B.TECH. PROJECT REPORT

On

BIOMETRIC RECOGNITION USING 3D EAR DATA

By

Radheshyam Gupta

DISCIPLINE OF COMPUTER SCIENCE & ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY INDORE

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BIOMETRIC RECOGNITION USING 3D EAR DATA

A PROJECT REPORT

Submitted in partial fulfillment of the

requirements for the award of the degrees

of

BACHELOR OF TECHNOLOGY
in
COMPUTER SCIENCE AND ENGINEERING

Submitted by:

Radheshyam Gupta
Computer Science and Engineering,
Indian Institute of Technology Indore

Supervised by:

Dr. Surya Prakash, Assistant Professor
Computer Science and Engineering

INDIAN INSTITUTE OF TECHNOLOGY INDORE
December 2018

CANDIDATE'S DECLARATION

I hereby declare that the project entitled **"BIOMETRIC RECOGNITION USING 3D EAR DATA"** submitted in partial fulfillment for the award of the degree of **Bachelor of Technology** in **Computer Science and Engineering** is an authentic work.

Dr. Surya Prakash, Assistant Professor, Discipline of Computer Science and Engineering, IIT Indore supervised the Project**.**

Further, I declare that I have not submitted this work for the award of any other degree elsewhere.

Radheshyam Gupta,

150001026,

Discipline of Computer Science and Engineering,
Indian Institute of Technology Indore.

CERTIFICATE BY BTP GUIDE

It is certified that the declaration made by the student in the previous page is correct to the best of my knowledge.

Dr. Surya Prakash,

Assistant Professor

Discipline of Computer Science and Engineering,

IIT Indore.

PREFACE

This report on “Biometric Recognition Using 3D Ear Data” is prepared under the guidance of Dr. Surya Prakash.

Through this Report I have tried to give a detailed explanation on Biometric Recognition Using 3D Ear Data. I have tried to the best of my abilities and knowledge to explain the content in more informative, illustrative and lucid manner. I have added certain figures of experimental setup to explain the mechanism. Simulation results and Experimental results are given in the respective section.

Acknowledgements

It is my privilege to express my gratitude to several persons who helped me directly or indirectly to conduct this research project work. I would especially like to thank my guide **Dr. Surya Prakash & Iyyakutti Iyappan G**. for providing his invaluable guidance, support, suggestions, and ideas throughout the course of the project. I also thank him for constantly motivating me to work hard.

This study has indeed helped me to explore more knowledgeable avenues related to this topic and I am sure it will help me in future.

Radheshyam Gupta

150001026

Discipline of Computer Science & Engineering

IIT Indore

ABSTRACT

Biometric authentication using ear image is a new research area. Many unique features of human ear are explored but few are used. The ear serves as the basis for a new class of biometrics, there is the need to show that it is viable (i.e., Universal, unique, Permanent, Collectable). In the same way any one can prove that fingerprints are unique or not, there is no separate way to visualize that each human has a unique pair of ears. Since every individual has ears, it is rational to show that the ear is unique. The ear is also collectable using various means. The ear has several universal key points which can be used for identification. The main challenge in ear recognition systems is producing an automated method to extract those specific key points. This project focuses on one such area, that is Authentication using ear image, it aims at the development of an automatic ear recognition system using 3D ear data(und 3D ear data set).

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Chapter 1

Introduction

Biometrics are automated methods of recognizing/identifying a person based on a physiological or behavioral characteristic.

For example:- face, fingerprint, hand geometry, iris, retina, signature, and voice.

The security field uses three different types of authentication:

1. Something you know — a password, PIN, or piece of personal information
2. Something you have — a card key, smart card, or token
3. Something you are — a biometric.

Chapter 2

BACKGROUND OF BIOMETRICS

2.1 NEED FOR BIOMETRICS

Biometric technologies are becoming the foundation of an extensive array of highly secure identification and personal verification solutions. As the level of security breaches and transaction fraud increases, the need for highly secure identification and personal verification technologies is becoming apparent.

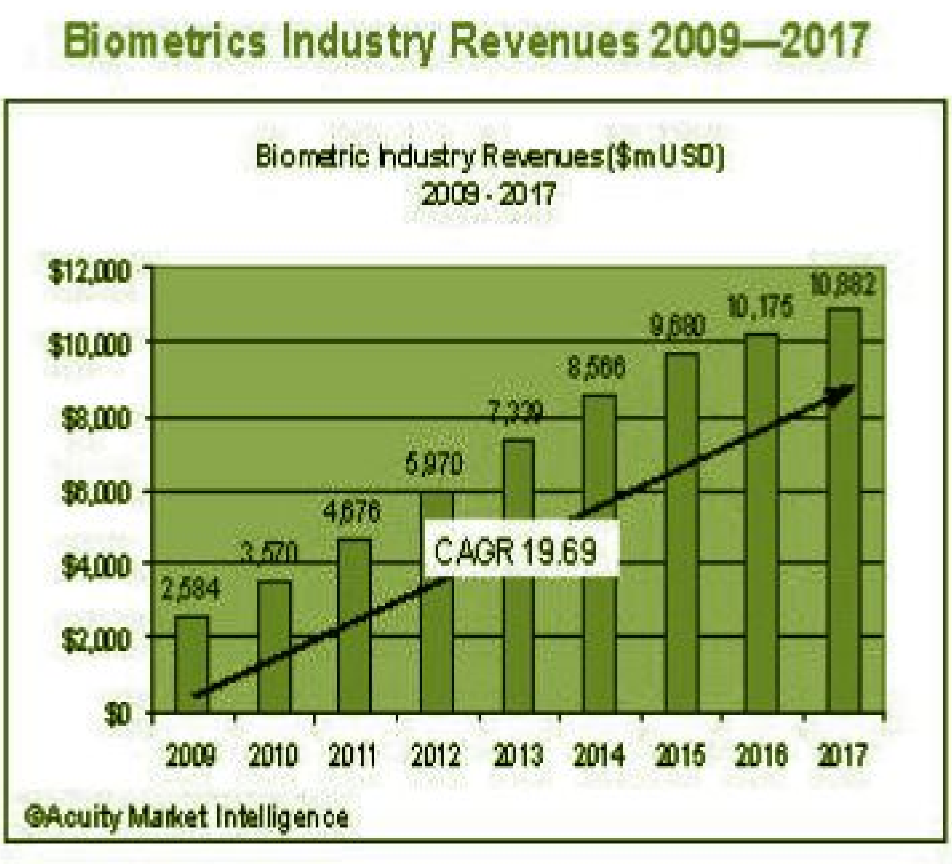


Figure 1 : shows the total biometrics revenues prediction in 2009–2017.

2.2 BIOMETRICS SYSTEM ARCHITECTURE

A biometrics system has four major components:

1.User Interface Module : Provides an Interface between users and the system.

2.Acquisition Module : Capturing the biometric traits for further Processing.

3.Recognition Module : It consists of image pre-processing, feature extraction, template creation, database updating, and matching. Then it gives an identification/verification result.

4.External Module : Receives the signal come from the recognition module, to allow some operations to be performed, or denied the operations requested.

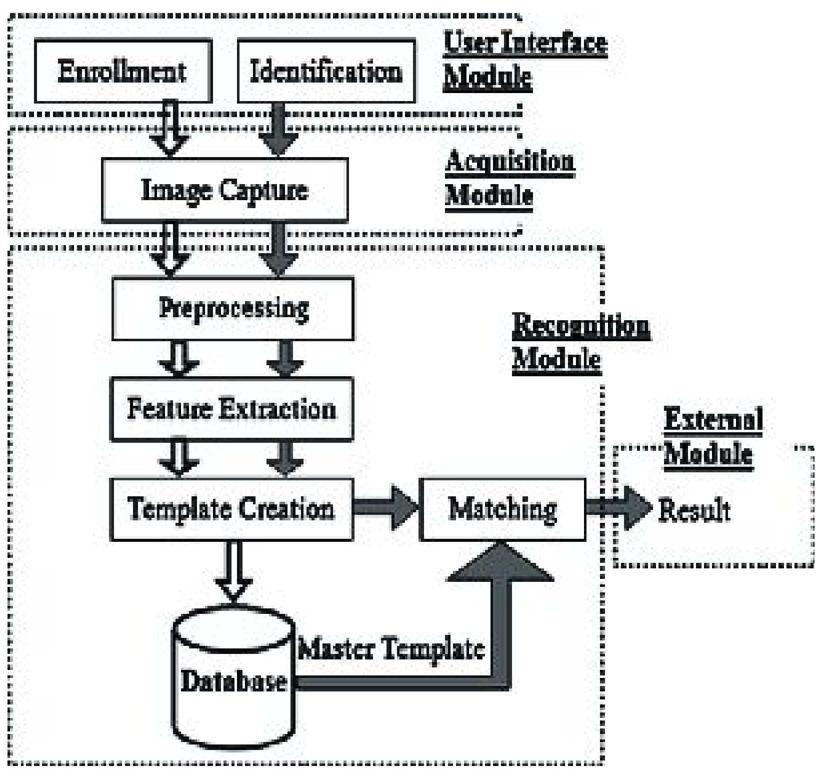


Figure 2 : Breakdown of each module of Biometrics authentication system.

2.3 OPERATIONS MODE OF A BIOMETRIC SYSTEM

1.Enrollment:

Before a user can be verified or identified by the system, he/she must be enrolled by the biometrics system.

2.Identification

This refers to the identification of a user based solely on his/her biometrics information, without any prior knowledge about the identity of a user Identification is referred to a 1-to-n matching.

3.Verification

This requires that an identity (ID card, smart card or ID number) is claimed, and then a matching of the verification template with master templates is performed to verify the person's identity claim.Verification is referred to a 1-to-1 matching, or authentication.

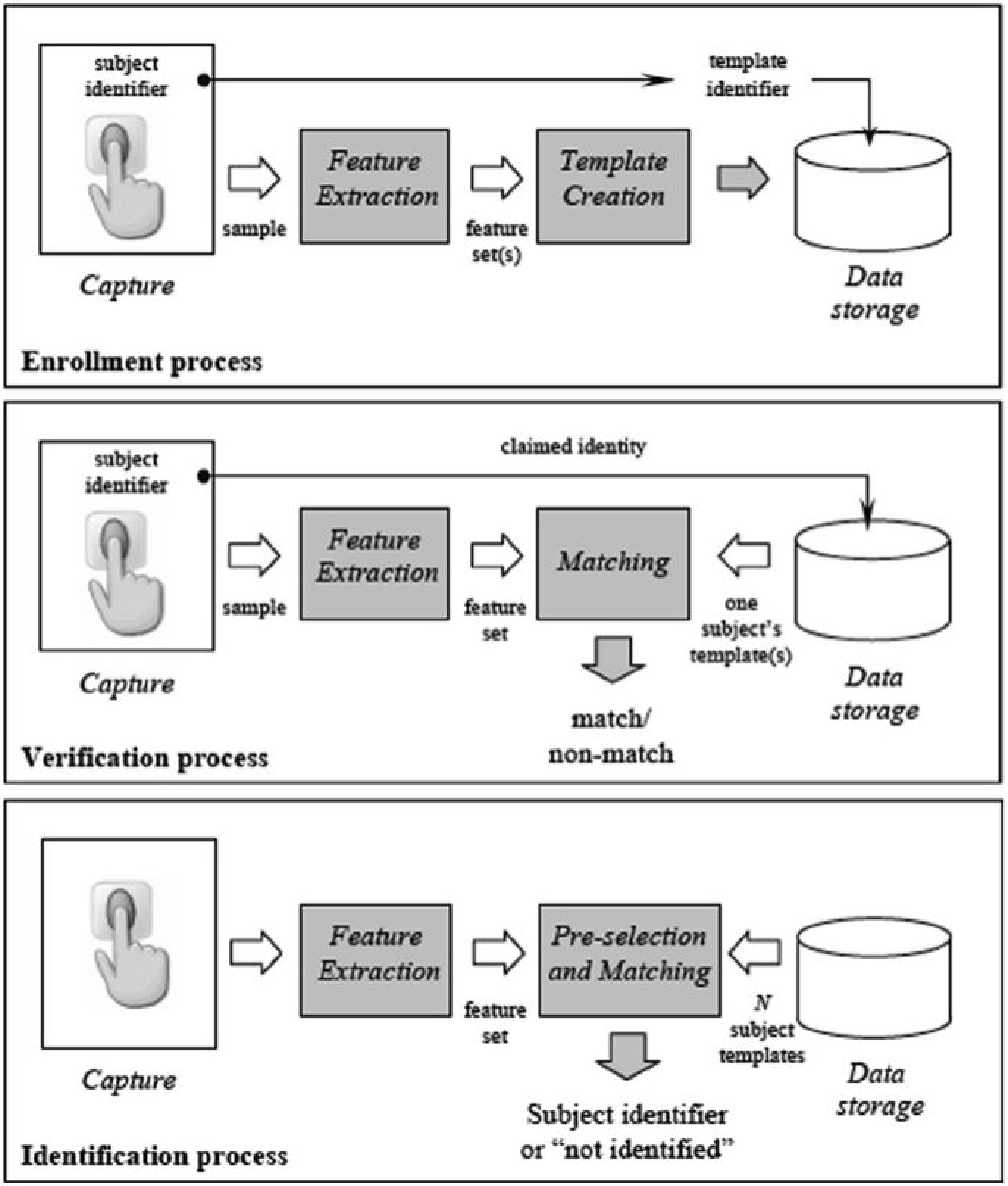


Figure 3 : Operations mode of a biometric system.

2.4 EVALUATION OF A BIOMETRIC SYSTEM

Seven factors affect the determination of a biometrics identifier, including: universality, uniqueness, permanence, collectability, performance, acceptability, and circumvention.

1. **Universality:** Biometrics is a set of features extracted from the human body or behaviour. Some human beings do not have some biometrics. For example, a worker may lose his/her fingerprint because of physical work. A dumb person does not have voice print. Universality points out the ratio of the human beings with special biometrics.

2. **Uniqueness:** If a Biometrics is unique, it can be used to completely distinguish any two persons in the world. The identical twins with the same genetic genotype are one of the important test for uniqueness. Observing the similarity of a biometrics in a large database is also an important indicator for uniqueness.

3. **Permanence:** Many biometrics will change time by time, such as voice print, face. Iris and fingerprint, which are stable in a long period of time, are relative permanence. Permanence is described by the stability of a biometrics.

4. **Collectability:** Although some biometrics have high permanence, uniqueness and universality, it cannot be used for public because of collectability. If the data collection process is too complex or requires high cost input devices, the collectability of this biometrics is low. DNA and retina suffer from this problem.

5. **Performance:** The term "Performance" is referred to accuracy, which is defined by two terms, False Acceptance Rate (FAR) and False Rejection Rate (FRR) which are

controlled by a threshold. Reducing FAR (FRR) must increase FRR (FAR). Equal Error Rate (EER) or crossover rate also refers accuracy.

6. **Acceptability:** Best to produce a user-friendly biometrics system. In fact, almost all the current biometrics systems are not physically intrusive to users but, some of them such as, retina based recognition system, are psychologically invasive system. Retina-based recognition system requires a user to put his/her eye very close to the equipment and then infrared light passes through his/her eye to illuminate his/her retina for capturing an image.

7. **Circumvention:** The term "Circumvention" refers to how easy it is to fool the system by using an artefact or substitute.

Chapter 3

A NEW TREND: 3D BIOMETRICS

In the past decade, biometrics recognition has been growing rapidly, and many biometrics systems have been widely used in applications. However, most of the biometrics recognition techniques are based on 1D signals or 2D images.

There are many limitations of 1D and 2D biometrics technologies until now:

1. Fingerprints may be distorted and unreadable or unidentifiable if the person's fingertip has dirt on it, or if the finger is twisted during the process of fingerprinting. In an ink fingerprint, twisting could cause the ink to blur, distorting the shape of the fingerprint and potentially making it unreadable.

2. It is found that with age, the voice of a person differs. Also, when the person has flu or throat infection the voice changes, or if there are too much noise in the environment this method may not authenticate correctly.

3. The conventional 2D palm print recognition is a fast and effective personal authentication method, but 2D palm print images can be easily counterfeited. Although 2D biometrics recognition techniques can achieve high accuracy, the 2D features can be easily counterfeited and much 3D feature structural information is lost. Therefore, it is of high interest to explore new biometrics recognition techniques: 3D Biometrics.
With the development of 3D techniques, it is possible to capture 3D characteristics in real time. Recently, 3D techniques have been used in biometrics authentication, such as 3D face, 3D fingerprint, 3D palmprint and 3D ear recognition, and shown many advantages, such as:

4. 3D biometrics is much more robust to illumination and pose variations than 2D biometrics.

5. 3D range data may offer a richer information source for feature extraction. And usually it also can fuse with 2D biometrics to enhance the system accuracy.

6. 3D biometrics systems are more robust to attack, since 3D information is more difficult to be duplicated or counterfeited.

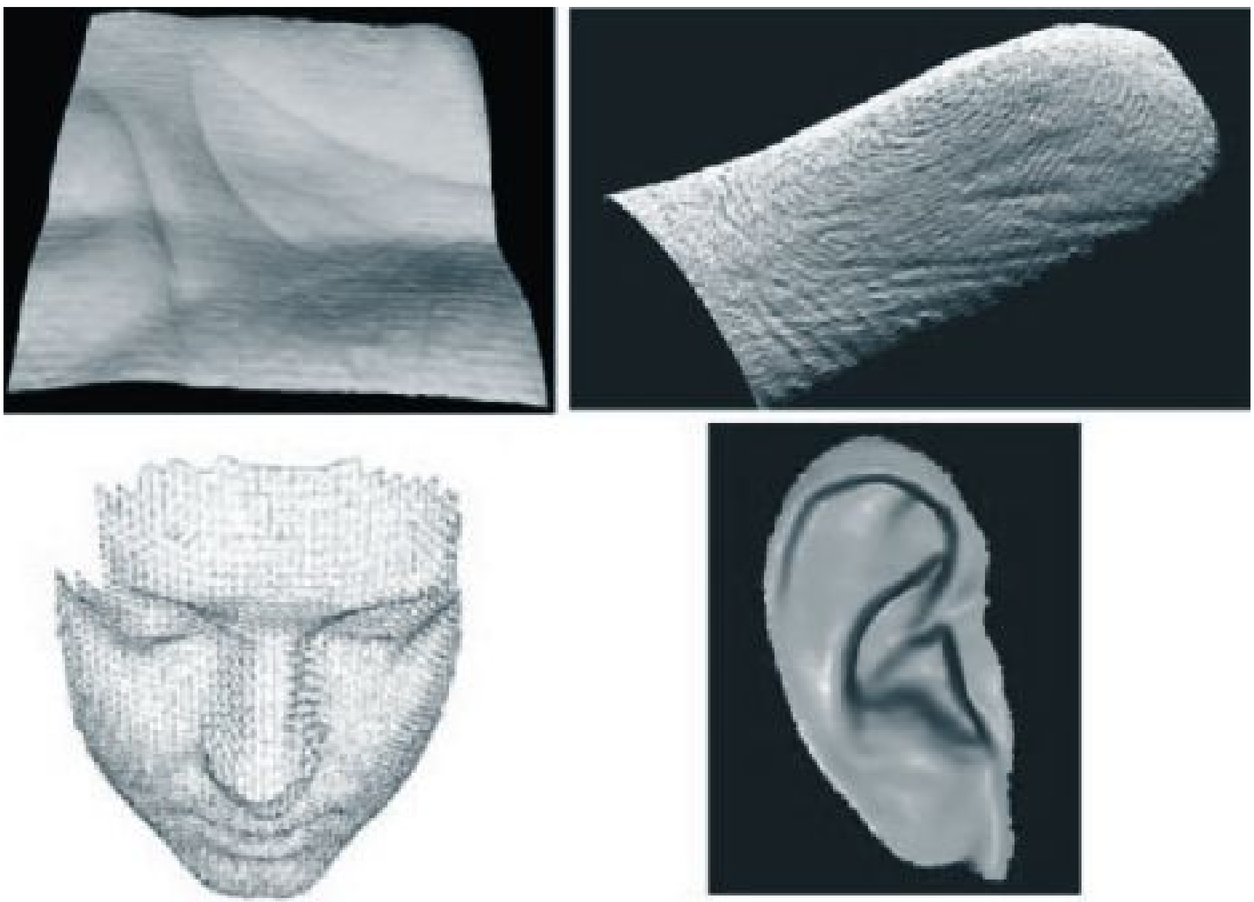


Figure 4 : Operations mode of a biometric system.

Chapter 4

3D EAR FEATURE EXTRACTION & RECOGNITION

1. Five different features in 3D ear, including point, line and area as local feature, and angle and distance as global feature. Then we discuss the methods to extract these features.

2. The experimental results are given to illustrate the effectiveness of the features. Finally, some applications in indexing and recognition are implemented.

3. Based on a 3D ear image collected by our laser capturing device, five kinds of features could be defined.

4. The point feature, line feature, and area feature describe key points, shapes and the local area of 3D ears. They will be treated as local features.

5. The angle feature and distance feature represent gesture and scale of a 3D ear, and we treat them as global features.

4.1 PERFORMANCE MEASURES OF BIOMETRIC SYSTEM

Performance:- The term “Performance” is referred to accuracy, which is defined by two terms, (1) False Acceptance Rate (FAR) and (2) False Rejection Rate (FRR) which are controlled by a threshold. Reducing FAR (FRR) has to increase FRR (FAR). Equal Error Rate (EER) or crossover rate also refers accuracy.

Apply Only ICP Between Test and Train Folder :

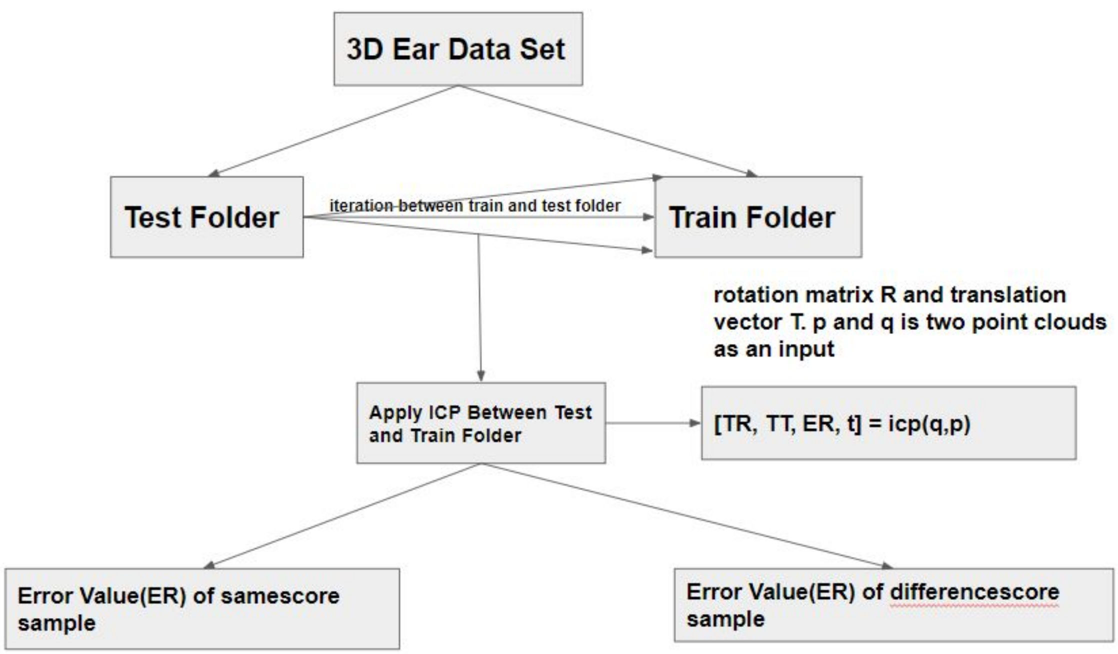


Figure 5 : ICP process.

PERFORMANCE EVALUATION

By applying a varying score threshold to the similarity scores, pairs of FRR and FAR calculated. Results are presented either as such pairs,i.e FRR at a certain level of FAR, or in plots (see below).

When comparing two systems, the more accurate one would show lower FRR at the same level of FAR.

Plotting performance evaluation results:

Plots FRR (Y-axis) vs. FAR (X-axis), i.e. false negative vs. false positive rate, often using logarithmic scale (at least for the FAR axis).

Equal Error Rate is defined as the value obtained at some threshold level of a biometric system where the False Acceptance Rate (FAR) and False Rejection Rate (FRR) are the same. It is also called a crossover error rate.

1. False Acceptance Rate (FAR): It is defined as the fraction of candidates falsely accepted by a biometric system. That means, it is the rate at which an imposter is incorrectly accepted as genuine person. A false acceptance may lead to damages and it occurs when matching score established by a biometric system for an imposter satisfies the threshold criteria of matching. Low value of FAR shows that the biometric system can efficiently capture the inter-class variability through its feature representation and matching.

$$\text{FAR} = \frac{\textit{Number of Imposters Accepted} \times 100}{\textit{Total Number of Imposter Comparisons}}\ \%$$

2. False Rejection Rate (FRR): It represents the fraction of candidates falsely rejected by a biometric system.

$$\text{FRR} = \frac{\textit{Number of Genuine Persons Rejected} \times 100}{\textit{Total Number of Genuine Comparisons}}\ \%$$

3. Equal Error Rate (EER): It is defined as the rate at which both FAR and FRR errors are equal, i.e. EER = FAR for which FAR = FRR.

4. Recognition Accuracy: It is used to measure the performance of a verification system and is defined as Recognition Accuracy = $(100 - \frac{FAR+FRR}{2})\%$.

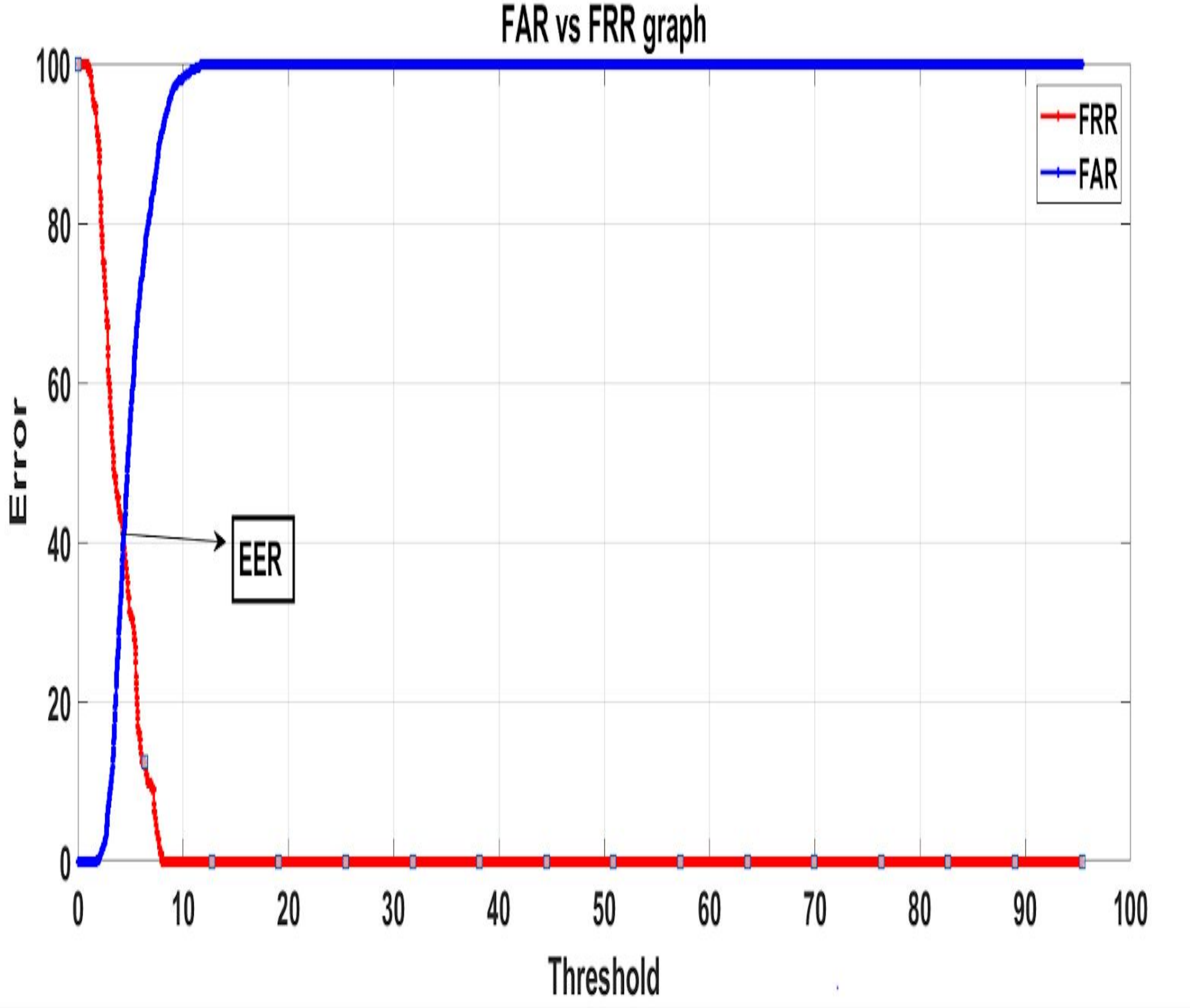


Figure 5: FAR vs FRR graph of 3D ear data and Equal Error Rate.

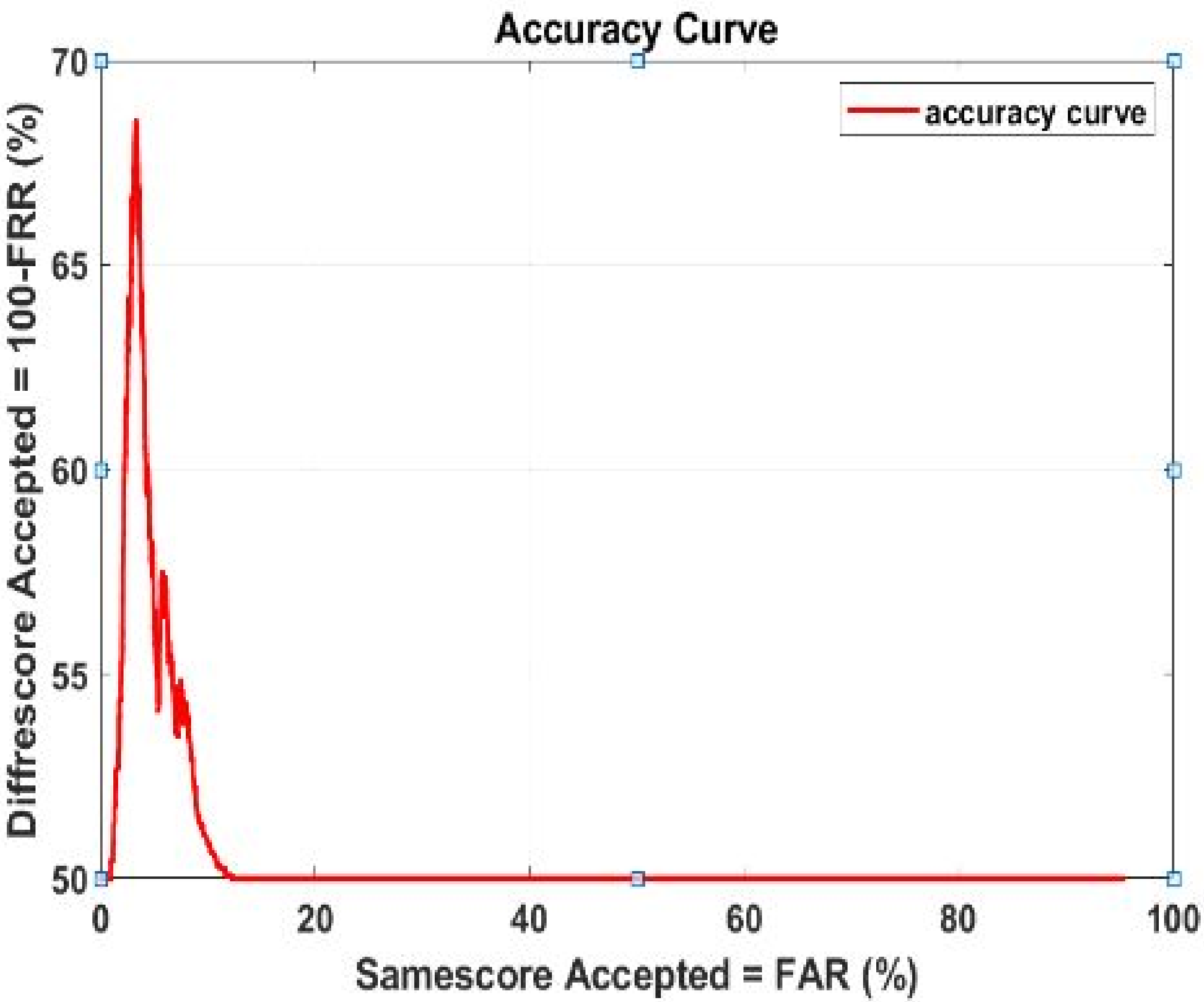


Figure 6 : Accuracy Curve of 3D ear data.

EVALUATION Of FAR/FRR/EER FOR RANDOMLY CHOSEN CLOUD POINT

Apply Two Time ICP 3D Data Set Between Randomly Chosen Cloud Point Test and Train Folder

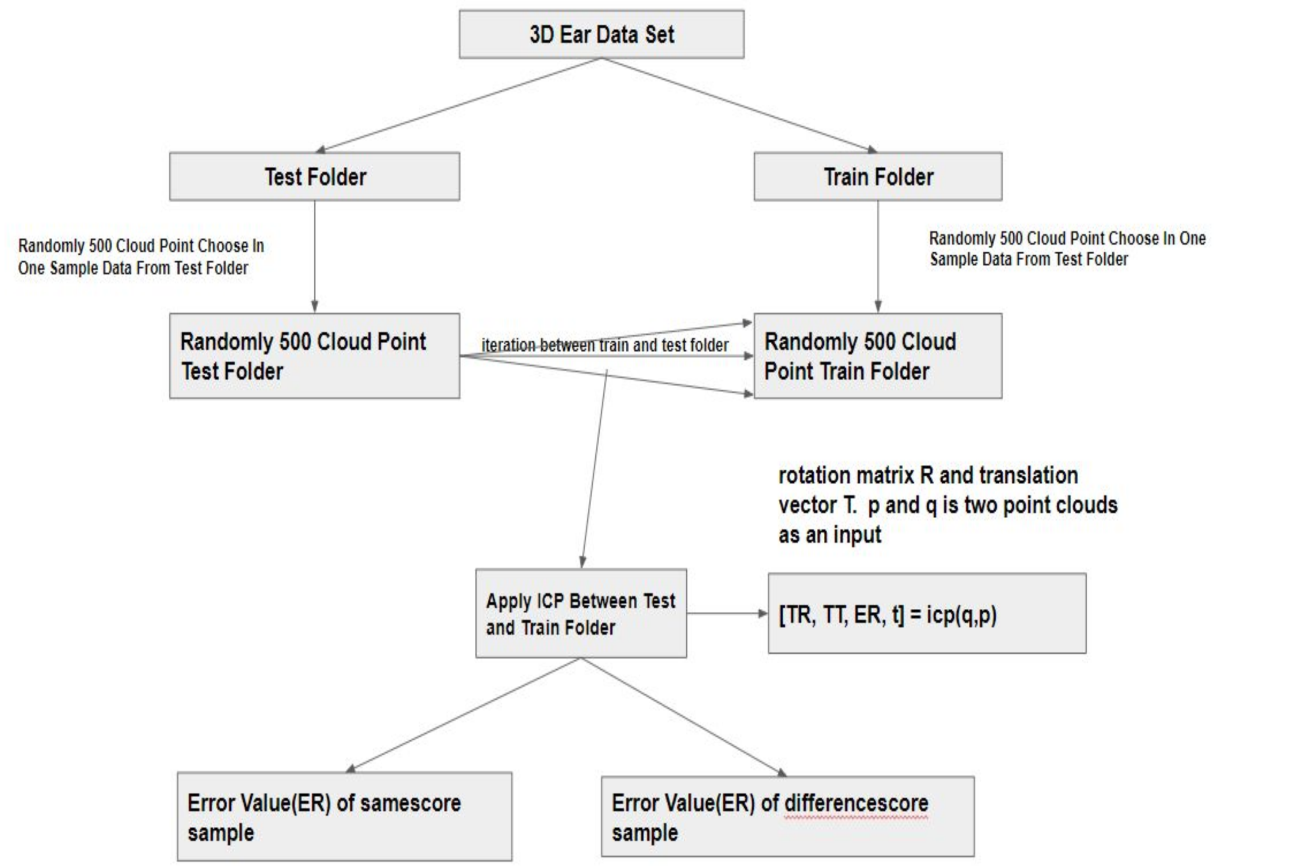


Figure 7 : ICP process between randomly chosen cloud point.

Plotting performance evaluation results:

plots FRR (Y-axis) vs. FAR (X-axis), i.e. false negative vs. false positive rate, often using logarithmic scale (at least for the FAR axis).

Equal Error Rate is defined as the value obtained at some threshold level of a biometric system where the False Acceptance Rate (FAR) and False Rejection Rate (FRR) are the same. It is also called a crossover error rate.

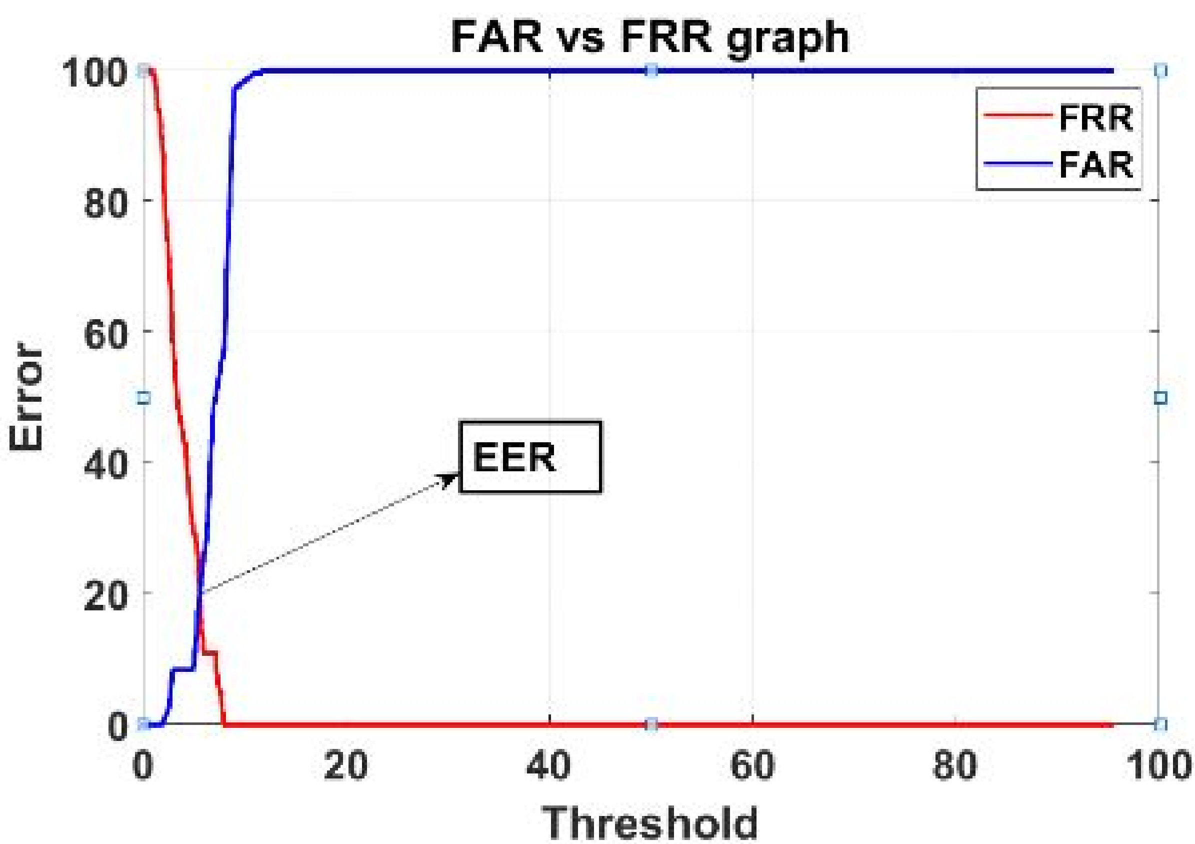


Figure 8 : FAR vs FRR graph of 3D ear data Randomly 500 chosen cloud point and Equal Error Rate(EER).

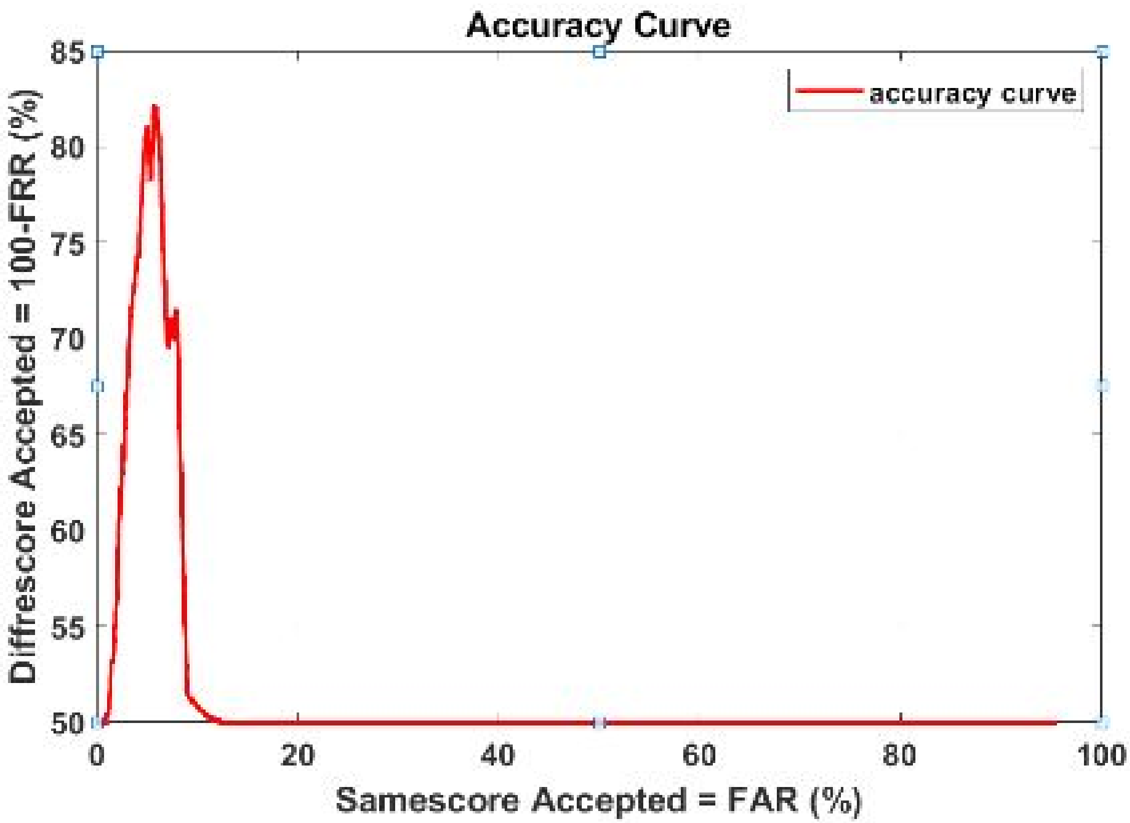


Figure 8 : Accuracy Curve of 3D ear data Randomly 500 chosen cloud point.

Apply Only ICP Between Test and Train Folder(500 subject) :

Plotting performance evaluation results:

plots FRR (Y-axis) vs. FAR (X-axis), i.e. false negative vs. false positive rate, often using logarithmic scale (at least for the FAR axis).

Equal Error Rate is defined as the value obtained at some threshold level of a biometric system where the False Acceptance Rate (FAR) and False Rejection Rate (FRR) are the same. It is also called a crossover error rate.

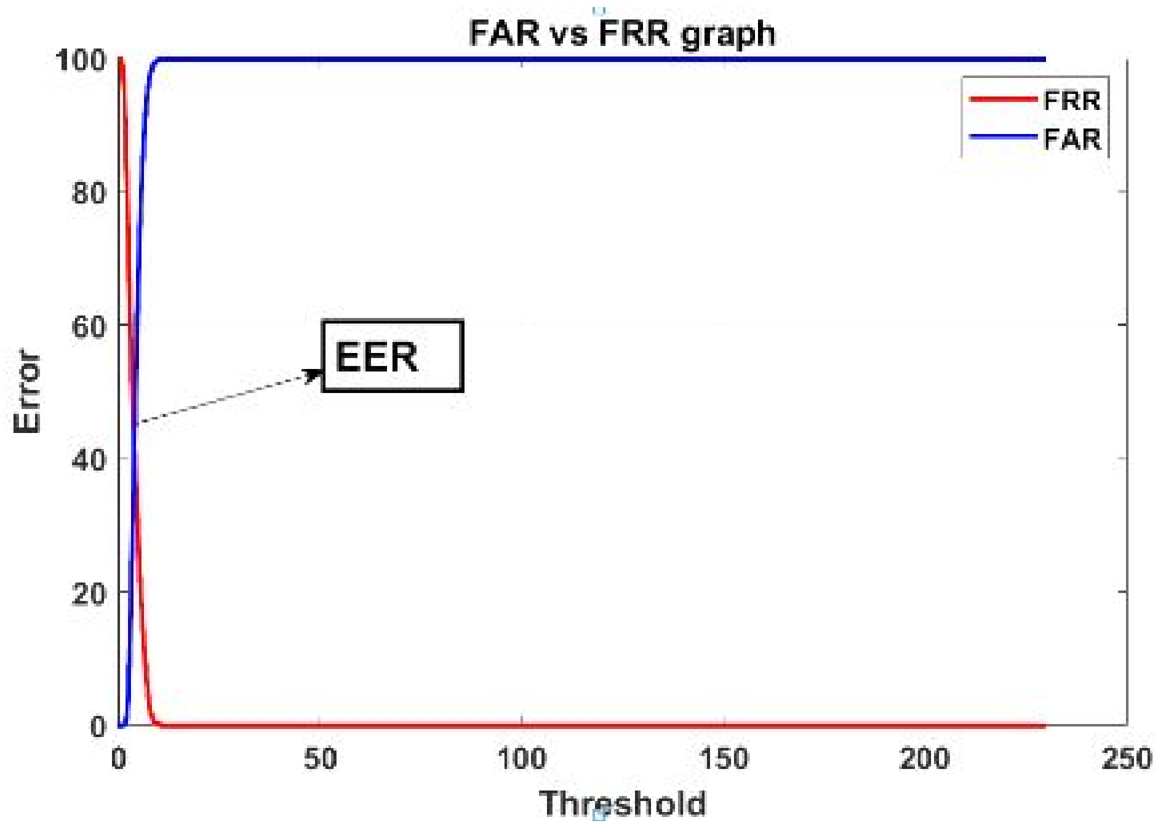


Figure 9 : FAR vs FRR graph of 3D ear data and Equal Error Rate.

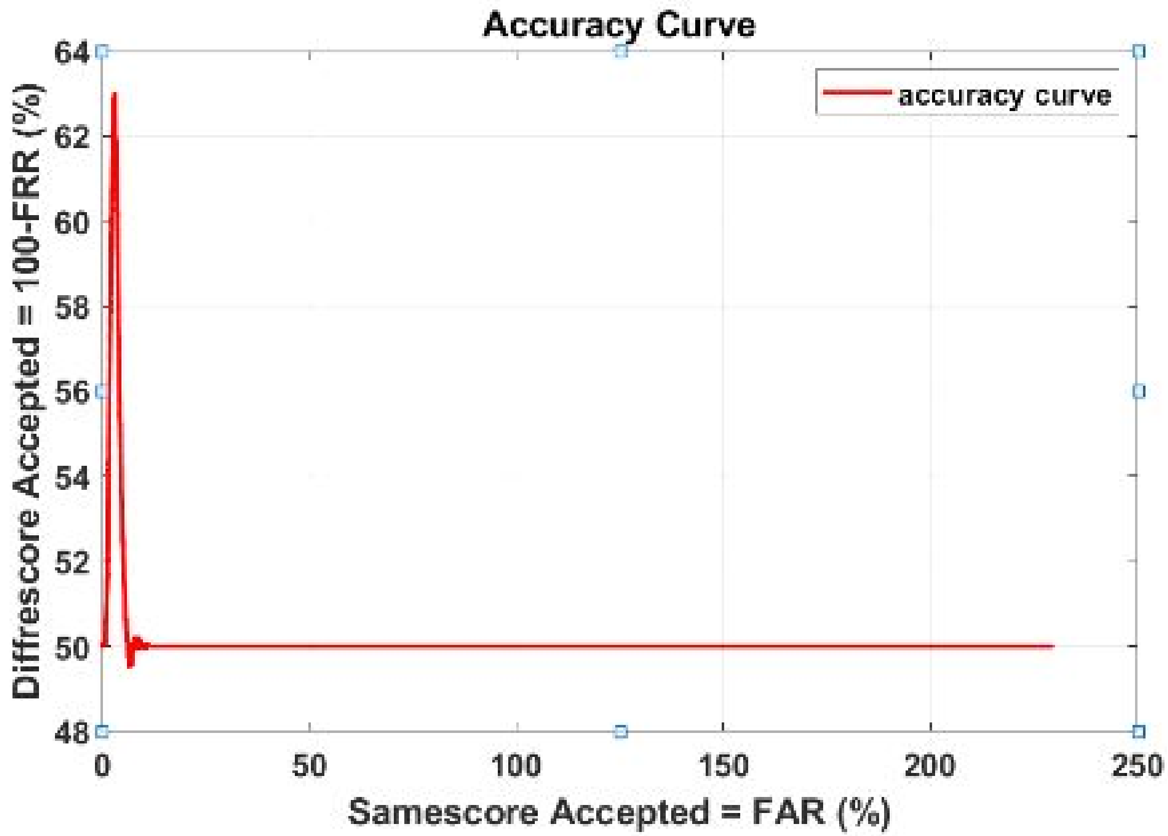


Figure 10 : Accuracy Curve of 3D ear data.

Apply Two Time ICP 3D Data Set Between Randomly Chosen Cloud Point Test and Train Folder(subject 500)

Plotting performance evaluation results:

plots FRR (Y-axis) vs. FAR (X-axis), i.e. false negative vs. false positive rate, often using logarithmic scale (at least for the FAR axis).

Equal Error Rate is defined as the value obtained at some threshold level of a biometric system where the False Acceptance Rate (FAR) and False Rejection Rate (FRR) are the same. It is also called a crossover error rate.

When We have minimum number of subject of 3D ear data (i.e. subject=1700) and randomly 500 cloud point then the Equal Error Rate(EER) is 19% and with the Accuracy 79%.

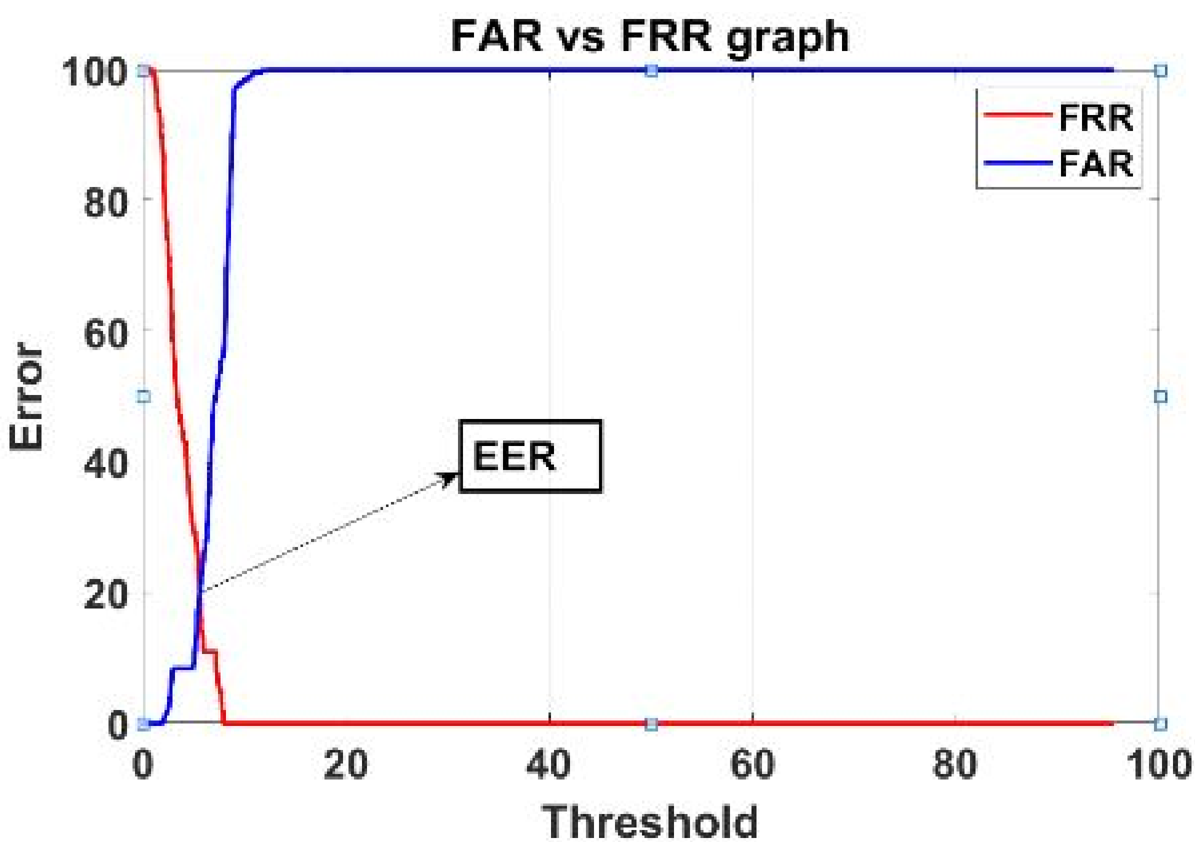


Figure 11 : FAR vs FRR graph of 3D ear data Randomly 500 chosen cloud point and Equal Error Rate.

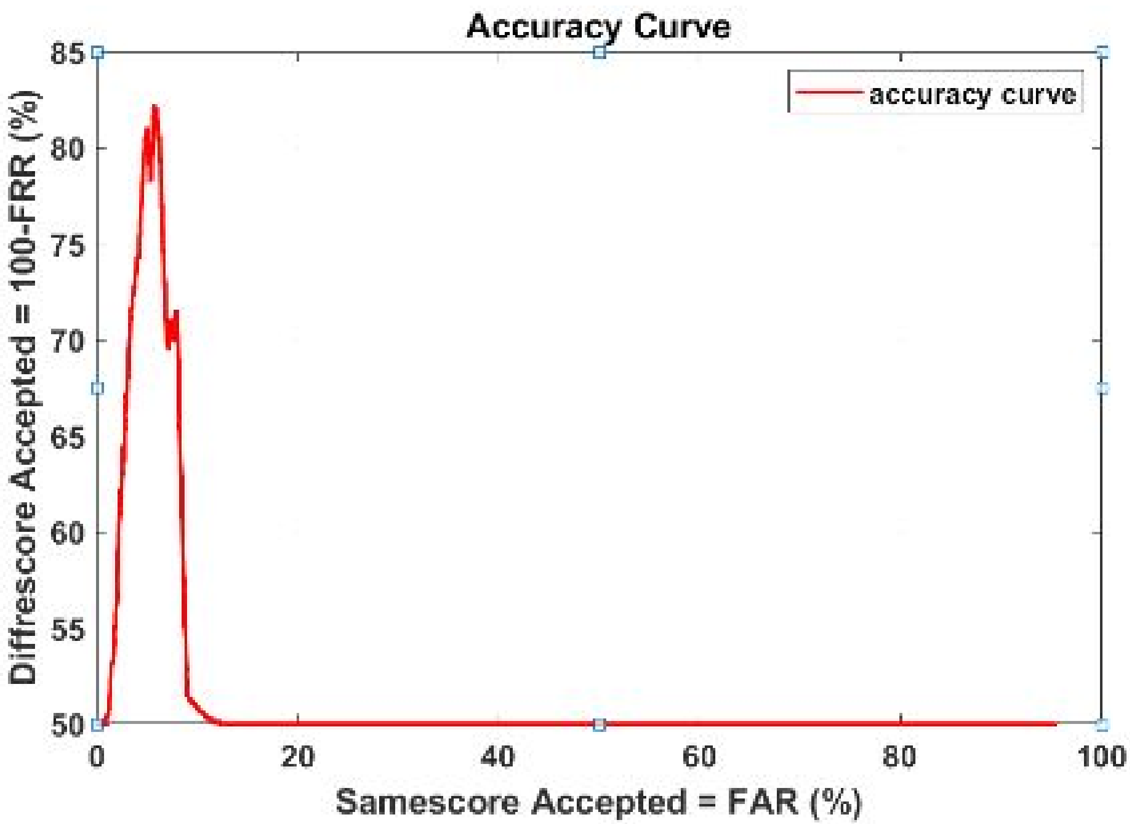


Figure 12 : Accuracy Curve of 3D ear data Randomly 500 chosen cloud point.

FEATURES EXTRACTION

4.2 POINT FEATURE HISTOGRAMS

1. The goal of the PFH formulation is to encode a point's k-neighbourhood geometrical properties by generalizing the mean curvature around the point using a multi-dimensional histogram of values. This highly dimensional hyperspace provides an informative signature for the feature representation, is invariant to the pose of the underlying surface, and copes very well with different sampling densities or noise levels present in the neighbourhood.

2. A Point Feature Histogram representation is based on the relationships between the points in the k-neighbourhood and their estimated surface normals. Simply put, it attempts to capture as best as possible the sampled surface variations by considering all the interactions between the directions of the estimated normals. **The resultant hyperspace is thus dependent on the quality of the surface normal estimations at each point.**

3. The figure 13 below presents an influence region diagram of the PFH computation for a query point , marked with red and placed in the middle of a circle (sphere in 3D) with radius **r**, and all its **k** neighbours (points with distances smaller than the radius **r**) are fully interconnected in a mesh. The final PFH descriptor is computed as a histogram of relationships between all pairs of points in the neighbourhood, and thus has a computational complexity of **O(k^2).**

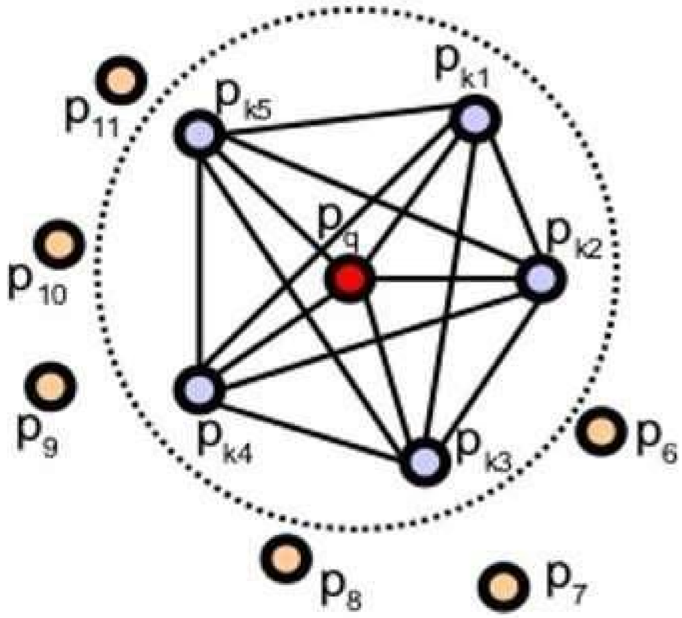


Figure 13 : Influence Region Diagram of PFH (R. B. Rusu, Z. C. Marton, N. Blodow, and M. Beetz, “Persistent Point Feature Histograms for 3D Point Clouds,” in Proceedings of the 10th International Conference on Intelligent Autonomous Systems, 2008**).**

To compute the relative difference between two points **P_i, P_j** and their associated normals **n_i** and **n_j**,we define a fixed coordinate frame at one of the points.

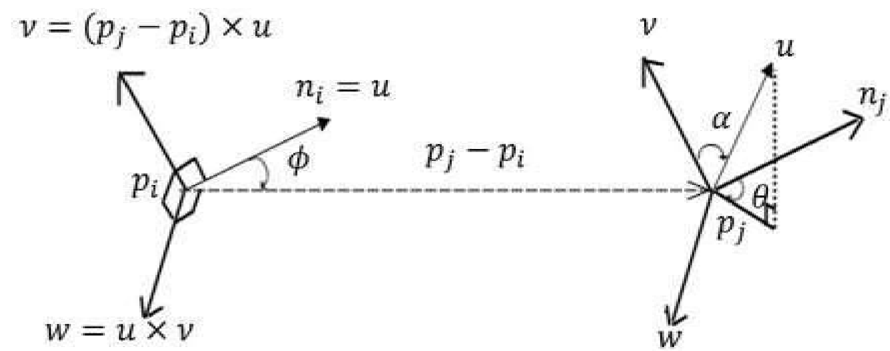


Figure 14 : Relative difference between two points (R. B. Rusu, Z. C. Marton, N. Blodow, and M. Beetz, “Persistent Point Feature Histograms for 3D Point Clouds,” in Proceedings of the 10th International Conference on Intelligent Autonomous Systems, 2008**).**

Using the above **uvw** frame, the difference between the two normal $\mathbf{n_s}$ and $\mathbf{n_t}$ can be expressed as a set of angular features as follows:

$$\alpha = v.n_t$$

$$\phi = u.(p_t - p_s)/d$$

$$\theta = \arctan(w.n_t, u.n_t)$$

where **d** is the Euclidean distance between the two points $\mathbf{P_i}$ and $\mathbf{P_j}$,

$\mathbf{d = \| P_j - P_i \|^2}$.The quadruplet **(α, θ,Ø,d)** is computed for each pair of two points in k-neighbourhood.

Chapter 5

IMPLEMENTATION

5.1 Database

1. Worked on a database containing 1778-point cloud data of UND 3D ear data database.

2. A Point cloud is a set of data points in some coordinate system which can be seen from **Figure 15**. It is the data of 14216 points on the ear.

3. In a three-dimensional coordinate system, these points are usually defined by *X*, *Y*, and *Z* coordinates, and often are intended to represent the external surface of an object.

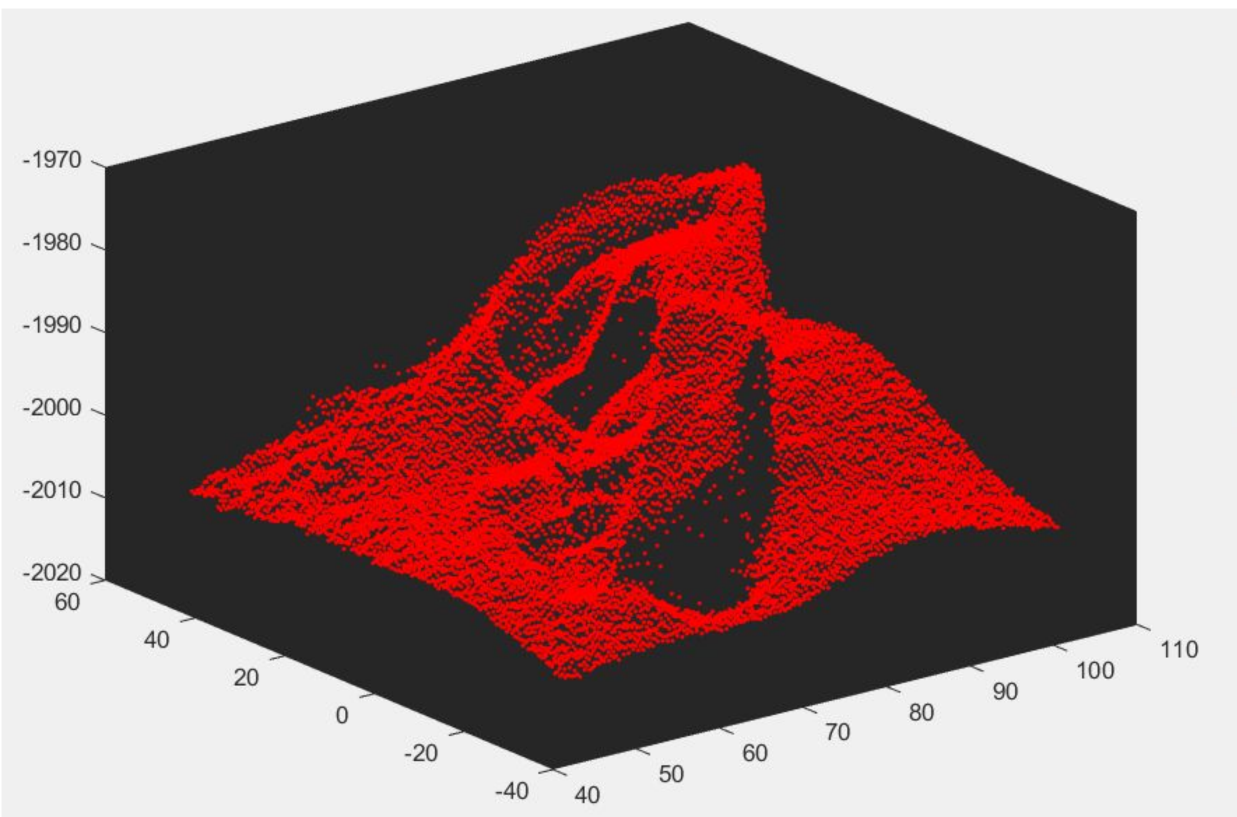


Figure 15 : Point Cloud Data of a ear

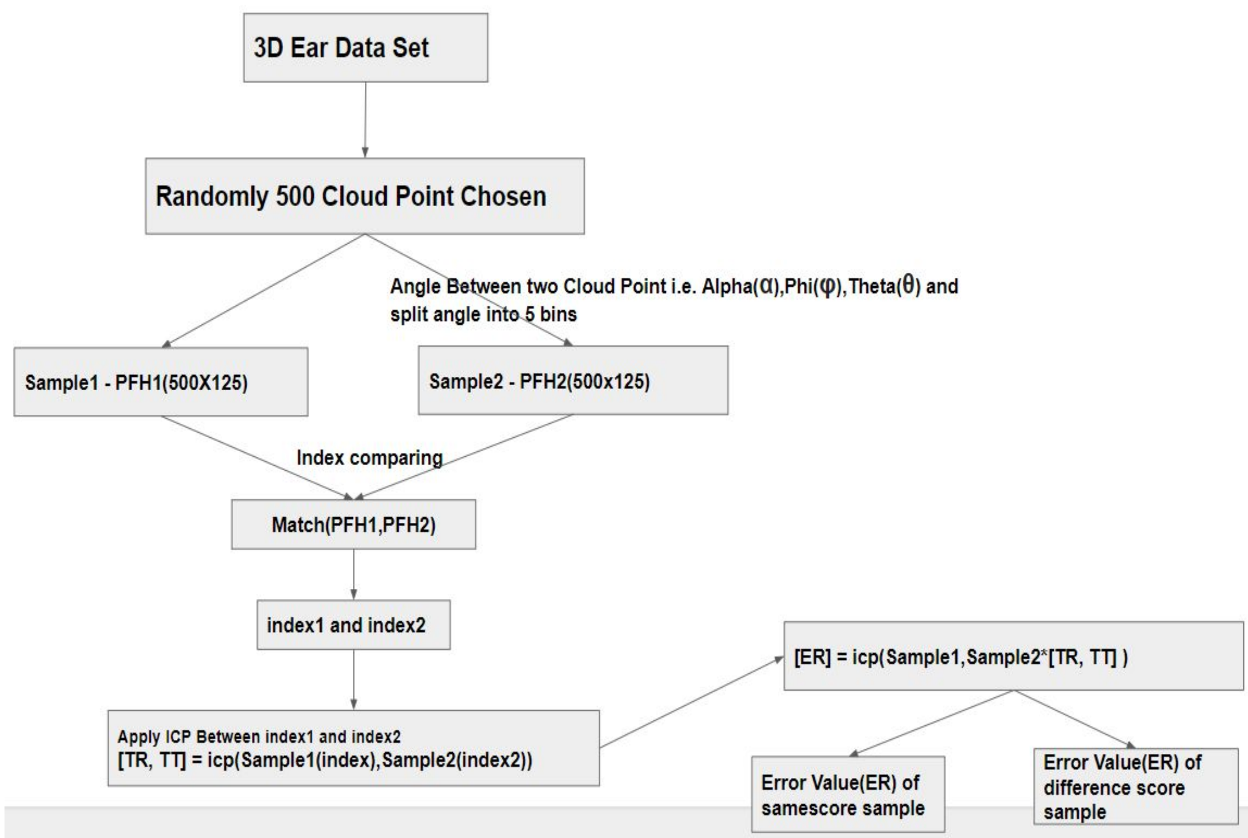
5.2 Implementing PFH On 3D Ear Data:

1. Firstly, Around 1778 point cloud data in the form of “.asc” files which had the values of X,Y and Z coordinates.

2. For every point calculate its k neighbours (k=500) and their normals.

3. To compute the relative difference between two points and and their associated normals and , calculated the u,v,w values of the points using the uvw frame.

4.Then calculate the angular features of those points using the u,v,w values which calculated earlier.stored all the data of each point cloud to its corresponding “.mat” file, so that could access the data further.



Name	Date modified	Type	Size
02463d002	10/4/2011 8:53 PM	ASC File	563 KB
02463d003	10/4/2011 8:53 PM	ASC File	587 KB
02463d004	10/4/2011 8:53 PM	ASC File	614 KB
02463d005	10/4/2011 8:53 PM	ASC File	731 KB
02463d006	10/4/2011 8:53 PM	ASC File	695 KB
02463d007	10/4/2011 8:53 PM	ASC File	694 KB
02463d008	10/4/2011 8:53 PM	ASC File	711 KB
02463d009	10/4/2011 8:53 PM	ASC File	695 KB
02463d010	10/4/2011 8:53 PM	ASC File	703 KB
02463d011	10/4/2011 8:53 PM	ASC File	664 KB
02463d012	10/4/2011 8:53 PM	ASC File	572 KB
02463d013	10/4/2011 8:53 PM	ASC File	778 KB
04201d001	10/4/2011 8:53 PM	ASC File	490 KB
04201d002	10/4/2011 8:53 PM	ASC File	507 KB
04201d003	10/4/2011 8:53 PM	ASC File	389 KB
04201d004	10/4/2011 8:53 PM	ASC File	466 KB
04201d005	10/4/2011 8:53 PM	ASC File	548 KB
04201d006	10/4/2011 8:53 PM	ASC File	469 KB
04202d001	10/4/2011 8:54 PM	ASC File	408 KB
04202d002	10/4/2011 8:54 PM	ASC File	439 KB
04202d003	10/4/2011 8:54 PM	ASC File	426 KB
04202d004	10/4/2011 8:54 PM	ASC File	396 KB
04202d005	10/4/2011 8:54 PM	ASC File	364 KB
04202d006	10/4/2011 8:54 PM	ASC File	337 KB
04202d007	10/4/2011 8:54 PM	ASC File	324 KB
04202d008	10/4/2011 8:54 PM	ASC File	363 KB
04202d009	10/4/2011 8:54 PM	ASC File	351 KB
04202d010	10/4/2011 8:54 PM	ASC File	382 KB
04202d011	10/4/2011 8:54 PM	ASC File	281 KB

Figure 16: Initial data of point cloud

Name	Date modified	Type	Size
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02463d009.mat	10/17/2018 3:03 A...	MAT File	3,213,648 ...
02463d011.mat	10/17/2018 3:39 A...	MAT File	2,936,493 ...
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04201d003.mat	10/17/2018 5:34 A...	MAT File	1,032,218 ...
04202d006.mat	10/17/2018 6:07 A...	MAT File	782,767 KB
04202d008.mat	10/17/2018 6:18 A...	MAT File	900,731 KB
04202d009.mat	10/17/2018 6:55 A...	MAT File	845,374 KB
04202d011.mat	10/17/2018 7:03 A...	MAT File	549,170 KB
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04239d004.mat	10/17/2018 9:15 PM	MAT File	1,147,101 ...
04239d005.mat	10/17/2018 10:15 ...	MAT File	1,390,511 ...

Figure 17: For each and every .asc file we generated a .mat file

Name	Date modified	Type	Size
04217d001	10/4/2011 8:55 PM	ASC File	321 KB
04217d001	10/23/2018 3:55 PM	Text Document	14 KB
04217d002	10/4/2011 8:55 PM	ASC File	270 KB
04217d002	10/23/2018 3:53 PM	Text Document	13 KB
04217d003	10/4/2011 8:55 PM	ASC File	283 KB
04217d003	10/23/2018 3:49 PM	Text Document	13 KB
04217d004	10/4/2011 8:55 PM	ASC File	356 KB
04217d004	10/23/2018 3:45 PM	Text Document	13 KB
04225d001	10/4/2011 8:55 PM	ASC File	586 KB
04225d001	10/23/2018 3:43 PM	Text Document	13 KB
04225d002	10/4/2011 8:55 PM	ASC File	523 KB
04225d002	10/23/2018 3:41 PM	Text Document	13 KB
04225d004	10/4/2011 8:55 PM	ASC File	510 KB
04225d004	10/23/2018 3:37 PM	Text Document	13 KB
04233d006	10/4/2011 8:56 PM	ASC File	401 KB
04233d006	10/23/2018 3:35 PM	Text Document	13 KB
04233d007	10/4/2011 8:56 PM	ASC File	470 KB
04233d007	10/23/2018 3:33 PM	Text Document	12 KB
04237d005	10/4/2011 8:56 PM	ASC File	431 KB
04237d005	10/23/2018 3:31 PM	Text Document	13 KB
04239d001	10/4/2011 8:56 PM	ASC File	469 KB
04239d001	10/23/2018 3:29 PM	Text Document	13 KB
04239d002	10/4/2011 8:56 PM	ASC File	480 KB
04239d002	10/23/2018 3:27 PM	Text Document	13 KB
04239d004	10/4/2011 8:56 PM	ASC File	411 KB
04239d004	10/23/2018 3:25 PM	Text Document	14 KB
04239d005	10/4/2011 8:56 PM	ASC File	453 KB
04239d005	10/23/2018 3:22 PM	Text Document	13 KB
04239d007	10/4/2011 8:56 PM	ASC File	445 KB
04239d007	10/23/2018 2:23 PM	Text Document	13 KB

Figure 18 : For each and every .asc file we generated a .txt file for distance

PFH

500x125 double

	1	2	3	4	5	6	7	8	9	10	11
1	0	0.0385	0	0.0128	0	0.0385	0.0513	0	0.0385	0	0.0256
2	0	0.0357	0	0	0	0	0	0	0	0	0.0357
3	0	0.0222	0	0	0	0.0667	0.0667	0.0222	0.0222	0	0.0222
4	0	0	0	0	0	0	0	0	0	0	0.0083
5	0	0	0	0	0	0	0	0	0	0	0.0083
6	0.0043	0.0260	0.0173	0.0043	0	0.0087	0.0303	0.0260	0.0346	0	0.0216
7	0	0.0260	0.0087	0	0	0.0303	0.0346	0.0216	0.0087	0	0.0346
8	0	0.0357	0	0	0	0	0	0	0	0	0.0357
9	0	0	0	0.0220	0	0	0	0	0	0.0110	0
10	0.0043	0.0260	0.0043	0.0043	0.0043	0.0216	0	0	0	0	0.0043
11	0	0.0130	0.0130	0	0	0.0087	0.1126	0.1212	0.0303	0.0043	0.0260
12	0	0.0173	0.0043	0	0	0.0260	0.0260	0.0173	0.0087	0	0.0433
13	0	0	0	0	0	0	0.0110	0	0	0	0
14	0	0.0182	0.0182	0	0	0	0	0	0	0	0.0182
15	0.0182	0.0182	0	0	0	0	0	0.0182	0	0	0.0182
16	0.0250	0.0250	0.0167	0.0083	0	0.0583	0.0333	0.0333	0.0500	0	0.0167
17	0.0196	0.0261	0.0196	0.0131	0	0.0261	0.0261	0.0392	0.0588	0	0.0065
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0.0043	0	0	0	0.0043
20	0	0	0	0	0	0	0	0	0	0	0
21	0.0474	0.0263	0	0	0	0.0842	0.1211	0.0737	0.0263	0.0053	0
22	0	0	0	0	0	0	0	0.0131	0	0	0
23	0	0	0	0	0	0	0.0110	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0
25	0	0.0381	0	0.0095	0	0.0762	0.0762	0.0476	0.0095	0.0095	0
26	0	0	0.0303	0	0	0.0303	0.1061	0	0	0	0.0303
27	0	0.0083	0.0083	0.0083	0	0.0083	0.0333	0.0333	0.0167	0	0.0500
28	0	0	0	0	0	0	0.0043	0	0	0	0.0043
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 19 : Contents of a .mat file

PERFORMANCE EVALUATION

By applying a varying score threshold to the similarity scores, pairs of FRR and FAR calculated. Results are presented either as such pairs,i.e FRR at a certain level of FAR, or in plots (see below).

When comparing two systems, the more accurate one would show lower FRR at the same level of FAR.

Plotting performance evaluation results:

plots FRR (Y-axis) vs. FAR (X-axis), i.e. false negative vs. false positive rate, often using logarithmic scale (at least for the FAR axis).

Equal Error Rate is defined as the value obtained at some threshold level of a biometric system where the False Acceptance Rate (FAR) and False Rejection Rate (FRR) are the same. It is also called a crossover error rate.

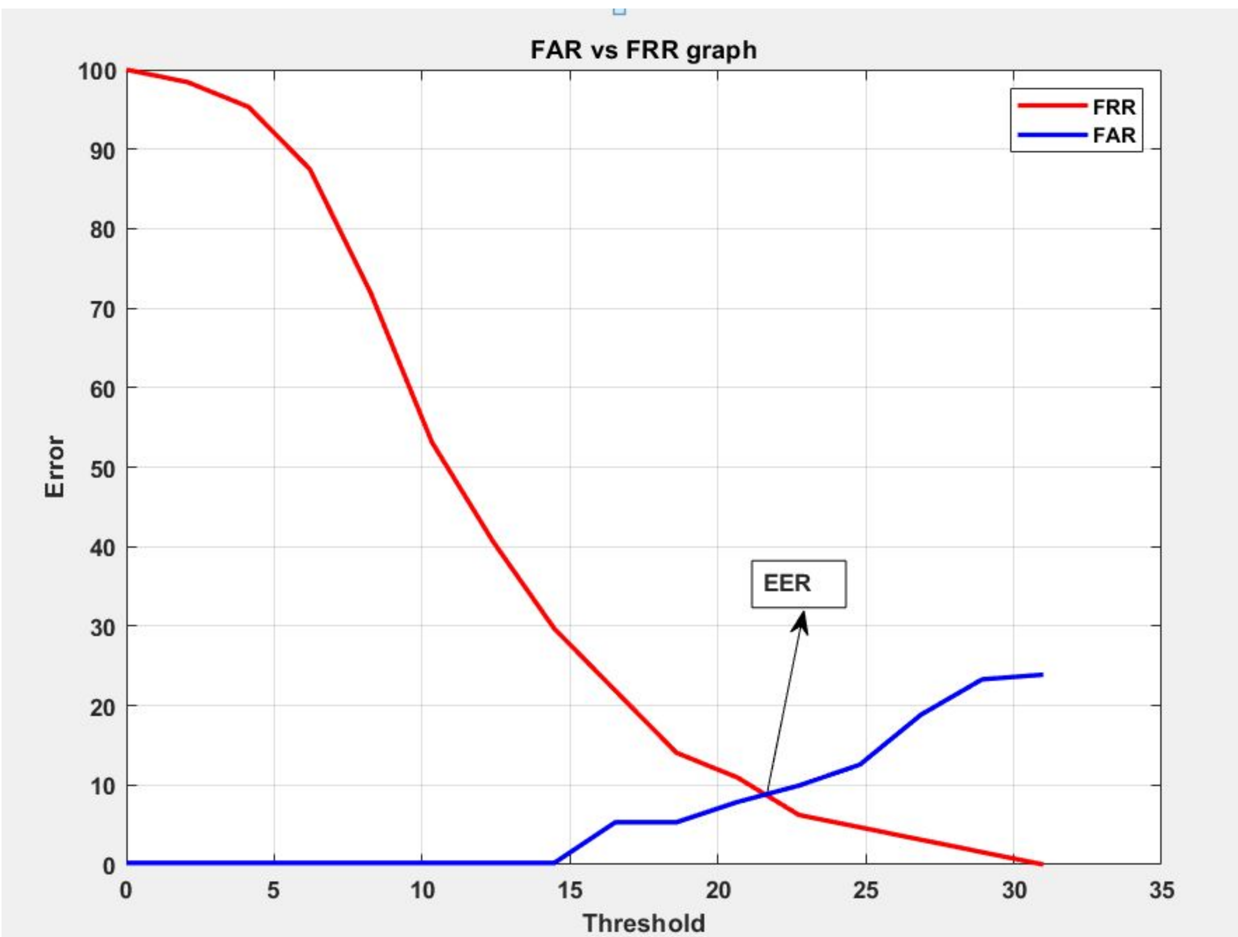

Figure 20 : FAR (Y-axis) vs. FRR (X-axis) PFH.

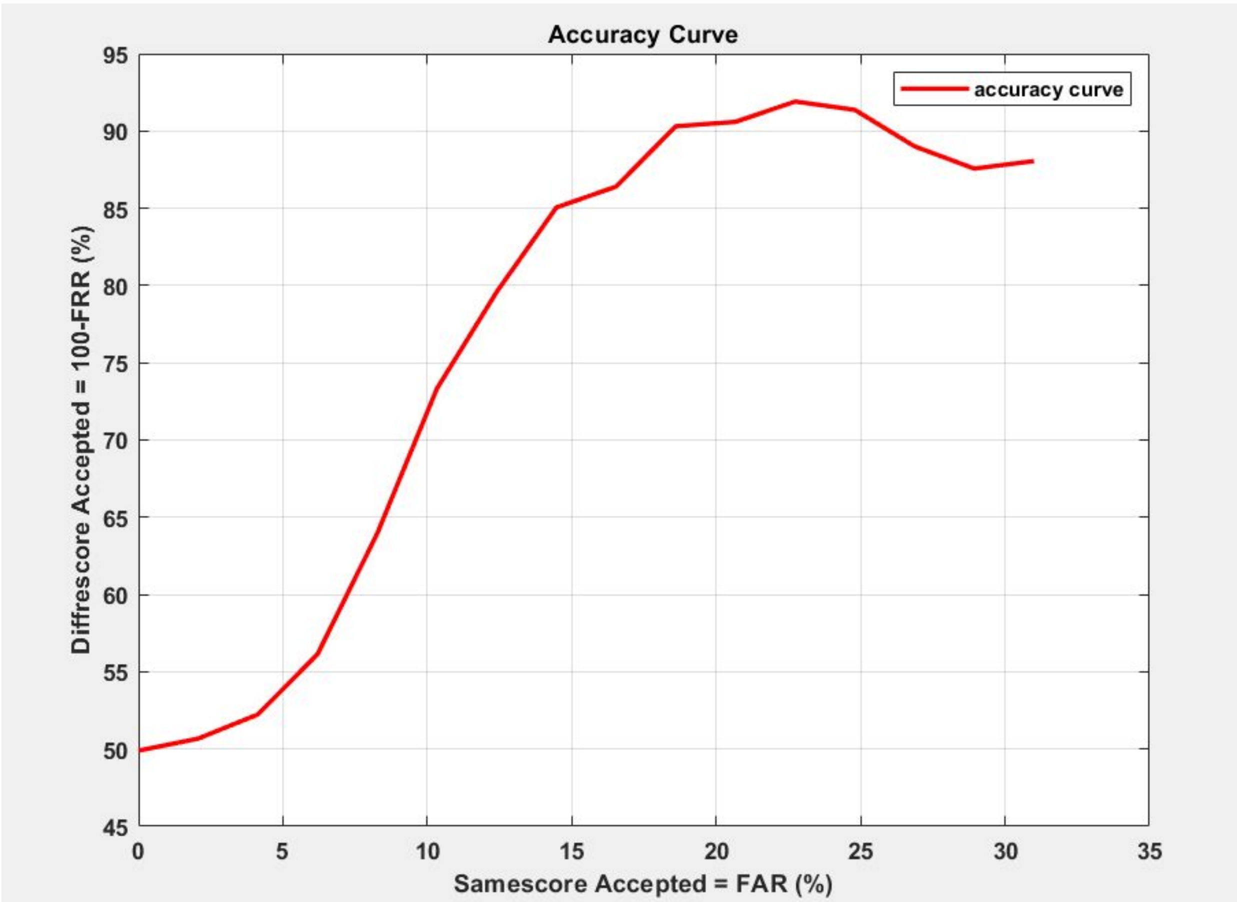

Figure 21 : Accuracy Curve of PFH.

2D POINT FEATURE HISTOGRAMS

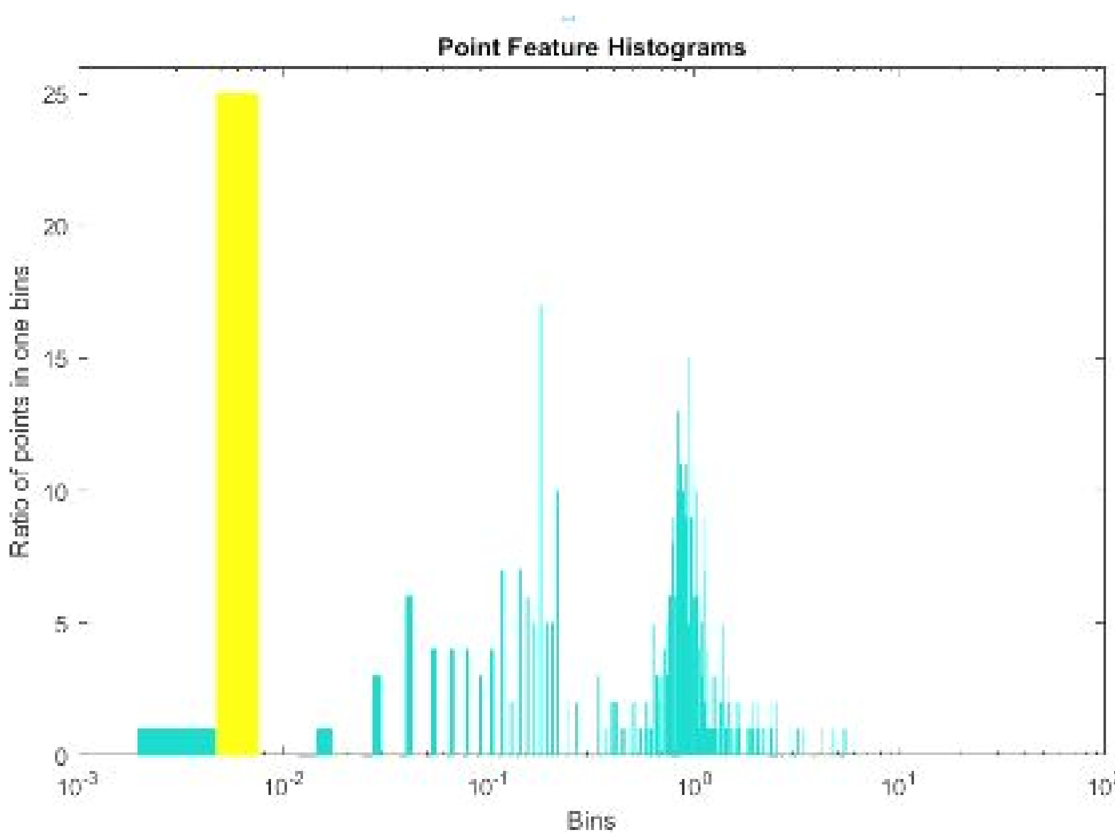

Figure 22 : 2D PFH.

3D POINT FEATURE HISTOGRAMS

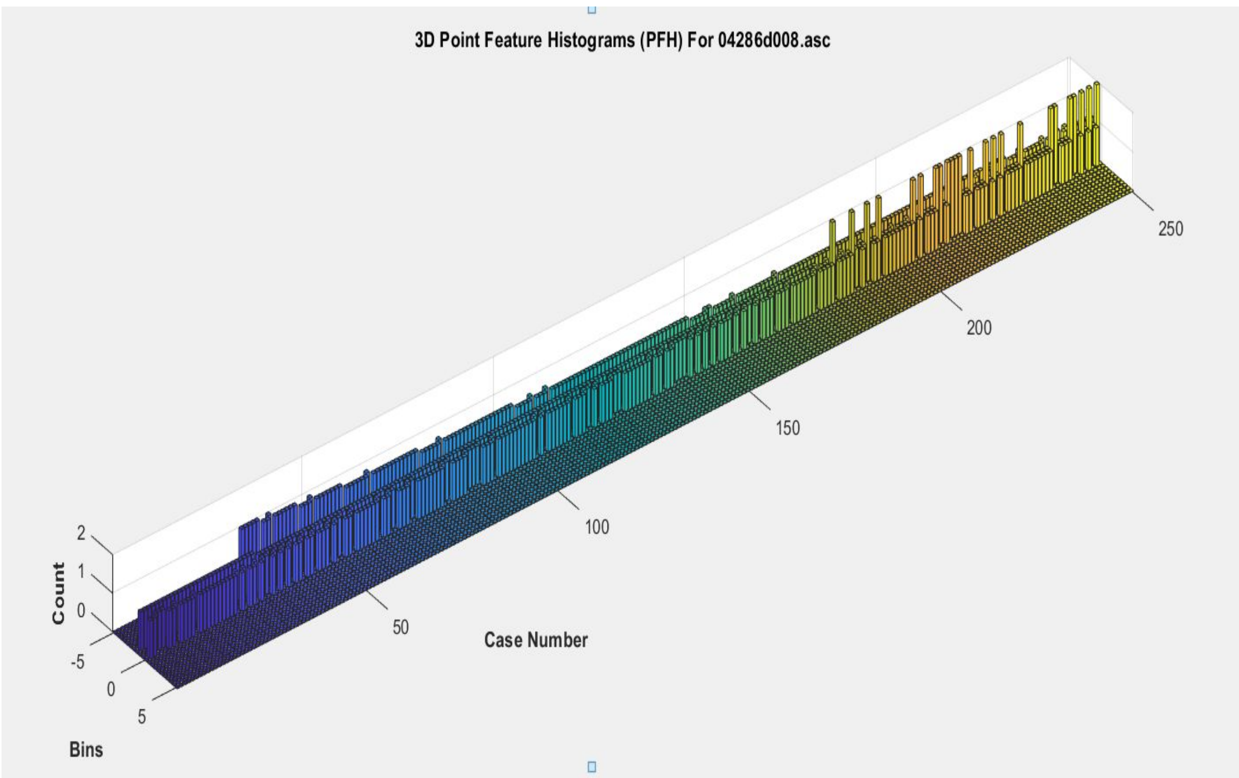

Figure 23 : 3D PFH.

Chapter 7

Conclusion

In this work, Point feature histogram method for matching of 3D biometric ear data.Implemented above method on point cloud data of ear and have used for ear matching. Using this technique, calculated the neighbours of each point and calculated their estimated normal. With the help of their normals, calculated the angular features and compared then these features of each point of a point cloud data of a test ear with each point of data of database ears of different and same subjects.

Evaluated the performance of the algorithm to find the Equal Error Rate and found it to be 8% on UND ear database. The computational complexity of the algorithm is $O(k^2)$. The obtained error of the presented technique based on used features is quite high and need to be improved with better feature selection.

Chapter 8

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