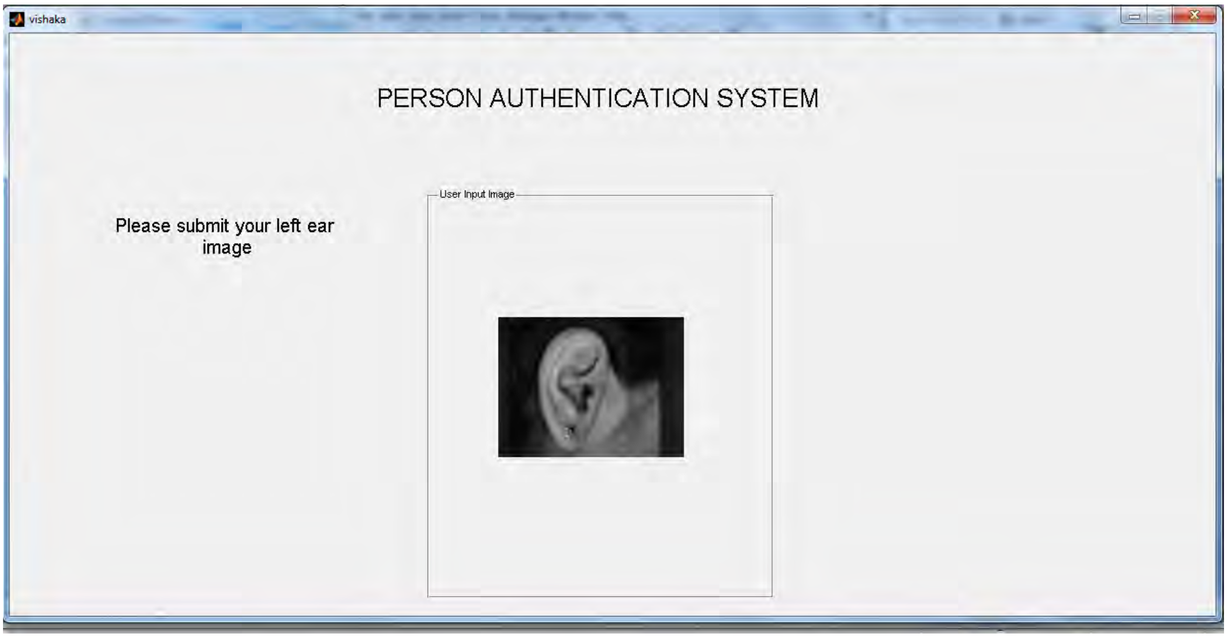

Fig: 8. user then submits a query image

In Fig. 8, the user submits the image for authentication

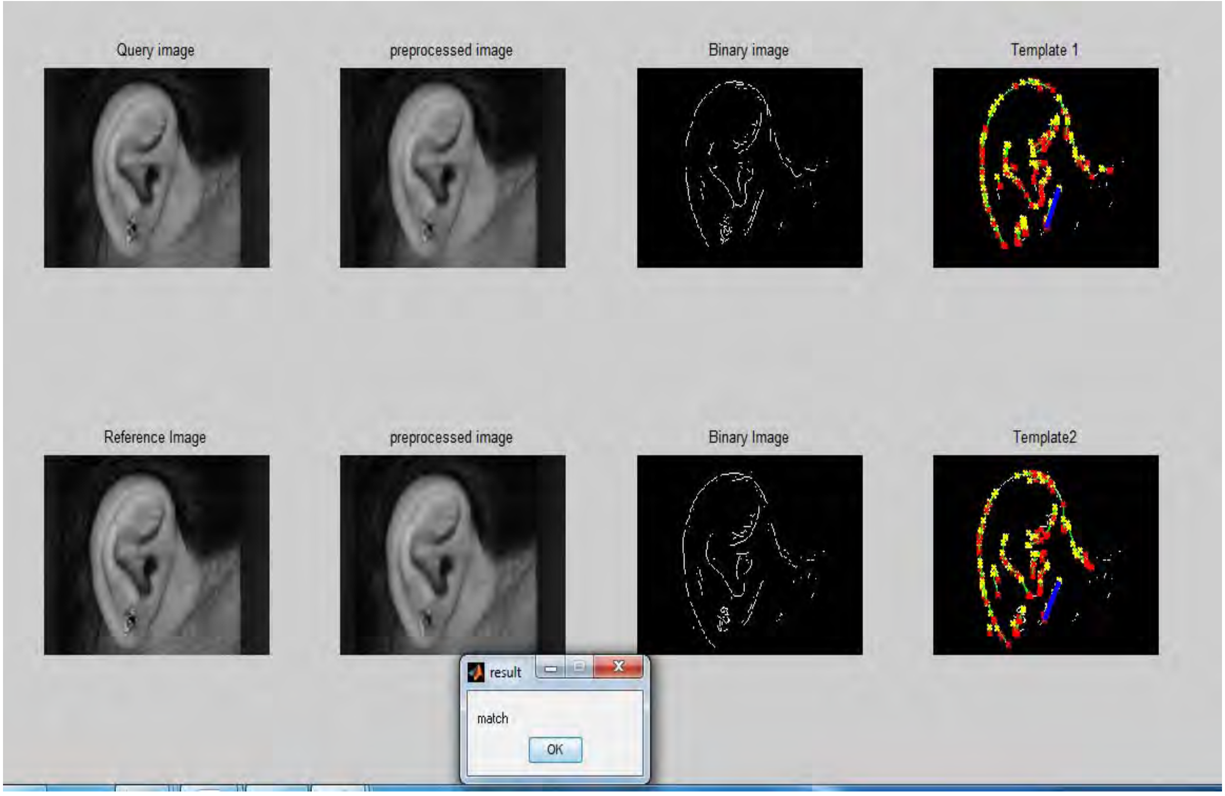

Fig 9. Authentication-Match

If the ear images match, the system displays a message ‘Match’ as shown in figure 9.If they do not match as in Fig. 10, the system displays a message ‘Not match’.

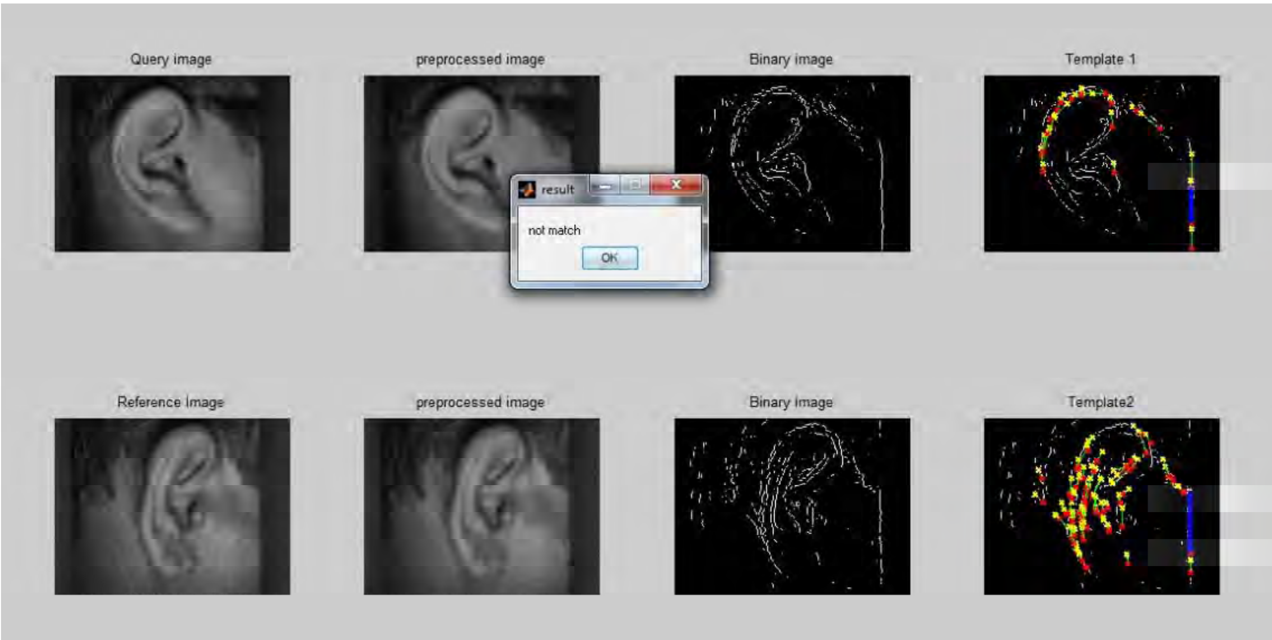

Fig 10. Authentication-Not match

The FAR and FRR are plotted for varying thresholds from 40% to 85% in and recorded in the Table III.

TABLE III
FAR and FRR or Different Thresholds

No.	Threshold in %	FAR	FRR
1	40	0	0.070
2	45	0	0.070
3	50	0	0.060
4	55	0	0.060
5	60	0	0.030
6	65	0	0.030
7	70	0	0.020
8	75	1	0
9	80	1	0
10	85	1	0
		Avg FAR=0.1	Avg FRR=3.4

From the plot FAR vs threshold in figure 11,it is seen that for a threshold value from 40% to 70%,the FAR is 0, which depicts that system performs efficiently and rejects all the impostor images.FAR is optimum at 70%.

The FRR declines rapidly with the increase in threshold from 40% to 75% as shown in in figure 12.The system performs efficiently from a threshold of 75% to 80% by rejecting all the impostor images.The EER is found to be 2% from Figure 13.The accuracy is calculated as

$$\text{Accuracy} = 100 - \left({}^{(FAR + FRR)}/_{2}\right) = 100 - \left({}^{(0.1 + 3.4)}/_{2}\right) = 98.26\%$$

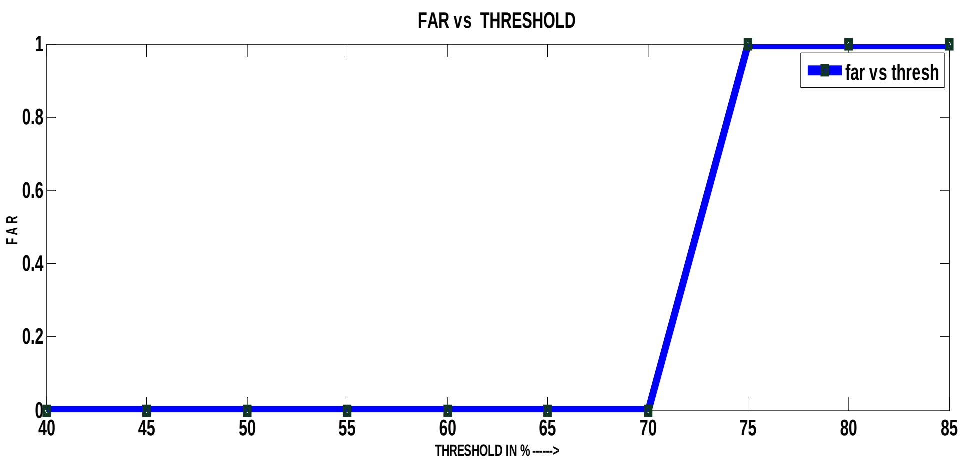

Fig 11. FAR vs Threshold

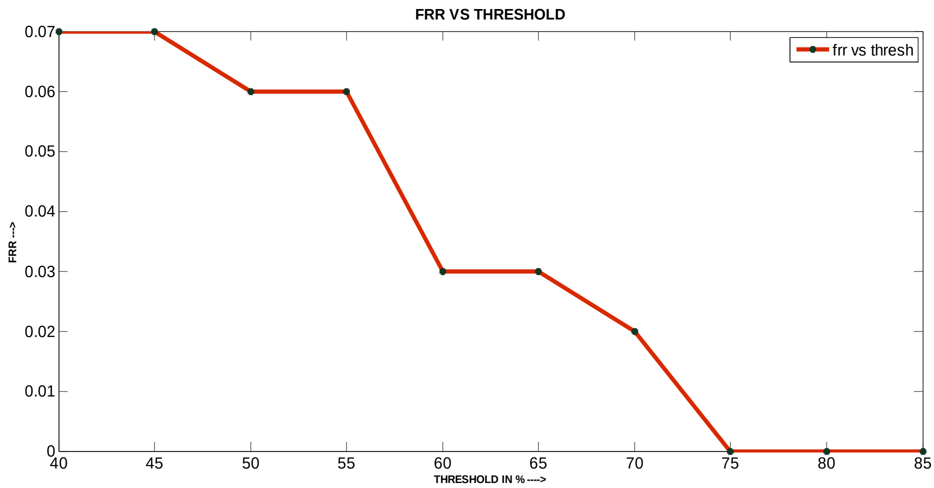

Fig 12 . FRR vs threshold

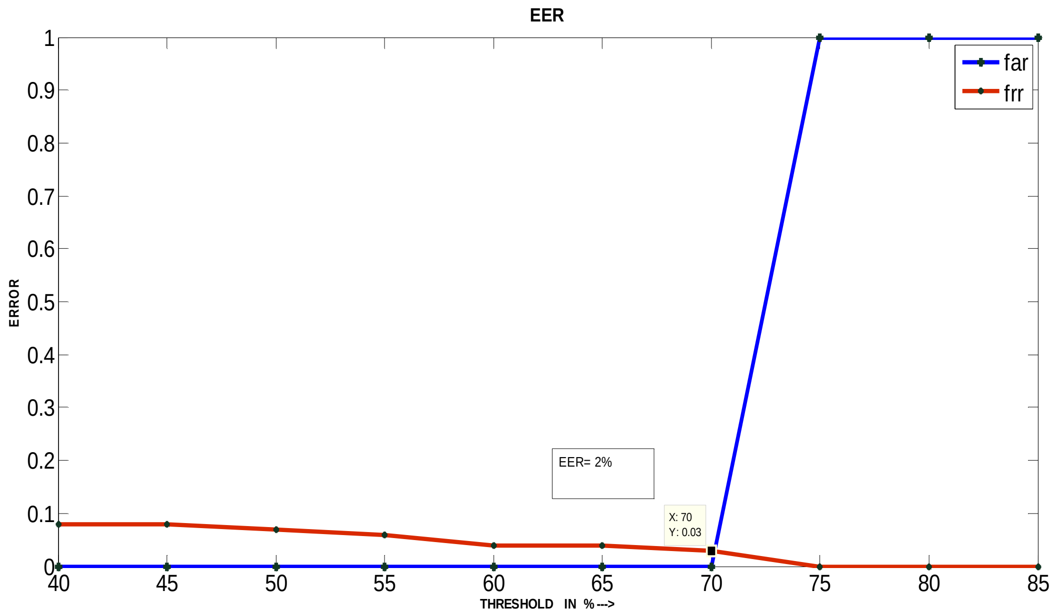

Fig 13. EER

The authentication system has a good FAR until the threshold of 70%.The FAR is maintained at zero till 70% threshold.The system behaves as a perfect system which rejects all impostors.Some genuine users are also classified as impostors.This is better because,the system does not authenticate and grant access to false users in any case.Some genuine users rejected do not pose much threat than granting access to fake users.The FRR has a maximum value of 0.08 and declines rapidly.It can be seen that FRR is initially 0.08% and declines rapidly ,it is maintained at 0 after a threshold of 75%.

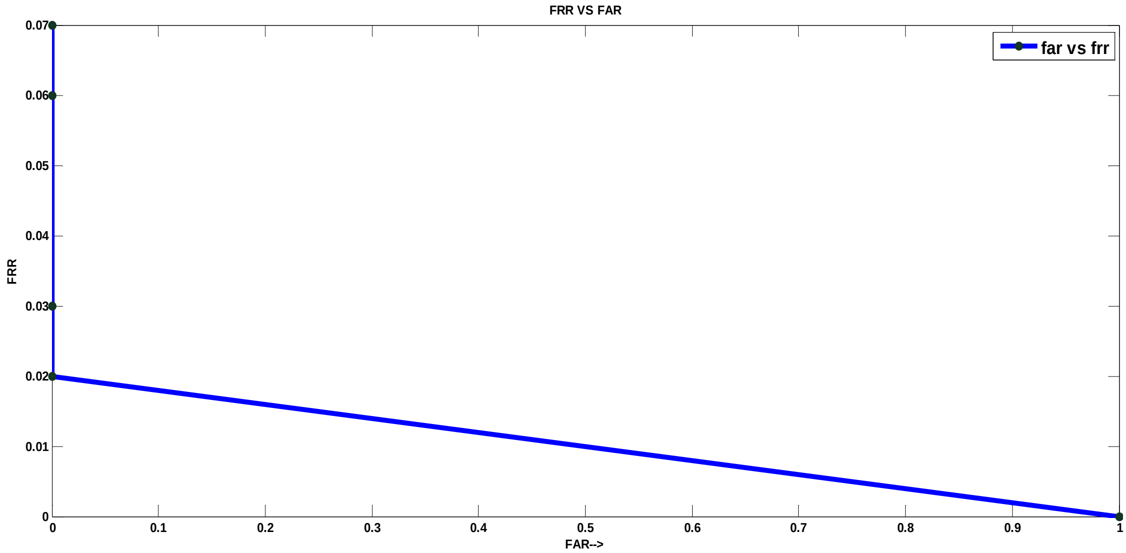

Fig 14. ROC

The receiver operating characteristic (ROC) graphs of Figure.14 is plotted by finding genuine acceptance, false acceptance and false rejection rates using the distance scores for each threshold. The curve of this system is on the axes until a threshold of 70%. It thereby gives enhanced output due to the scale, rotation and illumination invariance of the algorithm until this threshold.

TABLE IV
Comaprison of accuracy

Method used	No of test images	% accuracy
Connected edge based	490	95.88
Reduced Hough Transform	252	91
Outer Helix curve based[7]	700	93
Geometric approach[6]	160	97.5
Proposed Method (Hough Transform)	100	98.26

The Table IV compares the accuracy of the various existing algorithms. As it can be seen, this system performs better than the other approaches

VII. CONCLUSION & FUTURE WORK

This project implemented an efficient technique for automatic ear authentication using structural details of the ear. The technique detects the contours of the outer ear. The ear is extracted from the side face image by the use of Hough transform to build an edge map It is able to authenticate persons when ear images are captured with different rotations, angles and illumination efficiently based on the edge map and a secret code assigned to users. The use of the secret code increases the security of the system as it prevents circumvention. The proposed technique is tested on a database containing 25 subjects with four images each and achieves an accuracy of 98.26% which is greater than other edge based fusion techniques. The FAR is maintained at 0 until a threshold of 70%.The FRR is initially 0.08% and declines rapidly with the increase in threshold .It is maintained at 0 after a threshold of 75%.Hence a suitable trade off between FAR and FRR is achieved at 70 % threshold. The system may classify some genuine users as impostors but does not grant access to fake users thereby securing the system. The accuracy can be increased further by employing suitable filtering techniques to completely remove the extreme edges. Although the system performs well with images of varying rotation and intensity, it can be extended to give better results for images with heavy occlusion by hair, spectacles or hats.

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AUTHOR PROFILE

Annapurani.K Asst.Professor, Department of Computer Science and Engineering, S.R.M University, Chennai, India. She is doing her Research in Biometrics. She has over twenty three years of experience in teaching. Her areas of interest are Image processing, Data Mining and Network Security. She has published research papers in many international conferences and refereed journals.

Vishaka B Sekar completed her undergraduate degree (B.Tech) in Computer Science and Engineering from SRM University,Chennai in the year 2014. Her areas of interests include image processing ,Android app development and is a Robotics programmer certified by iCarnegie,an educational affiliate of the Carnegie Mellon University.

Dr.Mohammed Abdul Karim Sadiq is Asst.Professor, Department of Information Technology, College of Applied Sciences, Sohar. He earned Ph.D. in Computer Science & Engineering from Indian Institute of Technology, Madras. He has over fourteen years of experience in software development, research, management and teaching. His areas of interest are text processing, information retrieval and machine learning. Having published research papers in many international conferences and refereed journals of repute, he has a patent in the United States Patent and Trademark Office. He was an associate editor of Soft Computing Applications in Business, Springer. Moreover, he organized certain international conferences and is on the program committees. He has been awarded a star performer in the software industry.

C.MALATHY Professor, Department of Computer Science and Engineering, S.R.M University, Chennai,India. She is doing her Research in Biometrics. She has over Twenty three years of experience in Teaching. Her areas of interest are Image processing, Data Mining and Computer architecture. She has published research papers in many international conferences and refereed journals.