

Development of Novel Feature For Iris Biometrics

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Development of Novel Feature For Iris Biometrics

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Certificate

This is to certify that the work in the thesis entitled *Development of Novel Feature For Iris Biometrics* by *Ankush Kumar* is a record of an original research work carried out under our supervision and guidance in partial fulfillment of the requirements for the award of the degree of Master of Technology in Computer Science and Engineering. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

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Abstract

IRIS is one of the supreme biometric trait available, whose accuracy surprises everyone, better than DNA. There are numerous algorithms proposed for the efficient result but fails due to limitations. All traditional iris recognition systems are not meant especially for iris image. They are being derived from other trades hoping that it will work with iris also. The mainly known feature in iris biometric is J Daugman's Gabor filter. He has used Wavelet equation and applied Integro-differentiation operator to obtain Gabor filter. In this thesis, we have proposed a new scheme in feature detection, particularly for iris Biometric. We have taken Wavelet as a base equation and apply complex-exponential in the presence of gaussian envelop. Our approach starts with the efficient sector based normalization and noise removal techniques, in the pre-processing phase of iris biometric. Then Creating feature keypixel from that normalised image. The enhancement of the keypixel is done to increase accuracy rate.

The mother wavelets obtained by solving gaussian equation and wavelet equation simultaneously. This acts as a edge detection mask for the iris image and detects a fine edge as a keypixel. Thresolding at 85 percent leaves the optimal feature points. Enhancing these points improves the accuracy, we have applied this method on four iris databases. The speed and accuracy are obtained by decreasing the number of keypixels and increasing the thresold.

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Chapter 1

Introduction

UK Border Agency puts the multimillion-pound system under review after Manchester and Birmingham airport's scrap the technology of iris eye-scanner on 17 February. 2012. Security plays an important role in human life, if it deals with survival. Instead of restricting access to things through arbitrary locks and keys, we grant access to people if we can positively identify them by measuring some unique pattern on their body. If you think about it, an ordinary passport photo is a best crude example of biometrics. When the border guards look at your face and compares the photo present in your passport, what they're doing is intuitively comparing two images. Is one nose bigger than another? Are the eyes further apart? That's simple biometrics. A biometric system provides a machine based auto recognition of an individual, based on some unique specific characteristic owned by the individual. Biometric systems have been developed based on fingerprints, facial features, hand geometry, and the one presented in this report, the iris. Biometric systems work based on capturing sample records, such as face image, eye image, hand shape, finger shape. These sample records are transformed using some mathematical function to build biometric training path. These training paths will provide some characteristic property and strong point for identification. The problem with our face is that faces change all the time, and lots of people look very similar. So inter-class as well as an intra-class, both types of defects are present in it. Some of the paper says that fingerprint is a more reliable form of biometrics, but even they're not infallible: illnesses and injuries, as well as the basic wear-and-tear, can alter the pattern of tough ridges, minutia points on our fingers with time. Most of the biometric systems allow two operation modes,

. Most of the biometric systems allow two operation modes, which are an enrolment mode to build database by taking first time interaction and identification mode to give access to those databases.

Enrollment:

The System is unaware of the surroundings, thus the system needs to know about all the people, and they must have to have their eyes scanned properly. This process of letting the eye known by the system is called enrollment. Everyone has to stand in front of a very high-quality camera and has their eyes digitally photographed with both normal light and invisible infrared (a type of light being used in night-vision systems that has a slightly longer wavelength than ordinary red light, and have a higher wavelength than red light). This is also called as the constrained environment. In an iris recognition system, infrared helps to enlighten the unique features of darkly coloured eyes that are not clearly visible in regular light. These two digital photographs are then analysed and normalised by a system to remove unnecessary details (such as eyelashes) and identifies around 265 unique feature points. These feature points, which are unique to every eye, are saved as a template, binary digit number called an IrisCode in J Daughman iris recognition system [1], alongside the name and other details can also be saved, in a computer database. The enrollment process is totally automatic and usually takes only a couple of minutes.

Verification:

Once your information is stored in the system, it's a simple way to check your identity. You simply stand in front of another iris scanner and have your eye digitally photographed again, the system quickly processes the image and extracts the IrisCode from your eye image, before comparing it against the hundreds, or millions stored in its database. If your code matches one of the stored ones, you're identified as authentic user; if not, The algorithm fails to detect you as an authentic user. It either means that you're not known to the system or you're not the right person whom you claim to be. A view of the iris image acquisition process is shown in the below image from Afghanistan border. One of the benefits of this system is that once you are enrolled

you don't have to worry throughout your lifetime.

1.1 Iris Biometrics History

The idea of using the iris for personal identification was originally proposed by the ophthalmologist, Frank Burch, in 1936. He had identified the basis of why this would potentially be a successful security measure: because of the entirely random and unique nature of iris patterns. The iris has been historically recognized to possess characteristics that are unique to everyone. In 1980s, two ophthalmologists Dr. Leonard Flom and Aran Safir[2], proposed the concept that no two irises was alike. They researched and documented the potential of using the iris for identifying people and were awarded a patent in 1987. Soon after, the intricate and sophisticated algorithm that brought the concept to reality was developed by Dr. John Daugman and patented in 1994[?]. The original work and continued development have established the canny edge Detector iris recognition algorithm as the mathematically unrivaled means for authentication. This was the inception of the creation of the eye-recognition security systems in place today.

1.1.1 Inventors of iris scans

- 1936: US ophthalmologist Frank Burch suggests the idea of recognizing people from their iris patterns long before technology for doing so is feasible.
- 1981: American ophthalmologists Leonard Flom and Aran Safir discuss the idea of using iris recognition as a form of biometric security, though technology is still not yet advanced enough.
- 1987, Leonard Flom and Aran Safir gain US patent 4,641,349 for the basic concept of an iris recognition system.
- 1994: US-born mathematician John Daugman (currently a professor of computer science at Cambridge University, England) works with Flom and Safir to develop the algorithms (mathematical processes) that can turn photographs of irises into unique numeric codes. He is granted US patent 5,291,560 for a "biometric



Figure 1.1: IrisGuard at UAE Enrollment Station

personal identification system based on iris analysis” the same year. Daugman is widely credited as the inventor of practical iris recognition since his algorithm is used in most iris-scanning systems.

- 1996: Lancaster County Prison, Pennsylvania begins testing iris recognition as a way of checking prisoner identities.
- 1999: Bank United Corporation of Houston, Texas converts supermarket ATMs to iris-recognition technology.
- 2000: Charlotte/Douglas International Airport in North Carolina and flughafen Frankfurt Airport in Germany become two of the first airports to use iris scanning in routine passenger checks.

The above Figure1.1 shows the enrolment station in Afghanistan’s border. Both the eyes are unique in nature so both eyes must be enrolled and properly matched during the verification process. It works through a combination of computer vision, image processing and pattern recognition. As I said earlier a high-resolution camera zooms into the iris and records a clear image of an eye, which is then digitized and stored on a computer database which can be used whenever it is needed. This process



Figure 1.2: Collecting iris image in AADHAAR scheme

is also known as 'Biometric Security' i.e. Securing the personal stuff with the password present in your body itself, and it has already been successfully implemented as a security measure in large-scale applications because of its accuracy and safety. The Unique Identification Authority of India (UID)^{7.5} is a new branch of the Government of India, which is responsible for providing the AADHAAR^[3] numbers to all Indians, a unique biometric identification project, that keeps a record of your iris information as well as all 10 fingerprints. It was established in the month of February 2009, and will own and operate the Unique Identification Number database. The authority aims to provide a unique id number to all Indians, but not smart cards. The authority will maintain a biometric database of residents containing iris biometric and fingerprint biometric together. A picture of obtaining iris image in the AADHAAR scheme in Utter Pradesh is shown in the figure 1.2.

Iris recognition as a security method is commonly utilized in establishing the identity of people in also high-risk environments such as border control, aviation security and a host of government programmes. This is the most robust and accurate form of biometric technology in today's market. There are also some of the places where iris recognition fails, as most people have just one eye or even no eye. The

verification process[4] speed of this biometric authentication technology is the merely one to work in an exhaustive search mode, i.e. there is no limitation of the number of results saved to the database during enrolment, and the false accept rate is very less as that of other biometric trait. Furthermore, there is no need to remove your glasses or contact lenses during a scan, until it is black or dark glass. They do not interfere with the process of recognizing the unique imprint of each iris.

1.2 What Is Iris?

The human Iris is an internal organ of the eye, protected by the eyelid, cornea and the aqueous humour. The iris is the plainly visible, coloured ring that surrounds the pupil. It is a muscular structure that controls the amount of light entering the eye, with intricate details that can be measured, such as striations, pits, and furrows. The iris is not to be confused with the retina, which lines the inside of the back of the eye. The iris in a human eye is a thin ring-shaped diaphragm which lies between the cornea and the lens. The iris is cantered by a hole of disc-shaped aperture known as the pupil. The iris usually has a brown, blue, gray, or greenish colour, with complex patterns that are visible to close inspection. The function of the iris is to control the amount of light entering the pupil. This is done with the use of sphincter and the dilator muscles which adjust the size of the pupil according to the light available. The approximate diameter of an average iris is about 12-13 mm. The pupil size can vary from 10 percent to 80 percent of the iris diameter. Iris recognition is a method of identifying people based on unique patterns within the ring-shaped region surrounding the pupil of the eye. Because it makes use of a biological characteristic, iris recognition is considered a form of biometric verification.

Iris is part of the middle coat of the eye and lies in front of the lens. It is the only internal organ of the body that is normally visible externally. Iris is considered the unique and data rich physical structure on the human body. One of the key characteristics of iris is that the iris features remain constant throughout the years. The iris is composed from several layers. The lowest layer, epithelium layer, contains dense pigmentation cells. Next layer, the stromal layer, contains thin blood vessels,

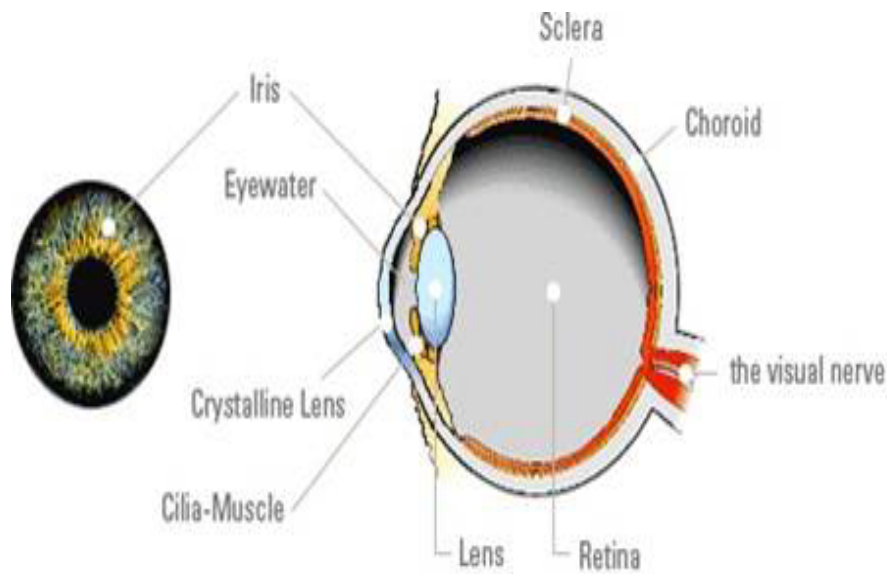


Figure 1.3: Anatomy of Human Eye

pigment cells and iris muscles. The density of this pigmentation determines the colour of the iris. Every iris is unique, and it remains unchanged in digital photographs. It was proposed to use the iris of the eye as a kind of optical fingerprint for personal identification. It works even good when people wear clear sunglasses or contact lenses. No two irises are alike. in spite of left eye iris of an individual is far-far different from his right eye. There is no detailed relation between the iris patterns of even identical twins. The amount of in formation that can be obtained and measured ina single iris is much greater than any fingerprints, and the accuracy is even greater than DNA. Nowadays, biometric systems play vary important role with a maximum security is required where bank, military base, prison, airport, laboratory, intelligence office and etc. Inorder to produce a good biometric system, probability of having sathe same characteristics should be minimal for individuals, so that the feature of individual does not change over time. Furthermore, the system should easily capture images in order to provide efficient access. Some of the the properties of the iris that enhance its suitability for use in automatic identifications are:

- Immunity from the external environment
- Impossibility of surgically modifying without the risk of vision

- Physiological response to light
- Ease of registering its image at some distance

1.2.1 How does iris detection work?

The process of iris recognition is usually divided into four steps:

- Capturing the image.
- Find the location of the iris and optimising the iris image
- Storing in database
- Matching the image

1.2.2 Capturing the Image

The image of the iris can be captured using a standard camera using both visible and infrared Light and may be either a manual or automated procedure. The camera can be positioned between three and a half inches and one meter to capture the image. In the manual procedure, the user needs to adjust the camera to get the iris in focus and needs to be within six to twelve inches of the camera. This process is much more manually intensive and requires proper user training to be successful. The automatic procedure uses a set of cameras that locate the face and iris automatically thus making this process much more user friendly. Image acquisition: Since iris is small in size and dark in colour, it is difficult to acquire good images for analysis using the standard camera and ordinary lighting. Image acquisition provides iris image of sufficiently high quality. We have so far got the eye image after image acquisition from the camera as in [Figure1.4](#)

1.2.3 Image Pre-processing

Once the camera has located the eye, the iris recognition system then identifies the image that has the best focus and clarity of the iris. The image is then analysed to identify the outer boundary of the iris where it meets the white sclera of the eye, the pupillary boundary and the centre of the pupil. This results in the precise location of



Figure 1.4: (left) Image acquisition with portable device (right) Image acquisition with CCD device.

the circular iris. The iris recognition system then identifies the areas of the iris image that are suitable for feature extraction and analysis. This involves removing areas that are covered by the eyelids, any deep shadows and reflective areas. The following diagram shows the optimisation of the image. It is done to remove some irrelevant parts (e.g. eyelid, pupil etc.) from the image.

1.2.4 Storing in Database

Once the image has been captured, this information is used to produce what is known as the IrisCode, which is a 512-byte record. This record is then stored in a database for future comparison. When a comparison is required the same process is followed but instead of storing the record it is compared to all the IrisCode records stored in the database

1.2.5 Feature Extraction

The feature extraction step extracts feature using local and global behaviour of the iris images. The feature points are correlated with each other neighbours to select the best and accurate feature. Further detailed steps are shown.

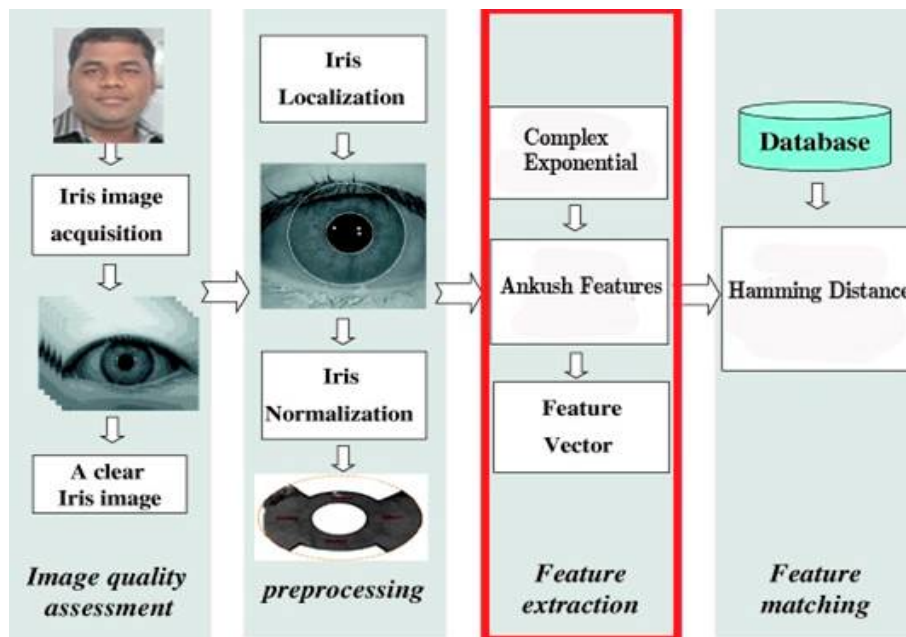


Figure 1.5: Steps of Iris Recognition Process

1.2.6 Matching the iris Images

The feature vectors are compared using a similarity measure. In order to compare the stored IrisCode record with an image just scanned, a calculation of the Hamming Distance is required. The Hamming Distance is a measure of the variation between the IrisCode record for the current iris and the IrisCode records stored in the database. Once all the bits have been compared, the number of non-matching bits is divided by the total number of bits to produce a two-digit figure of how the two IrisCode records differ. For example a Hamming Distance of 0.20 means that the two IrisCode differ by 20%.

1.3 Global and Local Features

We can Broadly classify feature in two class; either feature can be local or global feature. The Global feature defines the physical behaviour of the image and local feature explore deep in image to create feature. Some of the global features are as follows:

- The Discrete Cosine Transform (DCT)

- The Discrete Wavelet Transform (DWT)
- Gabor filter

The local features are as follows:

- Scale Invariant Feature Transform (SIFT)
- Speeded-Up Robust Feature (SURF)
- Gradient Location and Orientation Histogram(GLOH)
- Histogram of Oriented Gradients (HOG)

The feature which we have created is a *Local feature* and named as Complex-Exponential Operator (CEO). It is a complex exponential form of the mother wavelet equation in the presence of the Gaussian envelop with a position vector. It can be treated as an image descriptor.

1.4 Problem Definition

When talking about Definitude Biometric Security, Iris comes at the leading position as seen in previous section 1.4. We have some of the best iris algorithms with us, with great accuracy and perfection. But with all leading perfection and appropriateness we are unable to achieve 100%results, this is because of lack of optimized and correct set of algorithms involve in the recognition process and the carefully removal of the errors present at different steps of the methods used. The efficient methods are available, but not for all sets of iris image database and for all environment, like cooperative and non-cooperative. All the local and global feature discussed in previous steps are not particularly made for iris Recognition System .SIFT feature was invented to detect the image orientation, SURF has its own limitation . These features are not particularly designed for iris. DCT and DWT are designed for the signal analysis and hence this process doesn't lead to 100 percent result. The iris detection process is divided in several modules and steps: Image acquisition, Segmentation, localisation and normalisation, Feature Extraction, and Matching. My thesis is completely focused

on developing new feature for iris detection System. I have already studied all previous existing features present in iris detection System like Gabor, SIFT, SURF, DCT etc. In this paper I have tried to achieve the maximum accuracy and fastest approach for both cooperative and non-cooperative dataset of iris images. This new feature is only for iris recognition System. I want to create a feature which is robust, efficient and universal in terms of Database.

1.5 Iris Databases

To measure the performance of automated iris biometric system, extensive experiments have been carried out at various levels. This section discusses in detail about the databases used in experiments. Experimental results are obtained on various available datasets such as UBIRIS version 1, BATH, CASIA version 3 and Indian Institute of Technology Delhi (IITD) to take all possible factors into consideration like rotation, illumination, scaling and noise. These databases are classified into cooperative and non-cooperative categories based upon the restrictions imposed on the user while capturing images.

BATH Database

The University of Bath (BATH)[5] iris image database is constantly growing and at present contains over 16000 iris images taken from 800 eyes of 400 subjects. It results of a project which aims to build a "high quality iris image resource". The majority of the database comprises images taken from students and staff of the University of Bath the images are of very high quality, taken with a professional machine vision camera, mounted on a height-adjustable camera-stand. The illumination was provided through an array of infrared LEDs, positioned below the camera and set at an angle such that reflections were restricted to the pupil. Further, an infrared pass filter was used in order to cut out the daylight and other environmental light reflections on the irises region.

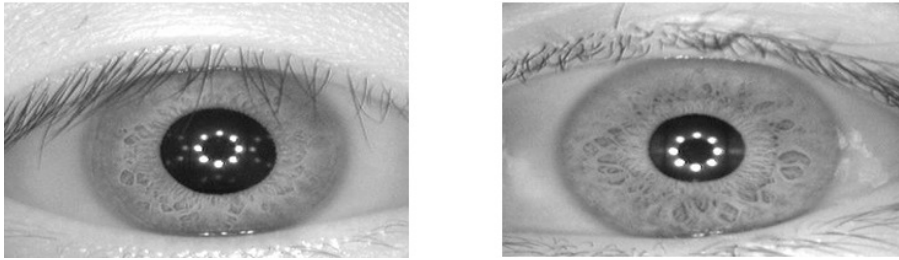


Figure 1.6: Example iris images in CASIA-Iris-Interval

CASIA Database

Iris recognition has been an active research topic of the Institute of Automation from the Chinese Academy of Sciences[6]. Having concluded about a lack of iris data for algorithm testing, they developed the CASIA image database. CASIA-IrisV4 is an extension of CASIA-IrisV3 and contains six subsets. The three subsets from CASIA-IrisV3 are CASIA-Iris-Interval, CASIA-Iris-Lamp, and CASIA-Iris-Twins respectively. It contains a total of 54,601 iris images from more than 1,800 genuine subjects and 1,000 virtual subjects. All iris images are 8 bit gray-level JPEG files, collected under near infrared illumination or synthesized

MMU Database

MMU1 iris database[7] contributes a total number of 450 iris images which were taken using LG IrisAccess2200. This camera is semi-automated and it operates at the range of 7-25 cm. On the other hand, MMU2 iris database consists of 995 iris images. The iris images are collected using Panasonic BM-ET100US Authenticam and its operating range is even farther with a distance of 47-53 cm away from the user. These iris images are contributed by 100 volunteers with different age and nationality. They come from Asia, Middle East, Africa and Europe. Each of them contributes 5 iris images for each eye. There are 5 left eye iris images which are excluded from the database due to cataract disease.

IIT Delhi Iris Database

The IIT Delhi[8] Iris Database mainly consists of the iris images collected from the students and staff at IIT Delhi, New Delhi, India. This database has been acquired in

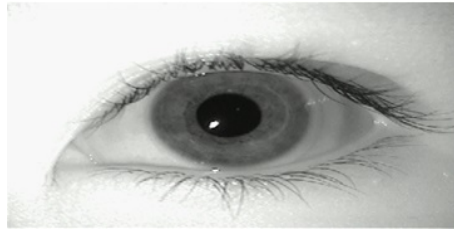


Figure 1.7: Example iris images in MMU1



Figure 1.8: Example iris images from "IIT Delhi" Iris Database

Biometrics Research Laboratory during Jan - July 2007 (still in progress) using JIRIS, JPC1000, digital CMOS camera. The image acquisition program was written to acquire and save these images in bitmap format and is also freely available on request. The currently available database is from 224 users, all the images are in bitmap (*.bmp) format. All the subjects in the database are in the age group 14-55 years comprising of 176 males and 48 females. The database of 1120 images is organized into 224 different folders each associated with the integer identification/number. The resolution of these images is $320 * 240$ pixels and all these images were acquired in the indoor environment.

people have only one eye or even no eye. The verification process speed of this biometric authentication technology

1.6 Motivation

Iris detection is one of the most accurate and secures means of biometric identification while also being one of the least invasive. Fingerprints of a person can be faked-dead people can come to life by using a severed thumb. Thief's can do a nifty mask to fool a simple face recognition program. The iris has many properties which make it the

ideal biometric recognition component. The iris has the unique characteristic of very little variation over a life's period yet a multitude of variation between individuals. Irises not only differ between identical twins, but also between the left and right eye. Because of the hundreds of degrees of freedom the iris gives and the ability to accurately measure the textured iris, the false accept probability can be estimated at 1 in 1031. Another characteristic which makes the iris difficult to fake is its responsive nature. Being this much accurate only few patent feature based algorithm exists in the world. Only one man has fully contributed in this failed, many have tried but within the limits. It requires some more attention to create such a feature which has zero False Acceptance Rate (FAR). These failures motivate me to create a fast, robust and efficient FEATURE especially for the iris recognition system. The accuracy of the local feature is much greater than the global features, thus our aim is to create a local feature for iris in this thesis.

1.7 Thesis Organization

The entire thesis constitutes seven chapters following this chapter. The rest of the thesis is organized as follows:

Chapter 1: Introduction of Biometrics and thesis This chapter explains about the Biometrics and comparison of different biometric traits. The organisation of the thesis is also shown in this chapter.

Chapter 2: Literature Review

All Local and global features are properly reviewed in this chapter. Global features like DCT, DWT and Gabor filter is described properly in this chapter. Local features like SIFT SURF are also explained briefly. Iris recognition process is also shown in this step. Capture by portable and CCD cameras, Iris localization, Segmentation and Noise removal techniques. This chapter explains about localisation techniques and edge detection technique, Normalisation of iris image is also shown in this chapter; Normalisation using Daugman's rubber sheet model, sector based normalisation is also explained in this chapter for finding pupil and iris boundary.

Chapter 3: New Feature This chapter mainly explains about the new local

feature being generated by us. First the wavelet analysis and the generation of mother wavelet equation is also shown in this chapter. Then Fourier transform of the mother wavelet and creation of feature keypoints. Creating the feature point by calculating the amplitude ,phase quantisation and Position vector simultaneously.

Chapter 4: Matching This chapter tells about the matching algorithms used in this Biometric process and the matching process being used in this paper is Hamming distance.

Chapter 5: Experimental Results This chapter tells us about all the results and observations obtained during experiment. It tells us about the efficiency and accuracy of the algorithm being used in this paper.

Chapter 6: Conclusions and Future Work This is the final chapter that concludes all the results and observation presented in this paper. The comparative analysis of the existing feature over the new feature is also shown .It also tells us about the future scope if the algorithm.

Chapter 2

Literature Review

2.1 Iris Recognition Process

Iris recognition depends on the unique patterns of the human iris to identify or verify the identity of an individual. For iris recognition, Iris is detected from the eye and the feature (points or descriptor) are extracted. These features are encoded into pattern which is stored in the database for enrollment and are matched with the database for authentication.

To achieve automated iris recognition, following are the main steps:

2.1.1 Image Capture

The iris image should be rich in iris texture as the feature extraction stage depends upon the image quality. Thus, the image acquired by camera is placed at a distance of approximately 10 cm from the user eye. The approximate distance between the user and the source of light is about 10-12 cm. 2.1

The following attentions have been taken care at the time of grabbing the image

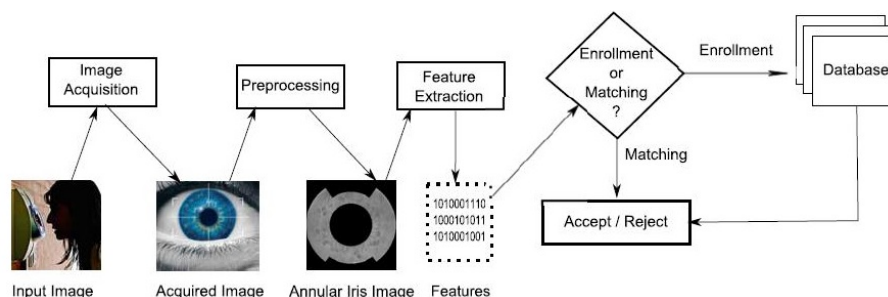


Figure 2.1: Iris recognition process steps overview

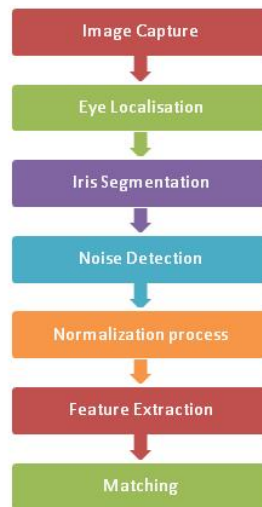


Figure 2.2: Image processing steps flowchart

- High resolution and good sharpness: It is necessary for the accurate detection of outer and inner iris circle boundaries.
- normal lighting condition: The system of diffused light is used to prevent spot-light effect.

2.1.2 ImagePreprocessing

Localisation

As the iris image is captured with a high resolution camera. The obtained iris image has to be preprocessed and localized to detect the iris and pupil. The iris can be obtained by simply subtracting the outer boundary (of the sclera) to that of the inner boundary (of pupil). The annular portion finally obtained is the iris portion. The first step in iris localization is to detect pupil which is the black circular part surrounded by iris tissues. The centre of pupil can be used to detect the outer radius of iris patterns. The following sub steps for localisation are as follows:

Pupil Boundary Detection

First the iris image is converted into grayscale to remove the effect of illumination. The pupil is situated at the center and is the largest black portion in the intensity image; its edges can be detected easily from the binary image by using suitable threshold[9]. But the problem of binarization arises in case of persons who is having darker iris.



Figure 2.3: Detection of inner pupil boundary

The localization of pupil fails in such iris. In order to resolve these problems Circular Hough Transformation for pupil detection can be used. The basic idea of this method is to find the curves that can be parameterized like straight lines, polynomials, circles, etc., in a suitable space. The final transformation is able to overcome the artifacts like noise and shadow. The procedure first finds the intensity image gradient at all the locations in the given image. This can be found by convolving the image with the sobel filters, one of the best edge detection technique. The gradient images (as Gvertical and GHorizontal) along x and y direction, is obtained by kernels that detect horizontal and vertical changes in the image.

Outer Sclera Localization

The inner boundary is obtained in the Pupil Boundary detection. The external boundary is left. Noise is present in the iris image. These extra noise is removed by regularly blurring the given intensity image. But too much blurring may remove the boundaries of the edge or may make it difficult to detect the outer iris boundary, which separates the eyeball and sclera. Thus smoothing filter like the median filter is used on the original image. This type of spatial filtering eliminates sparse noise while preserving its boundaries. After filtering, histogram equalization[9] is done to increase its sharpness as shown in Figure (a). Thus by drawing the concentric circles around the pupil we can easily detect the sclera boundary, the place where sharp intensity changes Figure (b). Among the candidate iris circles, the circle having a maximum change in intensity with respect to the previous drawn circle is the iris outer boundary. Finally Figure (c) shows an example of localized iris image.



Figure 2.4: (a) Contrast image (b) Concentric circles (c) Localized Iris boundary

Segmentation Iris segmentation refers to the process of automatically detecting the pupillary (inner) and limbus (outer) boundaries of an iris in a given image. This process helps in extracting features from the discriminative texture of the iris, while excluding the surrounding regions. A particular image showing the pupillary and limbus boundaries are seen. Iris segmentation plays a key role in the performance of an iris recognition system. This is because improper segmentation can lead to incorrect feature extraction from less discriminative regions (e.g., sclera, eyelids, eyelashes, pupil, etc.), thereby reducing the recognition performance. The first stage of iris recognition is to isolate the actual iris region in a digital eye image. The iris region can be approximated by two circles, one for the iris/sclera boundary and another, interior to the first, for the iris/pupil boundary. The eyelids and eyelashes normally occlude the upper and lower parts of the iris region. Also, specular reflections can occur within the iris region corrupting the iris pattern. A technique is required to isolate and exclude these artefacts as well as locating the circular iris region[10].

A significant number of iris segmentation techniques have been proposed in the literature. Two most popular techniques are based on using an integro-differential operator and the Hough transforms, respectively. The performance of an iris segmentation technique is greatly dependent on its ability to precisely isolate the iris from the other parts of the eye. Both the above listed techniques rely on curve fitting approach on the edges in the image. Such an approach works well with good quality, sharply focused iris images.

Normalization

Iris normalization is done in order to make the image independent of the dimen-

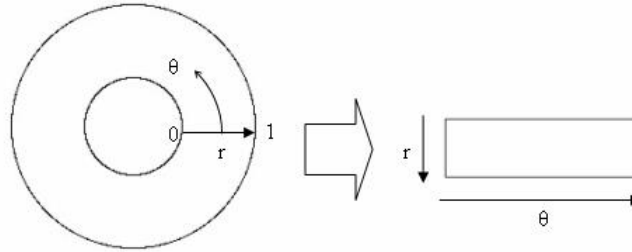


Figure 2.5: Daugman's rubber sheet model.

sions of the input image. Once the iris region is successfully segmented from an eye image, the next stage is to transform the iris region so that it has fixed dimensions in order to allow comparisons. The dimensional inconsistencies between eye images are mainly due to the stretching of the iris caused by pupil dilation from varying levels of illumination. For normalization, Daugman's Rubber Sheet Model, Efficient Sector Normalization, Virtual Circles (proposed by Boles) are as follows.

Daugman's Rubber Sheet Model

The basic rubber sheet model was first introduced by Daugman. He changes each point within the iris region from a pair of polar coordinates (r, θ) to rectangular coordinate where r is on the interval $[0, 1]$ and θ is angle $[0, 2\pi]$.

The mapping of the iris region from polar to (x, y) Cartesian coordinates to the normalised non-concentric polar representation is as follows:

$$I(x(r, \theta), y(r, \theta)) \rightarrow I(r, \theta)$$

With, $x(r, \theta) = (1-r)x_0(\theta) + rx_1(\theta)$ and $y(r, \theta) = (1-r)y_0(\theta) + ry_1(\theta)$

Where $I(x, y)$ is the iris region image, (x, y) are the original Cartesian coordinates, (r, θ) are the corresponding polar coordinates, and (x_0, y_0) and (x_1, y_1) are the coordinates of the pupil and iris boundaries along the direction. The rubber sheet model takes into account pupil dilation and size inconsistencies in order to produce a normalised representation with constant dimensions. Thus we can easily change the whole round shape into linear form. In this way the iris region is modelled as a sheet with the pupil centre as the reference point.

Even though the rubber sheet model accounts for pupil dilation, imaging distance and non-concentric pupil displacement, it does not compensate for rotational inconsistencies. In the Daugman system, rotation is accounted for during matching by shifting the iris templates in the θ direction until two iris templates are aligned.

Efficient Sector Normalization

Inner pupil circle is not fixed; it changes as per the illumination sources condition. Thus we see the variation of the inner pupil radii, whereas the outer circle remains fixed. Normalization means to shell out the minor deformation present in the sectors. After finding the optimal pupil radii and outer edge of the iris, it's time to get rid of the eyelash. The problem of occlusions can be solved by Efficient Sector Normalization in better way. The following Steps remove the eyelash present in the iris:

Iris Localization: The Center of pupil can be determined by localization of iris and pupil centers at (x_0, y_0) . With reference to the center we can divide whole iris image into four sectors. Then the removal of unwanted noise i.e. eyelids. The coordinates of the pupil and iris are given by:

$$\begin{aligned} (x_p(\theta), y_p(\theta)) &= x_0 + r_p \cos(\theta), \\ y_0 + r_p \sin(\theta) &= (y_i(\theta), x_i(\theta)), \\ (x_i(\theta), y_i(\theta)) &= x_0 + r_i \cos(\theta), \\ y_0 + r_i \sin(\theta) & \end{aligned}$$

Where (x_p, y_p) are the points lying on the pupil and (x_i, y_i) are the points lying on iris outer boundary, with center (x_0, y_0) .

Sector Division: Once the proper iris is obtained, it is now time for removing eyelids by sector division. Whole iris is divided into four sectors i.e. Sector1, sector2, sector3 and sector4 as in figure ???. Sector1 and Sector2 are nearly same in dimension with very little occlusion, θ range of sector 1 is $[-65, 45]$, Sector2 ranges from $[135, 245]$, Sector3 range is from $[245, 295]$ and finally the θ range of Sector4 is $[45, 135]$ [11]. The modification is done in the upper and lower sectors, only for noise free result.

The upper Sector (Sector4) is chopped in half, basically to remove the eyelids. The lower Sector (Sector3) is also clipped in 4/5. Both can be represented as:

$$D_4 = ((r_i - r_p))/2$$

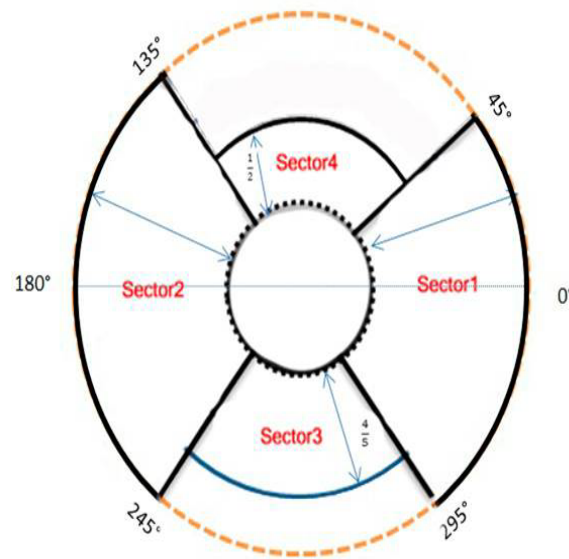


Figure 2.6: Representation of all Sectors in radial and Angular form

$$D3 = [(ri - rp) - 0.2 * (ri - rp)]$$

This gives the corrected size of the normalized iris strip as shown in the fig 3a. The correct angle can remove most of the noise present in the image. It is done to avoid the generation of keypoints in the noise (i.e. eyelid) region. It may lead to false matching (since the keypixel in eyelid region is basically from black eyelash and other people can also have the black eyelash keypixel which lead to the matching error). The normalization improves the accuracy about 20 percent from non-normalized image.

2.2 Classification with Global Features

Many iris recognition systems use global features that describe an entire image of the iris or eye. It is mainly the physical property of an eye. Most points and texture descriptors fall into this category. Such feature points are attractive because they produce very compact representations of images where each image corresponds to a point in a high dimensional feature space[12]. As a result, any standard classifier can be used.

On the other hand global features are sensitive to clutter and occlusion. As a result it is either assumed that an image only contains a single object, or that a good

segmentation of the object from the background is available. In our case, an image often does contain a single object, but sometimes several organisms or particles are present. We have found that a simple global bimodal segmentation is usually effective for separating the plankton from the background, which tends to be significantly darker than the object.

2.3 Classification with Local Features

A different paradigm is to use local features, which are descriptors of local image neighbourhoods computed at multiple interest points. In this paper, I have described be typical ways in which local features are used with examples. One of the key issues in dealing with local features is that there may be differing numbers of feature points in each image, making comparing images more complicated. Hausdorff Average is a standard technique for comparing point sets of different sizes, and it can be used to compare images represented with local features. Typically, interest points are detected at multiple scales and are expected to be repeatable across different views of an object. The interest points are also expected to capture the essence of the object's appearance. The feature descriptor describes the image patch around an interest point. The usual paradigm of using local features is to match them across images, which requires a distance metric for comparing feature descriptors. This distance metric is used to devise a heuristic procedure for determining when a pair of features is considered a match, e. g. by using a distance threshold.

One advantage of using local features is that they may be used to recognize the object despite significant clutter and occlusion. They also do not require a segmentation of the object from the background, unlike many texture features, or representations of the object's boundary (shape features).

2.4 Existing Features in Iris detection

2.4.1 The Discrete Cosine Transform (DCT)

The Discrete Cosine Transform (DCT) [13],[14] is a real transform, it calculates a series possessing and can be implemented using the Discrete Fourier Transform (DFT).

There are several variants but the one most commonly used operates on a real sequence x_n of length N to produce coefficients C_k , following Ahmed et al.

$$C_k = \frac{2}{N} w(k) \sum_{n=0}^{n-1} x_n \cos\left(\frac{2n+1}{2N} \pi k\right)$$

Due to its strong energy compaction property, the DCT is widely used for data compression. In addition, the feature extraction capabilities of the DCT coupled with well-known fast computation techniques have made it a candidate for pattern recognition problems such as the one addressed here. In particular, the DCT has been shown to produce good results on face recognition, where it has been used as a less computationally intensive replacement for the Karhunen-Loeve transform (KLT)[14], which is an optimal technique according to the least squares metric for projecting a large amount of data onto a small dimensional Subspace. The KLT decomposes an image into principal components ordered on the basis of spatial correlation and is statistically optimal in the sense that it minimizes the mean square error between a truncated representation and the actual data. The DCT, with its variance distribution closely resembling that of the KLT, has been shown to approach its optimality with much lower computational complexity. Additionally, its variance distribution decreases more rapidly compared to other deterministic transforms. Although no transform can be said to be optimal for recognition, these well-known properties motivated us to investigate the DCT for effective no semantic feature extraction from human iris images.

As in our Fourier-based iris coding work, we start from a general paradigm whereby the feature vectors will be derived from the zero crossings of the differences between 1D DCT coefficients calculated in rectangular image patches. Averaging across the width of these patches with appropriate windowing helps to smooth the data and mitigate the effects of noise and other image artifacts. This then enables us to use a 1D DCT to code each patch along its length, giving low-computational cost. The selection of the values for the various parameters was done by extensive experimentation over the CASIA and Bath databases to obtain the best predicted Equal Error Rate (EER). The two data sets were used in their entirety to optimize the parameters of the

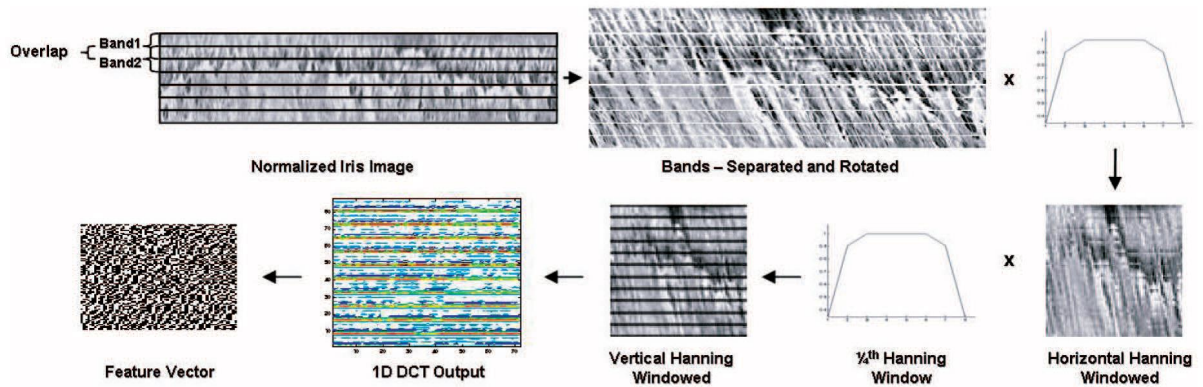


Figure 2.7: Illustrating the various steps in forming feature vectors from normalized iris images

method. Experimentally, overlapping patches gave the best EER in combination with the other parameters. It was also found that horizontally aligned patches worked best, and a rotation of 45 degrees was better than 0 degrees or 90 degrees. This distinctive feature of our code introduces a blend of radial and circumferential texture allowing variations in either or both directions to contribute to the iris code. To form image patches, we select bands of pixels along 45 degree lines through the image. A practical way of doing this is to slew each successive row of the image by one pixel compared to its predecessor. Patches are then selected in 11 overlapping horizontal bands as shown. Each patch has eight pixels vertically (overlapping by four) and 12 horizontally (overlapping six). In the horizontal direction, a weighted average under a 1/4 hamming[15] window is formed. In effect, the resolution in the horizontal (iris circumferential) direction is reduced by this step.

2.4.2 The Discrete Wavelet Transform (DWT)

Discrete wavelet coefficients at every possible scale is a fair work, and it generates lot of data. That is why people choose only a subset of scales and positions at which to make their calculations. It turns out, rather remarkably, that if we choose scales and positions based on powers of two called dyadic scales and positions then their result will be much more efficient and accurate. The discrete wavelet transform (DWT)[16] equation can be mathematically given as:

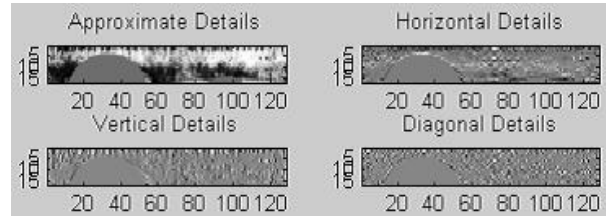


Figure 2.8: Approximation and detail coefficients of the normalized iris image

$$DWT = \sum_{k=1}^{\infty} \sum_{l=-\infty}^{+\infty} Q(k, l) \Psi 2^{-k} t - 1$$

An efficient way to implement this scheme using filters was developed in 1988. This algorithm is in fact a classical scheme known in the signal processing community as a two-channel sub band coder. This very practical filtering algorithm yields a fast wavelet transform a box into which a signal passes, and out of which wavelet coefficients quickly emerge.

Steps involved in DWT

Step 1: In encoding stage, two level Discrete Wavelet Transformation (DWT) [17] is applied on the segmented and normalized iris region to get approximation and detail coefficients as shown in figure. Haar wavelet is used as the mother wavelet. The two-dimensional DWT leads to a decomposition of approximation coefficients at level j in four components: the approximation at level $j + 1$, and the details in three orientations (horizontal, vertical, and diagonal).

Step 2: In encoding stage, unique iris texture features are extracted from both second level horizontal details sub band CH2 and vertical detail sub band CV2. Both sub bands are first segmented into non-overlapping 8x8 non-overlapping blocks.

Step 3: Apply Discrete Cosine Transform (DCT) to each of the 8x8 block of both sub bands. The energy-compaction characteristics of DCT in both sub-bands are used further to capture iris texture variations.

Step 4: Calculate the energy of each 8x8 DCT block for both the subbands.

Step 5: Form binary image template using both subband energy vectors representing iris texture variations using the following criteria. Then set all pixels of



Figure 2.9: Binary image template formed using energies in DWT-DCT domain

corresponding 8x8 block of binary template as 255 i.e. all white pixels. Else set all pixels of corresponding 8x8 block binary template as 0 i.e. all black pixels as shown.

Step 6: Form final binary bit stream/unique code B corresponding to above binary iris image template using following rule, "If all pixels of 8x8 block is marked as 0 then corresponding bit will set as 0 Else corresponding bit will set as 1."

2.4.3 Gabor Filter

J. DAUGMAN, 1993 (Daugman's Integro-differential Operator)[18, 19, 1]

In image processing, a Gabor filters, named after Dennis Gabor, is a linear filter used for edge detection. In the spatial domain, a 2D Gabor filter is a Gaussian kernel function modulated by a sinusoidal plane wave. Its impulse response is defined by a harmonic function multiplied by a Gaussian function. Because of the multiplication-convolution property (Convolution theorem), the Fourier transform of a Gabor filter's impulse response is the convolution of the Fourier transform of the harmonic function and the Fourier transform of the Gaussian function. The filter has a real and an imaginary component representing orthogonal directions. The two components may be formed into a complex number or used individually.

$$G(x, y) = \exp\left(-\frac{x^2 + \gamma^2 y^2}{2\sigma^2}\right) \exp\left(i\left(2\pi \frac{x}{\gamma} + \Psi\right)\right)$$

Where $x' = x \cos \theta + y \sin \theta$ and $y' = -x \sin \theta + y \cos \theta$

In this equation, represents the wavelength of the sinusoidal factor, represents the orientation of In this equation, represents the wavelength of the sinusoidal factor, represents the orientation of the normal to the parallel stripes of a Gabor function, is the phase offset, is the sigma of the Gaussian envelope and is the spatial aspect ratio, and specifies the ellipticity of the support of the Gabor function.

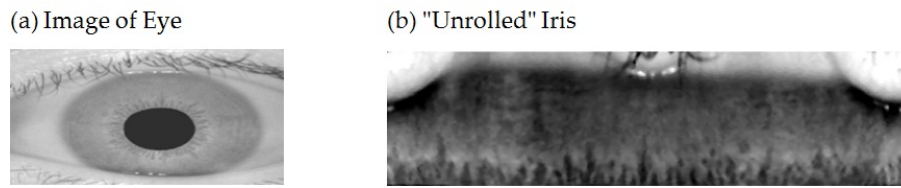


Figure 2.10: (a) Eye (b) Unrolled Iris



Figure 2.11: The real and imaginary parts of iris image

Generating an Iris Code Using Gabor Filter

Now that we have Gabor wavelets, let's generate IrisCode[19] with them. Let's start with an image of an eye and then unroll it (map it to Cartesian coordinates)?? so we have something like the following:

What we want to do is somehow extract a set of unique features from this iris and then store them. That way if we are presented with an unknown iris, we can compare the stored features to the features in the unknown iris to see if they are the same. We'll call this set of features an "Iris Code." Any given iris has a unique texture that is generated through a random process before birth. Filters based on Gabor wavelets turn out to be very good at detecting patterns in images. We'll use a fixed frequency 1D Gabor filter to look for patterns in our unrolled image. First, we'll take a one pixel wide column from our unrolled image and convolve it with a 1D Gabor wavelet. Because the Gabor filter is complex, the result will have a real and imaginary part which is treated separately. We only want to store a small number of bits for each iris code, so the real and imaginary parts are each quantized. If a given value in the result vector is greater than zero, a one is stored; otherwise zero is stored. Once all the columns of the image have been filtered and quantized, we can form a new black and white image by putting all of the columns side by side. The real and imaginary parts of this image (a matrix), the iris code, are shown in figure 2.11

Now that we have an iris code, we can store it in a database, file or even on a card. What happens though if we want to compare two iris codes and decide how similar

they are?

Comparing Iris Codes

The problem of comparing iris codes arises when we want to authenticate a new user. The user's eye is photographed and the iris code produced from the image. It would be nice to be able to compare the new code to a database stored codes to see if this user is allowed or to see who they are. To perform this task, we'll attempt to measure the Hamming distance[20] between two iris codes. The Hamming distance between any two equal length binary vectors is simply the number of bit positions in which they differ divided by the length of the vectors. This way, two identical vectors have distance 0 while two completely different vectors have distance 1. It's worth noting that on average two random vectors will differ in half their bits giving a Hamming distance of 0.5. The Hamming distance is mathematically defined in this equation:

$$D = A \otimes B / \text{length}(A)$$

In theory, two iris codes independently generated from the same iris will be exactly the same. In reality though, this doesn't happen very often for reasons such as imperfect Cameras, lighting or small rotational errors. To account for these slight inconsistencies, two iris codes are compared and if the distance between them is below a certain threshold, we will call it a match. This is actually based on the idea of statistical independence. The iris is random enough such that iris codes from different eyes will always be statistically independent (i.e.: will have a hamming distance larger than the threshold value) and therefore only iris codes of the same eye will fail the test of statistical independence. Regular studies with millions of iris images have supported this assertion. In fact, when these studies used the threshold used in our method (.3) false positive rates fell below 1 in 10 million.

2.4.4 Speeded-Up Robust Feature (SURF)

The Speed-Up Robust Feature detector (SURF)[21] was conceived to ensure high speed in three of the feature detection steps: detection, description and matching (Bay et al., 2006)[22]. SIFT and SURF[21], algorithms employ a different ways of de-

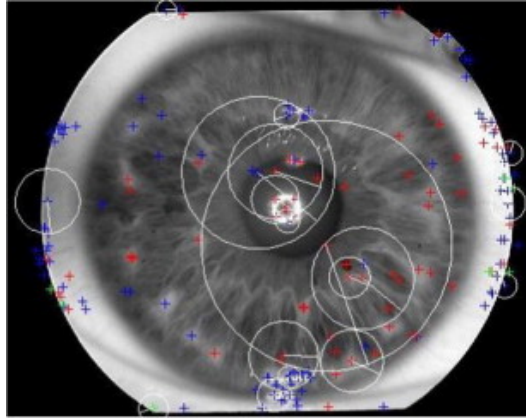


Figure 2.12: Detected SURF keypoints in an iris image

detecting features. SIFT builds an image pyramid, filtering each layer with Gaussians of increasing sigma values and taking the difference. This is called a Gaussian pyramid. Whereas, SURF creates a "stack" without down sampling for higher levels in the pyramid, resulting in images of the same resolution. By the use of integral images, SURF filters the stack using a box filter approximation of second-order Gaussian partial derivatives [2.12], as integral images allow the computation of rectangular box filters in near constant time. In the feature keypoint matching step, the nearest neighbour is defined as the keypoint with minimum Euclidean distance for the invariant descriptor vector. Lowe [23] used a more effective measurement that obtained by comparing the distance of the closest neighbor to that of the second-closest neighbor. The SURF matrix detector is based on the Hessian matrix followed by the SURF Descriptor. There are two components of the SURF Descriptor: (a) Orientation Assignment and (b) Descriptor Components (magnitude).

2.4.5 Gabor Filter As Local Feature

In image processing, a Gabor filter, named after Dennis Gabor, is a linear filter used for edge detection. In the spatial domain, a 2D Gabor filter is a Gaussian kernel function modulated by a sinusoidal plane wave. Its impulse response is defined by a harmonic function multiplied by a Gaussian function. Because of the multiplication-convolution property (Convolution theorem), the Fourier transform of a Gabor filter's impulse response is the convolution of the Fourier transform of the harmonic function

and the Fourier transform of the Gaussian function. The filter has a real and an imaginary component representing orthogonal directions. With the Gabor filters, three basic features, magnitude, phase and orientation, can be extracted. However, previous studies have shown that the local orientation information is the most robust and distinctive local feature for iris detection System. Hence, in this paper, we only take the local orientation as the local feature and make use of the Gabor filter based iris-Code. Such an orientation coding based feature extraction method is suitable for images containing abundant line-like structures and it has the merits of high accuracy, robustness to illumination variation and fast matching.

2.4.6 Scale Invariant Feature Transform

Scale Invariant Feature Transform (SIFT) is well known keypixel descriptor for image recognition. Fourier transforms, (Phase Component) is used to find the texture present in the image, because of the dependency of amplitude on extraneous factors. This approach is best for both cooperative and non-cooperative iris images. SIFT, as mentioned before, was developed by David Lowe in 2004 as a continuation of his previous work on invariant feature detection (Lowe),(1999)[23], and it presents a method for detecting distinctive invariant features from images that can be later used to perform reliable matching between different views of an object or scene. Two key concepts are used in this definition: distinctive invariant features and reliable matching. *What makes the Lowes features more suited to reliable matching than those obtained from any previous descriptor?* The answer to this lies, in accordance to Lowe's explanation, in the cascade filtering approach used to detect the features that transforms image data into scale-invariant coordinates relative to local features. SIFT isn't just Scale Invariant. we can change the following, and still get good results:

- Scale
- Rotation
- Illumination
- Viewpoint

The SIFT Algorithm

SIFT is quite an involved algorithm. It has a lot going on and can become confusing, so I've split up the entire algorithm into multiple parts. Here's an outline of what happens in SIFT.

- Constructing a scale space
- LoG Approximation
- Finding keypoints
- Get rid of bad key points
- Assigning an orientation to the keypoints
- Generate SIFT features

Finding Keypixels using SIFT:-SIFT (Scale Invariant Feature Transform) is a local Feature Extraction Technique not only for its scaling benefits but also for occlusion and illumination conditions. SIFT is very Complex and involved algorithm, a lot of process takes place in it, so for Simplicity we have divided it into five steps. First Step is converting our image in required scale (called Scale Space)[11].in this, the iris image is progressively blurred using Gaussian blur, and resize to half of the original image size. These blurred images are called the Octaves. "Blurring" is represented as:

$$L(x, y, \sigma) = G(x, y, \sigma) * Im(x, y)$$

The Gaussian blur can be written as:

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Where: $x' = x \cos \theta + y \sin \theta$ and $y' = -x \sin \theta + y \cos \theta$, L is the blurred image, G is Gaussian Blur Operator Im is an image, (x,y) are the location Coordinates, τ is the scale of blurring (amount of blurring). Once scaling is done, Second Step is to find

the DoG (Difference of Gaussian) instead of Laplacian of Gaussian (LoG). Laplacian is the second order derivative of iris image. The DoG is shown mathematically as:

$$D(x, y, \sigma) = L(x, y, \sigma) - L(x, y, \sigma)$$

LoG will locate the fine corner and edge present in image, which is good for finding the keypoints. But due to the extremely Sensitive characteristics of the second order derivative towards noise, we are unable to find the LoG. The solution is DoG which gives same result as that of LoG [11] but no noise, which provide accuracy to the method. In this method we simply subtract the preceding Gaussian blurred image minus the next image. Third Step is to determine Keypixels. Finding Keypixels consist of locating the maxima/ minima in DoG image by selecting the desired pixel P0 and comparing it with its nearest 26 pixels. In this comparison we compare the illumination conditions and the maximum and minimum pixel is calculated. The points observed in this process are the approximated maximum and minimum. As the maxima or minima never lies exactly on the pixel. It lies somewhere between the pixels, so we must locate its position mathematically. Then Sub-pixel maxima or minima are calculated by Taylor expression of iris image around P0.

At this point we have a lot of keypoints as an output. Fourth Step is to remove the flat region. It will be then tested on Harris-corner detector which will led to two outputs (i.e. gradients). Then based on these values edge, corner and flat region can be determined. An edge consist of huge gradient (only perpendicular to edge) other will be small, a corner consist of both gradient as big gradients. The flat region consists of both small gradients. Since corner and edge are invariant points we will consider only those points and filter the flat points. Then we assign the orientations around these keypoints. We have to collect Gradient direction and Gradient Magnitude around these keypoints. It can be calculated using the formula:

$$m(x, y) = \sqrt{(L(x+1, y) - L(x-1, y))^2 + (L(x, y+1) - L(x, y-1))^2}$$

$$\theta(x, y) = \tan^{-1} \left(\frac{(L(x, y+1) - L(x, y-1))}{(L(x+1, y) - L(x-1, y))} \right)$$

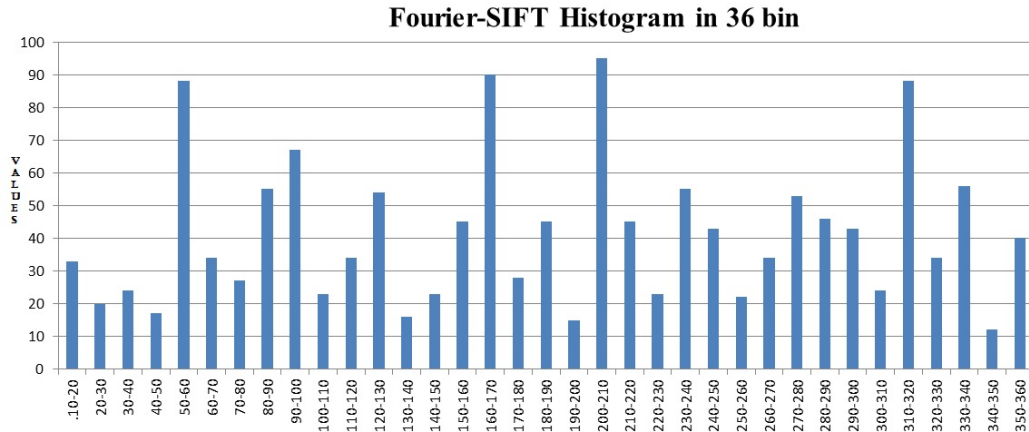


Figure 2.13: Graph Showing Histogram of the Fourier SIFT

Then a histogram is created by dividing 360 in 36 bars each of 10 as shown in the diagram 2.13.

Fifth Step is to create SIFT feature with the generated keypoints in previous step. A 16X16 window is taken around the keypixel and it is further divided into 4 X 4 windows. Within all 4 X 4 window gradient magnitude and gradient orientation are calculated. These are further kept in 8 bins Histogram [0 -45], [45 -90], [90 -135], [135 -180], [180 -225], [225 -270], [270 -315] and [315 -0] 2.13. The amount added to the bin equals to magnitude of gradient. The value in the bin can be kept according to their original magnitude values. Then a histogram is generated. From the histogram the bar whose value is greater than 85 percent is taken as the keypoints. In the above diagram only four points are taken. Since the amount also depends upon distance from the keypixel, thus the gradient far away from keypixel will also be neglected. It can be better explained by Gaussian Weighting Function.

$$G(\text{Weighting}) = (m(x, y) * \Theta(x, y)) * H(\text{Mean})$$

2.5 Comparative analysis of local and global featurea

The most accurate feature is Local feature then global feature 2.5. Some of the local features are shown above along with the global features. The Fastest and accurate

Feature	FAR	FRR	EER
LOCAL FEATURE (SIFT and SURF)	11.1	3.5	1.2
GLOBAL FEATURE(DCT and DWT)	6.1	1.1	6.7

Table 2.1: Results of Comparative Analysis

feature available till date is the SIFT and SURF feature with an accuracy of 98.2 and 98 respectively. The Global feature has its own accuracy and drawback. The following accuracy has been already observed:

Chapter 3

New Novel Feature

3.1 Overview

In order to provide accurate recognition to the individuals, the most discriminating information present in an iris pattern must be extracted properly with effective accuracy. Only the significant (greater than 85 percent) features of the iris must be encoded so that comparisons between templates can be made. Most iris recognition systems make use of a band-pass decomposition of the iris image to create a biometric feature template. The feature extraction algorithm must be designed to preserve the information of interest. The special problem such as compression, denoising, or classification must be taken into consideration while extracting feature. The template that is generated in the feature encoding process will also need a corresponding matching metric, which gives a measure of similarity between two iris templates. This metric should give one range of values when comparing templates generated from the same eye, known as intra-class comparisons, and another range of values when comparing templates created from different irises, known as inter-class comparisons. These two cases should give distinct and separate values, so that a decision can be made with high confidence as to whether two templates are from the same iris, or from two different irises

3.2 Wavelet Analysis

Wavelet analysis is the ability to perform local feature analysis. Wavelet analysis is able to reveal signal aspects that other analysis techniques miss, it is one of the best

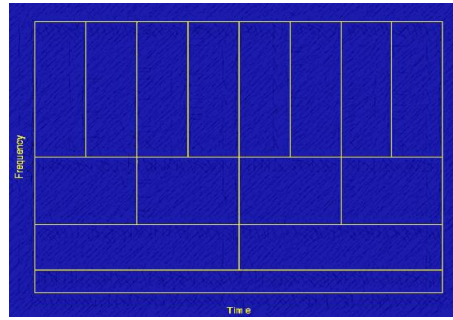


Figure 3.1: Multi-resolution time-frequency plane

techniques in signal processing, the other techniques that are missed are trends, breakdown points, discontinuities, etc. In comparison to the STFT, wavelet analysis makes it possible to perform a multi-resolution analysis which is also related to frequency and time domain. The general idea of multi-resolution analysis will be discussed in next section. The continuous wavelet transform (CWT) [24] is treated as discretized version of the CWT.

3.3 Multi-resolution analysis

The time-frequency resolution problem is caused by the Heisenberg uncertainty principle and exists regardless of the used analysis technique. For the STFT, a fixed time-frequency resolution is used. By using an approach called multi-resolution analysis (MRA) it is possible to analyse a signal at different frequencies with different resolutions. The change in resolution is schematically displayed in Figure 3.1. **A wavelet must have finite energy**

In comparison to the Fourier transform, the analysing function of the wavelet transform can be chosen with more freedom, without the need of using sine-forms. A wavelet function $\Psi(t)$ is a small wave, which must be oscillatory in some way to discriminate between different frequencies. The wavelet contains both the analysing shape and the window. An analysing function $\Psi(t)$ is classified as a wavelet if the following mathematical criteria are satisfied:

- A wavelet must have finite energy, The energy E equals the integrated squared magnitude of the analysing function $\Psi(t)$ and must be less than infinity

- If $\Psi(f)$ is the Fourier transform of the wavelet $\psi(t)$, the following condition must hold

$$C_{\Psi} = \int_0^{\infty} \frac{\Psi(f)^2}{f} df < \infty$$

This condition implies that the wavelet has no zero frequency component ($\Psi(0) = 0$), i.e. the mean of the wavelet $\psi(t)$ must equal zero. This condition is known as the Admissibility Constant. The value of C_0 depends on the chosen wavelet.

3.4 Complex Exponential equation

J Daugman has used Integro-differential Operator which can be broadly explained as the combination of Integration and differentiation of the wavelet equation with the presence of Gaussian carrier as an envelope. My new feature is the combination of complex exponential form of the wavelet equation in the presence of Gaussian carrier as an envelope. The Equation of test signal is: $x(t)$. The vector space and wavelet signal can be treated as same function. So the properties of vector space can be implemented on wavelet functions as follows:

- A basic vector space v is a set of linearly independent vectors. so it can be written as combination of basic vectors. (In 2D the basic will have 2 vectors)

$$V = \sum_k u^k b_k$$

u^k = Corresponding Coefficient b_k = Basic Vector

This concept given in vectors can easily generalised to function by replacing b_k with basic function ϕ_k and vector v with function $f(t)$.

$$f(t) = \sum_k u^k \phi_k$$

The Complex Exponential (Sine and Cosine) function are basic function for the FT(Fourier transform).and they are Orthogonal.

Let's make Mother Wavelet:

Let $f(t)$ and $g(t)$ are two function in $l[a,b]$. The inner product of two function can be defined as:

$$\langle f(t), g(t) \rangle = \int_a^b f(t)g^*(t)dt$$

According to the definition of inner product, CWT (contentious wavelet transform) can be written as inner product of basic function $\Psi(\tau, s)(t)$ and test signal.

$$\Psi(\tau, s)(t) = \int_{-\infty}^{+\infty} x(t)\Psi^*(t)dt$$

Where,

* means complex conjugate

$$\psi(\tau, s)(t) = 1/\sqrt{s}\Psi\left(\frac{t-\tau}{s}\right)$$

τ = translation S = scaling Now we have to correlate the signal with wavelet with different scale: If signal have the major component as of frequency corresponding to current scale ,then wavelet at current scale will be similar or close to a signal at particular location where frequency occurs. The three conditions are:

- inner products
- Orthogonally
- Orthonormality

Two vectors v , and w are said to be orthogonal if their inner product is = zero Similarly two functions $f(t)$ and $g(t)$: A set of vectors (v_1, v_2, \dots, v_n) is said to orthogonal if they are pairwise orthogonal to each other and have length 1.

Now we have to add position vector to the following by the boundary specification equation function, Taking all boundaries together we have, for 2D image: $\vec{r} = \vec{x} + \vec{y}$

Now the Gaussian Equation:

Where Let $(x-u)=t$

Double derivative of the following equation is in terms of exponential equation:

$$\Psi(\tau, s)(t) = e^{-iat} e^{-\frac{t^2}{2\sigma^2}}$$

$$G(x, y) = \frac{1}{2\pi\sigma} e^{-\frac{1}{2}\left(\frac{x-y}{\sigma}\right)^2}$$

Figure 3.2: Gaussian Equation

Mother Wavelet in terms of p

$$\Psi(\tau, s)(t) = e^{-iat+su} e^{\frac{2Pu-P^2+u^2}{2\sigma^2}}$$

The CWT coefficients can be considered as a correlation coefficient and a measure of similitude between the wavelet and the signal in the time-scale plane. The higher coefficient is, the more the similarity. It is noted that the wavelet scale is not a Fourier frequency, but revealed as an inverse of frequency. Accordingly, a relationship between the Fourier frequency and wavelet scale can be approximated:

$$f_F = \frac{f_o f_s}{S}$$

Where f_F : Fourier frequency; S : wavelet scale; f_o : central frequency and f_s : sampling frequency. Now, creating the mother wavelet function with the above given functions, along with the Gaussian envelope and position. In general, the mother wavelet is not arbitrary function. Here list three constraints in designing mother wavelet:

- Zero mean value
- Normalization
- Admissibility condition

3.5 Transforms of Mother Wavelet

3.5.1 Fourier transform (FT)

As we know, Fourier transform convert the signal which is in time domain to frequency domain by integrating over the whole time axis. However, if the signal is non-stationary, the signal in frequency is actually a function of time and we cannot know when the frequency component changes, we also know that the time information is completely lost after Fourier transform. Frequency axis is divided uniformly, and

$$\Psi_{(\tau, s)}(w) = PC\pi\frac{1}{4} \left(e - \frac{1}{2}t' \left(e^{(P\sigma - Pw)^2} - \kappa P\sigma^{-\frac{1}{2}w^2} \right) \right)$$

Figure 3.3: Mother wavelet equation

the frequency resolution may be precise when we integrate along the whole time axis.

Applying Fourier Transform (FT)

The Fourier equation is given as :

$$F(f) = \int_{-\infty}^{+\infty} x(t)e^{-j2\pi ft} dt$$

Mother wavelet equation is:

$$\Psi_{(\tau, s)}(t) = e^{-iat+su} e^{\frac{2Pu - P^2 + u^2}{2\sigma^2}}$$

The shape of the equation is similar to an impulse [3.3](#), resulting in high correlation between $x(t)$ and $\Psi a(t)$. Thus we can easily calculate the fourier transform of this equation. The Fourier transform of the given wavelet is:

At this stage we get two outputs the amplitude and phase modulation, the third output Position vector conjugate will be calculated later. Amplitude is a constant value . The Mother wavelet obtained has a form very similar to the Gabor transform. The important difference is that the window function dose also be scaled by the scaling parameter, while the size of window in Gabor transform is fixed.

3.5.2 Convolution

we have used three 5x5 convolution Kernels. The Digital convolution can be explained as the combination of the image matrix to that of the kernel. we have used three convolution kernels (-1), (0,+3) , (0, -2)

What we're going to do is generate the destination pixels. To do so, we take data from the corresponding source pixel as well as the source pixel's neighbours. We merge it all together with the help of kernels, described below, and the result is the new destination pixel. The convolution is done only to the centre of the image edge

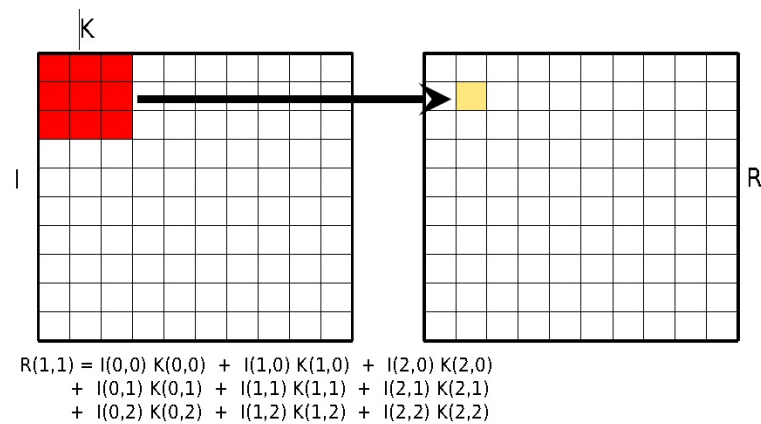


Figure 3.4: Example of Convolution of image

of the image is not convolved. So what to do with the edge:

- Either set to zero (0)
- Keep the original image values
- Partial convolution
- On one part of the kernel
- Mirror the image $f(-x,y) = f(x,y)$

In my kernel^{3.5} the size is 55 pixels and has three box kernels. The first box kernel has dimensions of (55) pixels with +1 as amplitude value, and the second one has dimensions of (33) pixels with +3 as the amplitude value. The third one has dimensions of (11) pixels with +2 as the amplitude value. We multiply these pixel values by the multipliers in the matrix, and then we add them all up. Then, lastly, we divide the result by a divisor to bring it back down to something sensible. By the superposition of kernels, they are also combined to one kernel as shown

3.5.3 Calculation of P

First normalised image is taken and changed into $[x,y]$ Cartesian coordinates as shown in figure .then it is converted in to a matrix using a matlab function called grayco-matrix. Before graycomatrix conversion: I have taken a 16 x 16 matrix^{3.7} around all feature points obtained by convolving the real and imaginary equation with our

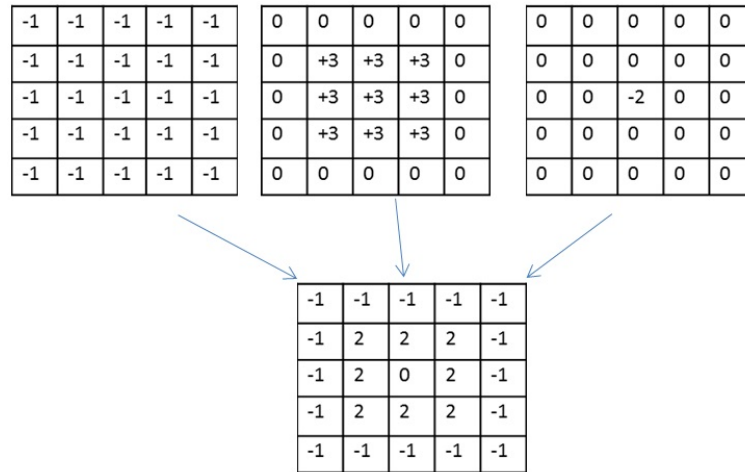


Figure 3.5: Convolution kernel matrix

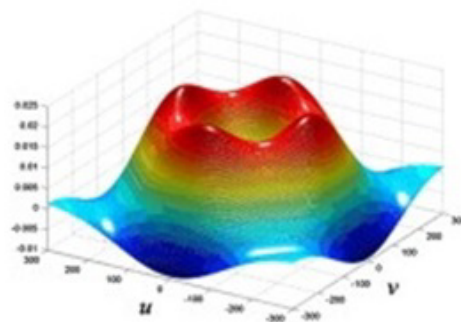


Figure 3.6: Fourier Spectrum of the kernels

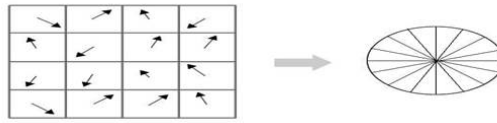


Figure 3.7: 16 Resultants in 16 bin

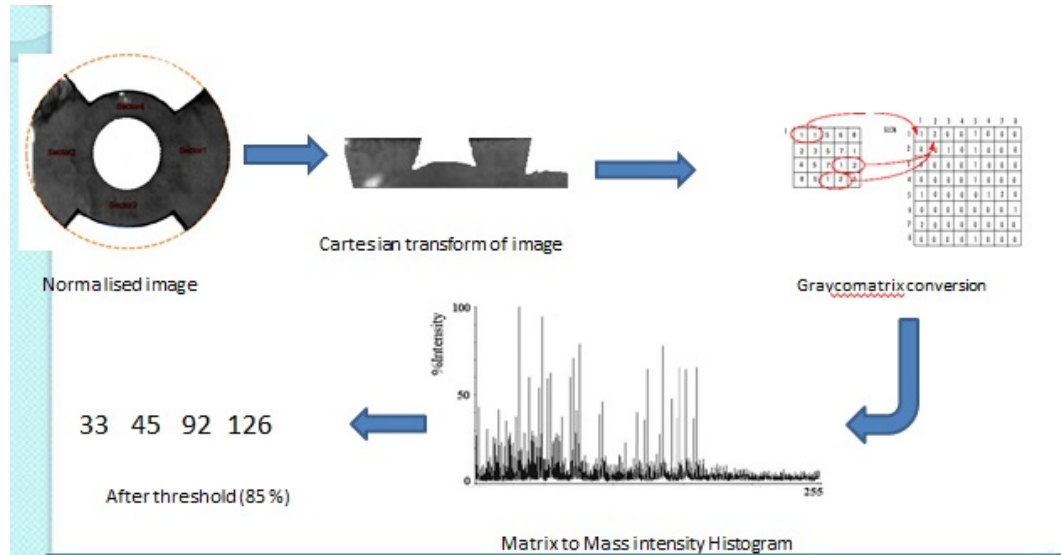


Figure 3.8: Calculating Position Conjugate

iris image. These 16 bins are totally random orientations and pit into 16 bins (for simplicity). You do this for all sixteen 44 regions. So you end up with $4 \times 4 \times 16 = 256$ numbers. Once you have all 256 numbers, you normalize them (just like you would normalize a vector in school, divide by root of sum of squares). These 256 numbers form the "feature vector". This keypoint is uniquely identified by this feature vector.

Then a histogram is plotted by taking the scale of [0,250] and the Cartesian image is plotted into intensity to mass histogram. Hear mass is the superposition of the real and imaginary quantised value to that of the position conjugate. Then a threshold of 85 is applied to it and we get the new feature points. Some of the bad feature keypoints are also removed .This will be stored in the Database for further process like matching and identification. In the above diagram 33, 45, 92 and 126 are not just values these are the corresponding coordinates of the iris image whose frequency of occurrence is much high.

Quantisation

Once we get the value of the position conjugate we have the following outputs:

- Position vector
- Phase Quantisation(real and imaginary)
- Amplitude

So these wave forms must be quantised to get feature keypoints. The output of phase quantisation is chosen to be a gray code, so that while going from one quadrant to another, only 1 bit changes. This will minimize the number of bits disagreeing. Due to the presence of scale factor τ and position conjugate P. Now using a sine equation we can easily relate these three quantities together as one. We get the output as a series of numbers, which called the new feature template The output is the New feature template (NFT) . The output is: New Feature template. Shown in Results.

Chapter 4

Matching

4.1 Overview

During matching the New Feature Template (NFT) is matched with the query template (T) using Hamming distance method in an Euclidian scale space

$$HD_{Matching} = \frac{1}{n * m} \sum_{i,j=1}^{m,n} NFT_{ij} \otimes T_{ij}$$

Where $n * m$ is the size of template and \otimes is the bitwise XOR.

4.2 Literature Review of Matching Algorithms

4.2.1 Hamming Distance

The Hamming distance[20] gives a measure of how many bits are the same between two bit patterns. It matches the cluster of the feature point stored in the database and matches it with the new template cluster obtained. By using Hamming distance operator of two bit patterns, a distance measure can be made as to whether the two patterns were generated from different irises or from the same one. In comparing the bit patterns X and Y, the Hamming distance, is defined as the sum of disagreeing bits present in it(sum of the exclusive-OR between NFT and T) over two clusters, the total number of bits in the bit pattern. Since an individual iris region contains features with high degrees of freedom, each iris region will produce a bit-pattern which is independent to that produced by another iris, on the other hand, two iris codes produced from the same iris will be highly correlated. thus the matching accuracy will

be increased by it.

If two bits patterns are completely independent, such as iris templates generated from different irises, the Hamming distance[20] between the two patterns should equal 0.5, this is the threshold value of the hamming matching. This happens because independence bit patterns will be totally random, so there is 0.5 chance of setting any bit to 1, and vice versa. Therefore, half of the bits will agree and half will disagree between the two patterns. If two patterns are derived from the same iris, the Hamming distance between them will be close to 0.0, since they are highly correlated and the bits should agree between the two iris codes.

Chapter 5

Experimental Results

5.1 Overview

In this chapter, the performance of the new iris recognition system as a whole is examined. Tests were carried out to find the best separation, so that the false match and false accept rate is minimised, and to confirm that iris recognition can perform accurately as a biometric for recognition of individuals.[11] As well as confirming that the system provides accurate recognition, experiments were also conducted in order to confirm the uniqueness of human iris patterns by deducing the number of degrees of freedom present in the iris template representation.

5.2 DataSet

We have taken the publicly available MMU iris, the non-cooperative iris image like CASIA-irisV3 (all)[6] images. MMU[7] consist of a two group MMU1 and MMU2, MMU1 contains a total of 450 iris images of 90 different classes, the size of the image is 320*240 in BMP format.CASIA-irisV3 consist of different database section and captured in the indoor environment. We have performed our test on Lamp, interval and twins databases only. Most of the images were taken in two sessions within an interval of one month. It contains a total of 2655 images of 249 subjects of both left and right eye. Each section contains different images and different classes. The images of CASIA-irisV3 and MMUI1.61.7

Parameters used in iris recognition.

CRR:Correct Recognition Rate

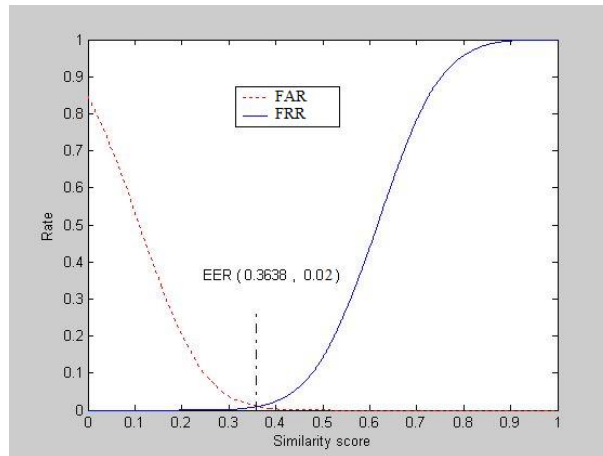


Figure 5.1: Equal error rate

FAR: The false accept rate (FAR), measures the probability of an individual being wrongly identified as another individual.

FRR: The false reject rate (FRR), measures the probability of an enrolled individual not being identified by the system.

ROC: (receiver-operating characteristic): ROC is a graphical depiction of the relationship between the FRR and FAR. ROC curve helps to demonstrate how increasing or decreasing the decision threshold's value affects tradeoffs between FRR and FAR. The ROC curve is represented in a logarithmic scale.

ERR: (Equal error rate) [25] When increase threshold value, the FAR will increase and FRR will decrease. ERR is the value which $FAR=FRR$. **Decidability:** Decidability d is a distance measured in standard deviations and is a function of the magnitude of difference between the mean of the intra-class distribution and the mean of the inter-class distribution respectively. The higher the decidability, the greater is the separation of intra-class and inter-class distributions, which allows for more accurate recognition.

5.3 Results

The New Feature Template NFT is as follows:

===== Build started: =====

DATABASE	CRR	FAR/FRR			Feature Points (Avg)	Extraction time(s)	ERR(SEM)
		0.01%	0.1%	1%			
CASIA-IrisV3-Interval	98.2%	4.8%	2.8%	1.6%	47	0.13	0.02(0.417)
CASIA-IrisV3-Lamp	98%	9.2%	5.98%	3.18%	53	0.5	0.024(0.42)
BATH	96.3%	2.3%	1.25%	0.65%	130	0.07	0.006(0.40)
UBIRIS_2	85%	8.5%	5.04%	2.52%	34	0.08	0.02(0.40)
MMU iris	98.9%	9.22%	6.11%	3.67%	12	0.1	0.03(0.408)

Figure 5.2: Accuracy and speed of New Feature created on the iris Databases

1_i—— IRIS NEW FEATURE CREATED and STORED ——

no R0 R1 pmt smt mean sup noi dif

C:casia001LS1001L01.jpg

0 57 109 1 0.35 129.6 73.9 0 0.038

1 51 108 1 0.33 130.3 73.6 0 0.048

2 56 106 1 0.4 129.8 73.7 0 0.04

3 54 107 0.99 0.33 130.1 73.6 0 0.038

4 54 105 0.92 0.28 130.1 73.7 0 0.04

5 59 115 0.97 0.23 129.5 73.8 0 0.035

6 54 112 1 0.31 129.8 73.5 0 0.042

7 59 114 1 0.24 129.4 73.8 0 0.038

8 58 113 0.9 0.19 129.6 73.6 0 0.039

9 54 111 1 0.37 130 73.7 0 0.037

10 57 103 1 0.37 130.1 73.6 0 0.041

11 47 107 1 0.43 129.9 73.6 0 0.044

12 59 107 1 0.39 129.7 73.7 0 0.037

13 56 103 1 0.34 130 73.6 0 0.039

14 54 109 1 0.43 130 73.7 0 0.045

15 55 112 1 0.42 129.6 73.8 0 0.037

.....

- In the above template arrangement can be explain as the following:

FEATURES	RESULTS (Th =4)			Feature Points (average)	Extraction time(s)
	FAR	FRR	ACC		
GABOR (global)	3.0%	10%	89.6%	Binary(irisCode)	Around 4
SIFT (local)	1.0%	2.1%	98.8%	290	2.7
SURF (local)	2.3%	1.25%	97.6%	<320	3.7
New Approach (local)	5.5%	0.04%	92.2%	47	0.18

Figure 5.3: The Comparative Analysis of new feature over the existing feature

- First the Serial no of the image present in the database, all the images are stored serially taken, it does not saved as left or right.
- The second value is the inner radius, i.e.- pupil-iris boundary
- Third value is the outer boundary. i.e. iris- sclera boundary
- Fourth is the Position value. (P)
- Fifth is mean of Quantization value (real and imaginary).
- Then the average superposition of the three values.
- Finally noise present in each noise, calculated during sector normalization.
- Some of the error warning is also shown which is caused by the same value of superposition and mean in database.

The Comparative Analysis of new feature over the existing feature is summarised in the following table 5.3:

Chapter 6

Conclusions and Future Work

6.1 Summary of Work

This thesis presents a new feature in iris recognition system, which is tested on four iris database. This thesis proposes a novel effective sector based normalisation and mainly new feature extraction approaches. This paper presents a complete iris recognition system with new feature detection techniques. , The Accuracy of the local feature is 87.2 percent (on an average), which is tested on four iris database. My new Feature is fast and robust method then any of the existing features. The enrolment and matching process is very accurate up to 98 percent. The matching speed of this new feature is very low 0.18 s. The feature point detected is very less on an average of 47 in numbers due to inappropriate compilation of the whole process. Finally matching is done by Hamming distance measures in Euclidean space [26] matrix.

6.2 Summary of Findings

The New Complex exponential Feature is fast and robust method then any of the existing features. This method is only for iris recognition System. The Accuracy of the new local feature is 87.2 percent on an average, which is tested on four iris databases CASIA, MMU, IIT DELHI and BATH database. This new Feature is very fast and robust method then any of the existing features. The enrolment and matching speed of this new feature is very low 0.18 seconds The feature point detected is very less on an average of 47 in numbers due to inappropriate compilation of the whole process .The enrolment and matching process is very accurate up to 98 percent.

6.3 Suggestions for Future Work

The future work is to increase the number of feature points and decrease FAR and increase FRR by optimising the mother wavelet equation. The feature points are also very less, steps can be taken to set a unique threshold and increase the accuracy.

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Chapter 7

Appendix

7.0.1 IRIS Biometrics Standards

- Following biometrics standards have evolved to ensure similarity in all iris images in terms of formatting and the contents.
- International Organization for Standardization/ International Electro technical Commission (ISO/IEC) 19794-6:2005[27]
- The American National Standards Institute/ International Committee for Information Technology Standards (ANSI/INCITS) 379-2004
- The American National Standards Institute/ The US National Institute for Standards and Technology (NIST) ANSI/NIST-ITL 1-2007 TYPE 17
- The US Department of Defense Electronic Biometric Transmission (DoD EBTS)

7.0.2 Applications of the iris Recognition System



Figure 7.1: **Application 1:** A U.S. Marine Corps Sergeant uses an iris scanner to positively identify a member of the Baghdadi city council prior to a meeting with local tribal leaders, sheiks, community leaders and U.S. service members.



Figure 7.2: **Application 2:** Police forces across America plan to start using BI2 Technologies' mobile MORIS (Mobile Offender Recognition and Information System) in 2012



Figure 7.3: **Application 3:** Collecting images of iris in the Unique Identification Authority of India (AADHAAR)



Figure 7.4: **Application 3:** The tragic story of Sharbat Gula, the photo was first taken in the year 1984 when she was 12 (age) in a refugee camp in Pakistan by National Geographic channel (NGC) photographer Steve McCurry, and traced after 18 years to a remote part of Afghanistan using J Daugman's iris method. She was again photographed by McCurry, published in the April 2002 issue of NGC



Photograph by Alexandra Boulari



Photograph by Steve McCurry

Figure 7.5: Geographic turned to the inventor of automatic iris recognition, John Daugman, a professor of computer science at England's University of Cambridge. His biometric technique uses mathematical calculations, and the numbers Daugman got left no question in his mind that the haunted eyes of the young Afghan refugee and the eyes of the adult Sharbat Gula belong to the same person

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