A

REPORT

ON

IRIS RECOGNITION

FOR PARTIAL FULFILLMENT OF

STUDY ORIENTED PROJECT

Submitted by

NIKHIL MOTIANI *2011A8PS347P*

NAMAN MAHESHWARI *2011A3PS199P*

MENTOR & GUIDE - DR. ABHIJIT R. ASATI

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Abstract

A wide variety of systems require reliable personal recognition schemes to either confirm or determine the identity of an individual requesting their services. The purpose of such schemes is to ensure that the rendered services are accessed only by a legitimate user, and not anyone else. Examples of such applications include secure access to buildings, computer systems, laptops, cellular phones and ATMs. In the absence of robust personal recognition schemes, these systems are vulnerable to the wiles of an impostor. Biometric recognition, or simply biometrics, refers to the automatic recognition of individuals based on their physiological and/or behavioural characteristics. By using biometrics it is possible to confirm or establish an individual's identity based on "who she is", rather than by "what she possesses" (e.g., an ID card) or "what she remembers" (e.g., a password).

Iris recognition is an automated method of biometric identification that uses mathematical pattern-recognition techniques on video images of the irides of an individual's eyes, whose complex random patterns are unique and can be seen from some distance. It has a very high accuracy (infinitesimally small false match rates) and is non-destructive as compared to retina-scanning. Hence, it finds a great usage in security systems today and in future.

Introduction

Reliable automatic recognition of persons has long been an attractive goal. As in all pattern recognition problems, the key issue is the relation between interclass and intra-class variability: objects can be reliably classified only if the variability among different instances of a given class is less than the variability between different classes. For example in face recognition, difficulties arise from the fact that the face is a changeable social organ displaying a variety of expressions, as well as being an active 3D object whose image varies with viewing angle, pose, illumination, accoutrements, and age. It has been shown that for facial images taken at least one year apart, even the best current algorithms have error rates of 43% (Phillips et al. 2000) to 50% (Pentland et al. 2000). Against this intra-class (same face) variability, inter-class variability is limited because different faces possess the same basic set of features, in the same canonical geometry.

For all of these reasons, iris patterns become interesting as an alternative approach to reliable visual recognition of persons when imaging can be done at distances of less than a meter, and especially when there is a need to search very large databases without incurring any false matches despite a huge number of possibilities. Although small (11 mm) and sometimes problematic to image, the iris has the great mathematical advantage that its pattern variability among different persons is enormous. In addition, as an internal (yet externally visible) organ of the eye, the iris is well protected from the environment, and stable over time. As a planar object its image is relatively insensitive to angle of illumination, and changes in viewing angle cause only affine transformations; even the non-affine pattern distortion caused by pupillary dilation is readily reversible. Finally, the ease of localizing eyes in faces, and the distinctive annular shape of the iris, facilitate reliable and precise isolation of this feature and the creation of a size-invariant representation.

Biometrics is the science of establishing human identity by using physical or behavioral traits such as face, fingerprints, palm prints, iris, hand geometry, and voice. Iris recognition systems, in particular, are gaining interest because the iris's rich texture offers a strong biometric cue for recognizing individuals. Located just behind the cornea and in front of the lens, the iris uses the dilator and sphincter muscles that govern pupil size to control the amount of light that enters the eye. Near-infrared (NIR) images of the iris's anterior surface exhibit complex patterns that computer systems can use to recognize individuals. Because NIR lighting can penetrate the iris's surface, it can reveal the intricate texture details that are present even in dark-colored irides. The iris's textural complexity and its variation across eyes have led scientists to postulate that the iris is unique across individuals. Further, the iris is the only internal organ readily visible from the outside. Thus, unlike fingerprints or palm prints, environmental effects cannot easily alter its pattern. An iris recognition system uses pattern matching to compare two iris images and generate a match score that reflects their degree of similarity or dissimilarity.

Iris recognition systems are already in operation worldwide, including an expellee tracking system in the United Arab Emirates, a welfare distribution program for Afghan refugees in Pakistan, a border-control immigration system at Schiphol Airport in the Netherlands, and a frequent traveler program for preapproved low-risk travelers crossing the US-Canadian border.

Iris recognition efficacy is rarely impeded by glasses or contact lenses. Iris technology has the smallest outlier (those who cannot use/enrol) group of all biometric technologies. Because of its speed of comparison, iris recognition is the only biometric technology well-suited for one-to-many identification. A key advantage of iris recognition is its stability, or template longevity, as, barring trauma, a single enrolment can last a lifetime.

Biometrics & Its Need

Today's e-security are in critical need of finding accurate, secure and cost-effective alternatives to passwords and personal identification numbers (PIN) as financial losses increase dramatically year over year from computer-based fraud such as computer hacking and identity theft. Biometric solutions address these fundamental problems, because an individual's biometric data is unique and cannot be transferred. Biometrics which refers to identifying an individual by his or her physiological or behavioural characteristics has capability to distinguish between authorized user and an imposter. An advantage of using biometric authentication is that it cannot be lost or forgotten, as the person has to be physically present during at the point of identification process. Biometrics is inherently more reliable and capable than traditional knowledge based and token based techniques. The commonly used biometric features include speech, fingerprint, face, Iris, voice, hand geometry, retinal identification, and body odour identification.

Different types of Biometrics

To choose the right biometric to be highly fit for the particular situation, one has to navigate through some complex vendor products and keep an eye on future developments in technology and standards. Here comes a list of Biometrics with comparatives:

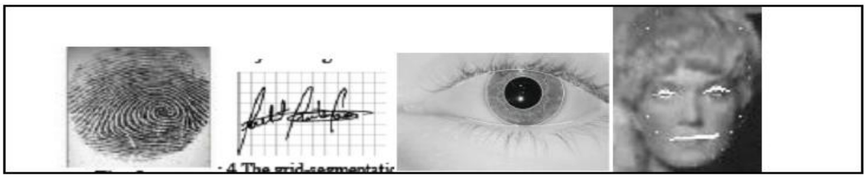


Figure1: Examples of Biometrics

Facial Recognition: Facial recognition records the spatial geometry of distinguishing features of the face. Different vendors use different methods of facial recognition, however, all focus on measures of key features of the face. Facial recognition has been used in projects to identify card counters or other undesirables in casinos, shoplifters in stores, criminals and terrorists in urban areas. This biometric system can easily spoof by the criminals or malicious intruders to fool recognition system or program. Iris cannot be spoofed easily.

Palm Print: Palm print verification is a slightly modified form of fingerprint technology. Palm print scanning uses an optical reader very similar to that used for fingerprint scanning; however, its size is much bigger, which is a limiting factor for use in workstations or mobile devices.

Signature Verification: It is an automated method of examining an individual's signature. This technology is dynamic such as speed, direction and pressure of writing, the time that the stylus is in and out of contact with the ―paper‖. Signature verification templates are typically 50 to 300 bytes. Disadvantages include problems with long-term reliability, lack of accuracy and cost.

Fingerprint: A fingerprint as in Figure1 recognition system constitutes of fingerprint acquiring device, minutia extractor and minutia matcher. As it is more common biometric recognition used in banking, military etc., but it has a maximum limitation that it can be spoofed easily. Other limitations are caused by particular usage factors such as wearing gloves, using cleaning fluids and general user difficulty in scanning.

Iris Scan: Iris as in Figure2 is a biometric feature, found to be reliable and accurate for authentication process comparative to other biometric feature available today which is as shown Table1 (a) (b).

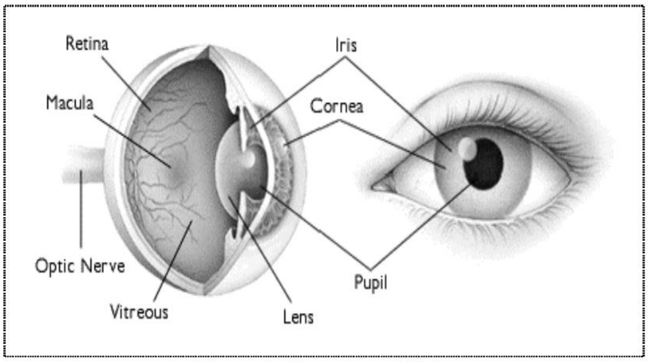


Figure2: Structure of iris.

Table1 (a): Biometric comparison List

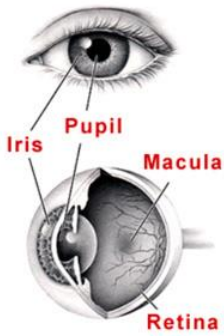
Method	Coded Pattern	Mis-identific	Security	Application
Iris Recognition	Iris pattern	1/1200000	High	High security facilities
Finger printing	Fingerprints	1/1,000	Medium	Universal
Hand Shape Size,	Length and thickness	1/700	Low	Low-security facilities
Facial Recognition	Outline, shape and distribution of eyes and nose	1/100	Low	Low-security facilities
Signature	Shape of letters	1/100	Low	Low-security facilities
Voice printing	Voice characteristic	1/30	Low	Telephone service

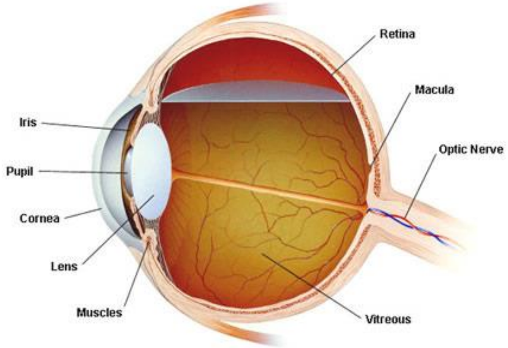
Table1 (b): Biometric comparison List

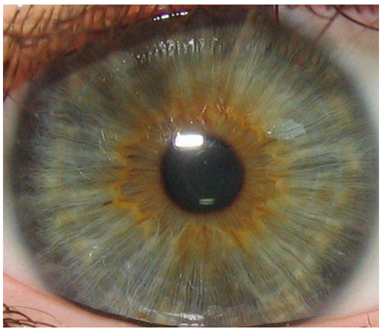
Biometrics	Crossover Accuracy
Retinal Scan	1:10,000,000+
Iris Scan	1:131,000
Fingerprints	1:500
Hand Geometry	1:500
Signature Dynamics	1:50
Voice Dynamics	1:50

Iris as a Biometric Identity

The iris is a muscle within the eye which regulates the size of the pupil, and it controls the amount of light which enters the eye. It is the coloured portion of the eye with colouring based on the amount of melatonin pigment within the muscle.



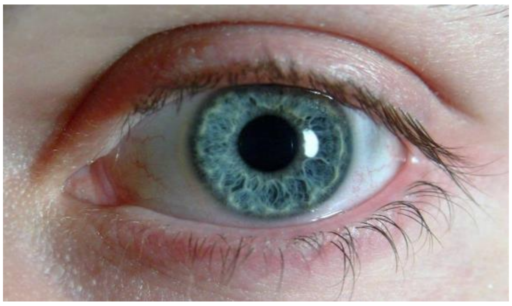




The iris is an internal organ of the eye - perhaps the only internal organ of the body that is routinely visible from outside and its patterns are resolvable with good video cameras from distances of up to about a meter. The iris is located behind the cornea of the eye, and behind the aqueous humour, but in front of the lens.

There is no genetic determination of the detailed iris texture, as sighted readers can confirm just by examining the detailed texture in their left and right eyes (which are, of course, genetically identical). Apart from the occasional appearance of freckles or other pigmentation changes caused by some eye drop treatments for glaucoma, there is no evidence for any change of iris pattern over a person's life.

As illustrated by the accompanying close-up iris photograph, iris patterns have a high degree of randomness in their structure. This is what makes them unique. Every biometric depends upon random variation amongst different persons in the chosen measurements, in order to guarantee that a particular pattern is unique to just one person and thus can serve as a reliable automatic identifier of them.



The iris patterns in the left and right eyes are different, and so scan be used quickly for both identification and verification applications because of its large number of degrees of freedom. Iris is like a diaphragm between the pupil and the sclera and its function is to control the amount of light entering through the pupil. Iris is composed of elastic connective tissue such as trabecular meshwork. The agglomeration of pigment is formed during the first year of life, and pigmentation of the stromal occurs in the first few years. The highly randomized appearance of the iris makes its use as a biometric well recognized. Its suitability as an exceptionally accurate biometric derives from:

i. The difficulty of forging and using as an imposter person;
ii. It is intrinsic isolation and protection from the external environment;
iii. It's extremely data-rich physical structure.
iv. Its genetic properties—no two eyes are the same. The characteristic that is dependent on genetics is the pigmentation of the iris, which determines its colour and determines the gross anatomy. Details of development, that are unique to each case, determine the detailed morphology;
v. Its stability over time; the impossibility of surgically modifying it without unacceptable risk to vision and its physiological response to light, which provides a natural test against artifice.

Advantages of Iris as Biometric Identity

- Extremely protected, internal organ of the eye;
- Externally visible;
- Iris patterns possess a high degree of randomness;
  - variability: 244 degrees-of-freedom
  - entropy: 3.2 bits per square-millimeter
  - uniqueness: set by combinatorial complexity
- Patterns apparently stable throughout life;
- Encoding and decision-making are tractable;
  - image analysis and encoding time: 30 milliseconds
  - decidability index (d-prime): d' = 6 to 8 typically
  - search speed: 1 million Iris Codes per second, with a 3 GHz CPU

Disadvantages

- Small target (1 cm) to acquire from a distance (1 m);
- Moving target;
- Located behind a curved, wet, reflecting surface;
- Covered by eyelashes, lenses, reflections;
- Partially covered by eyelids;

Iris Recognition – Daugman's Theory

After the discovery of iris, John G. Daugman, a professor of Cambridge University, suggested an image-processing algorithm that can encode the iris pattern into 256 bytes based on the Gabor transform.

In general, the iris recognition system is composed of the following five steps as depicted in Figure 3 According to this flow chart, pre-processing including image enhancement.

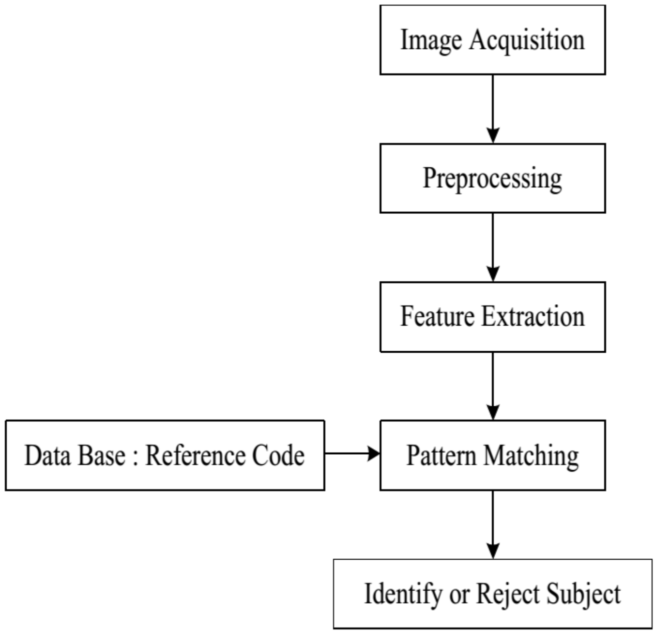


Figure 3: General steps of the iris recognition system

Finding the Iris in an Image

To capture the rich details of iris patterns, an imaging system should resolve a minimum of 70 pixels in iris radius. In the field trials to date, a resolved iris radius of 100 to 140 pixels has been more typical. Monochrome CCD cameras (480 x 640) have been used because NIR illumination in the 700nm - 900nm band was required for imaging to be invisible to humans. Some imaging platforms deployed a wide angle camera for coarse localization of eyes in faces, to steer the optics of a narrow-angle pan/tilt camera that acquired higher resolution images of eyes. There exist many alternative methods for finding and tracking facial features such as the eyes, and this well researched topic will not be discussed further here. In these trials, most imaging was done without active pan/tilt camera optics, but instead exploited visual feedback via a mirror or video image to enable cooperating Subjects to position their own eyes within the field of view of a single narrow-angle camera.

Focus assessment was performed in real-time (faster than video frame rate) by measuring the total high-frequency power in the 2D Fourier spectrum of each frame, and seeking to maximize this quantity either by moving an active lens or by providing audio feedback to Subjects to adjust their range appropriately. Images passing a minimum focus criterion were then analyzed to find the iris, with precise localization of its boundaries using a coarse-to-fine strategy terminating in single-pixel precision estimates of the center coordinates and radius of both the iris and the pupil. Although the results of the iris search greatly constrain the pupil search, concentricity of these boundaries cannot be assumed. Very often the pupil center is nasal, and inferior, to the iris center. Its radius can range from 0.1 to 0.8 of the iris radius. Thus, all three parameters defining the pupillary circle must be estimated separately from those of the iris. A very effective Integro-differential operator for determining these parameters is:

$$\max_{(r,x_0,y_0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r,x_0,y_0} \frac{I(x,y)}{2\pi r} ds \right|$$

Where I(x; y) is an image containing an eye. The operator searches over the image domain (x; y) for the maximum in the blurred partial derivative with respect to increasing radius r, of the normalized contour integral of I(x; y) along a circular arc ds of radius r and center coordinates (x0; y0). The symbol

* denotes convolution and Gσ(r) is a smoothing function such as a Gaussian of scaleσ. The complete operator behaves in effect as a circular edge detector, blurred at a scale set by _, which searches iteratively for a maximum contour integral derivative with increasing radius at successively finer scales of analysis through the three parameter space of center coordinates and radius (x0; y0; r) defining a path of contour integration. The operator serves to find both the pupillary boundary and the outer (limbus) boundary of the iris, although the initial search for the limbus also incorporates evidence of an interior pupil to improve its robustness since the limbic boundary itself usually has extremely soft contrast when long wavelength NIR illumination is used. Once the coarse-to-fine iterative searches for both these boundaries have reached single pixel precision, then a similar approach to detecting curvilinear edges is used to localize both the upper and lower eyelid boundaries.

ENCODING AND GABOR FILTER

In order to provide accurate recognition of individuals, the most discriminating information present in an iris pattern must be extracted. Only the significant 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 template. 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.

Wavelet Encoding: - Wavelets can be used to decompose the data in the iris region into components that appear at different resolutions. Wavelets have the advantage over traditional Fourier transform in that the frequency data is localised, allowing features which occur at the same position and resolution to be matched up. A number of wavelet filters, also called a bank of wavelets, is applied to the 2D iris region, one for each resolution with each wavelet a scaled version of some basis function. The output of applying the wavelets is then encoded in order to provide a compact and discriminating representation of the iris pattern.

Gabor Filters: - Gabor filters are able to provide optimum conjoint representation of a signal in space and spatial frequency. A Gabor filter is constructed by modulating a sine/cosine wave with a Gaussian. This is able to provide the optimum conjoint localisation in both space and frequency, since a sine wave is perfectly localised in frequency, but not localised in space. Modulation of the sine with a Gaussian provides localisation in space, though with loss of localisation in frequency. Decomposition of a signal is accomplished using a quadrature pair of Gabor filters, with a real part specified by a cosine modulated by a Gaussian, and an imaginary part specified by a sine modulated by a Gaussian. The real and imaginary filters are also known as the even symmetric and odd symmetric components respectively. The centre frequency of the filter is specified by the frequency of the sine/cosine wave, and the bandwidth of the filter is specified by the width of the Gaussian. Daugman makes uses of a 2D version of Gabor filters [1] in order to encode iris pattern data. A 2D Gabor filter over the an image domain (x, y) is represented as

$$G(x,y) = e^{-\pi[(x-x_0)^2/\alpha^2+(y-y_0)^2/\beta^2]}e^{-2\pi i[u_0(x-x_0)+v_0(y-y_0)]}$$

Where (x_o, y_o) specify position in the image, (α, β) specify the effective width and length, and (u_o, v_o) specify modulation, which has spatial frequency .The odd symmetric and even symmetric 2D Gabor filters are shown in Figure shown below

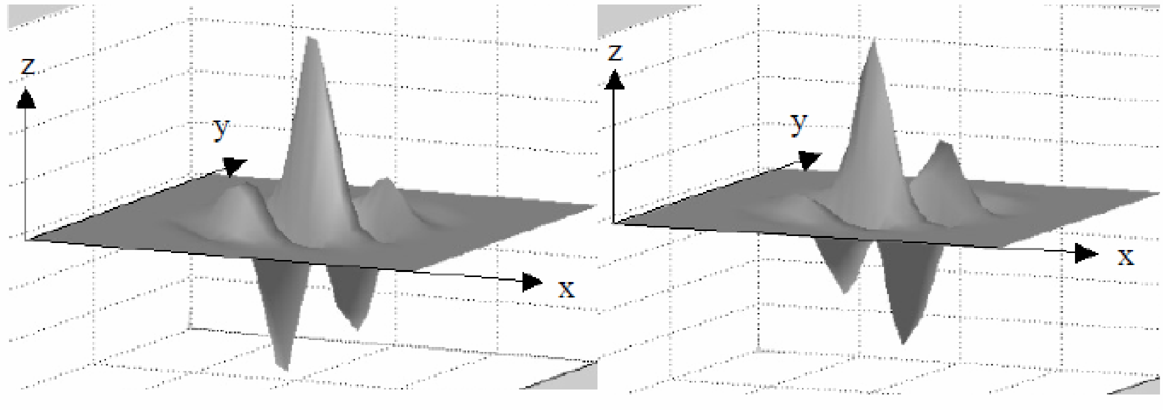


Fig: quadrature pair of 2D Gabor filters left) real component or even symmetric filter characterised by a cosine modulated by a Gaussian right) imaginary component or odd symmetric filter characterised by a sine modulated by a Gaussian.

Each isolated iris pattern is then demodulated to extract its phase information using quadrature 2D Gabor wavelets as also shown in the figure. It amounts to a patch-wise phase quantization of the iris pattern, by identifying in which quadrant of the complex plane each resultant phasor lies when a given area of the iris is projected onto complex-valued 2D Gabor wavelets:

$$h_{\{Re,Im\}} = \mathrm{sgn}_{\{Re,Im\}} \int_\rho \int_\phi I(\rho,\phi) e^{-i\omega(\theta_0-\phi)} \cdot e^{-(r_0-\rho)^2/\alpha^2} e^{-(\theta_0-\phi)^2/\beta^2} \rho d\rho d\phi$$

where h{Re, Im} can be regarded as a complex-valued bit whose real and imaginary parts are either 1 or 0 (sgn) depending on the sign of the 2D integral; I(ρ,φ) is the raw iris image in a dimensionless polar coordinate system that is size- and translation-invariant, and which also corrects for pupil dilation; α and β are the multi-scale 2D wavelet size parameters, spanning an 8-fold range from 0.15mm to 1.2mm on the iris; ω is wavelet frequency, spanning 3 octaves in inverse proportion to β; and (r_0; θ_0) represent the polar coordinates of each region of iris for which the phasor coordinates h{Re, Im} are computed.

Recognizing Irises Regardless of Size, Position, and Orientation

Robust representations for pattern recognition must be invariant to changes in the size, position, and orientation of the patterns. In the case of iris recognition, this means we must create a representation that is invariant to the optical size of the iris in the image (which depends upon the distance to the eye, and the camera optical magnification factor); the size of the pupil within the iris (which introduces a non-affine pattern deformation); the location of the iris within the image; and the iris orientation, which depends upon head tilt, torsional eye rotation within its socket (cyclovergence), and camera angles, compounded with imaging through pan/tilt eye-finding mirrors that introduce additional image rotation factors as a function of eye position, camera position, and mirror angles. Fortunately, invariance to all of these factors can readily be achieved.

For on-axis but possibly rotated iris images, it is natural to use a projected pseudo polar coordinate system. The polar coordinate grid is not necessarily concentric, since in most eyes the pupil is not central in the iris; it is not unusual for its nasal displacement to be as much as 15%. This coordinate system can be described as doubly-dimensionless: the polar variable, angle, is inherently dimensionless, but in this case the radial variable is also dimensionless, because it ranges from the pupillary boundary to the limbus always as a unit interval [0, 1]. The dilation and constriction of the elastic meshwork of the iris when the pupil changes size is intrinsically modelled by this coordinate system as the stretching of a homogeneous rubber sheet, having the topology of an annulus anchored along its outer perimeter, with tension controlled by an (off-centered) interior ring of variable radius.

The homogeneous rubber sheet model assigns to each point on the iris, regardless of its size and pupillary dilation, a pair of real coordinates (r; θ) where r is on the unit interval [0, 1] and θ is angle [0, 2pi]. The remapping of the iris image I(x; y) from raw Cartesian coordinates (x; y) to the dimensionless nonconcentric polar coordinate system (r; θ) can be represented as –

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

Where x(r, θ) and y(r, θ) are defined as linear combinations of both the set of pupillary boundary points (x_p (θ); yp(θ)) and the set of limbus boundary points along the outer perimeter of the iris ($x_s(\theta)$; $y_s(\theta)$) bordering the sclera, both of which are detected by finding the maximum of the Integro-differential operator defined above.

$$x(r,\theta) = (1-r)x_p(\theta) + rx_s(\theta)$$

$$y(r,\theta) = (1-r)y_p(\theta) + ry_s(\theta)$$

Since the radial coordinate ranges from the iris inner boundary to its outer boundary as a unit interval, it inherently corrects for the elastic pattern deformation in the iris when the pupil changes in size.

The localization of the iris and the coordinate system described above achieve invariance to the 2D position and size of the iris, and to the dilation of the pupil within the iris. However, it would not be invariant to the orientation of the iris within the image plane.

Algorithm Explanation (Stepwise)

1) Image Acquisition

An image of the eye to be analysed must be acquired first in digital form suitable for analysis. For the purpose of this study a small database of images of eyes of 3 individuals (both left and right) with 3 different angles is taken. The main use of this database is to minimize the requirement of user cooperation, i.e., the analysis and proposal of methods for the automatic recognition of Individuals, using images of their iris captured at a-distance and minimizing the required degree of cooperation from the users.

2) Pre-processing

a) Algorithm for Iris Detection & Segmentation

Iris Detection:

Irises are detected even when the images have obstructions, visual noise and different levels of illumination. Lighting reflections, eyelids and eyelashes obstructions are eliminated. Images with narrowed eyelids or eyes that are gazing away are also accepted using wavelet algorithm. **Automatic interlacing detection and correction:** The correction results in maximum quality of iris features templates from moving iris images.

Gazing-away eyes: A gazing-away iris image is correctly detected, segmented and transformed as if it were looking directly into the camera.

Correct iris segmentation:

Correct iris segmentation is achieved under these conditions:

The centres of the iris inner and outer boundaries are different Figure8. The iris inner boundary and its centre are marked in red; the iris outer boundary and its centre are marked in green.

Iris boundaries are definitely not circles and even not ellipses Figure9.and especially in gazing-away iris images.

Iris boundaries seem to be perfect circles. The recognition quality can still be improved if boundaries are found more precisely Figure10. Compared to perfect circular white contours.

Locating Iris

The first processing step consists in locating the inner and outer boundaries of the iris and second step to normalize iris and third step to enhance the original image as in (see Figure4). The Dougman's system, Integra differential operators as in (1) is used to detect the centre and diameter of iris and pupil respectively.

$$\max(r,x0,y0)=\left\{\frac{\partial}{\partial r}\int_0^{2\pi} I(r*\cos\theta+x0,r*\sin\theta+y0)\right\} \quad \text{--- (1)}$$

Where (x0, y0) denotes the potential centre of the searched circular boundary, and r its radius.

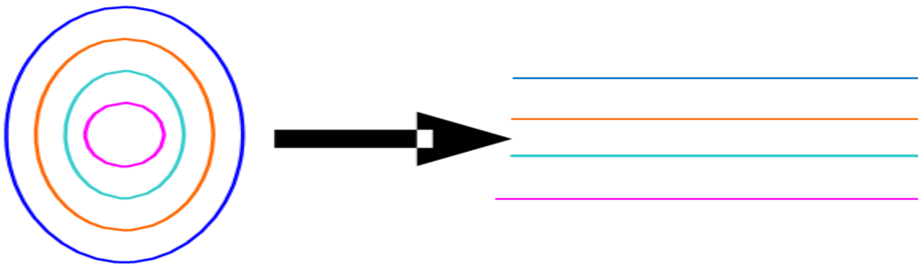


Figure 4: Polar transformation

b) Cartesian To Polar Transform

Cartesian to polar reference transform suggested by Daugman authorizes equivalent rectangular representation of the zone of interest as in (see Figure 4,5) remaps each pixel in the pair of polar co-ordinates(r, θ) where r and θ are on interval [0,1] and [0,π] respectively. The unwrapping in formulated as in (2).

$$I(x(r,\theta),y(r,\theta))\rightarrow I(r,\theta) \quad \text{--- (2)}$$

Such that

$$\left.\begin{aligned} x(r,\theta)&=(1-r)x_p(\theta)+rx_i(\theta),\\ y(r,\theta)&=(1-r)y_p(\theta)+ry_i(\theta)\end{aligned}\right\} \quad \text{--- (3)}$$

where I(x, y), (x, y), (r, θ), (xp, yp), (xi, yi) are the iris region, Cartesian coordinates, corresponding polar coordinates, coordinates of the pupil, and iris boundaries along the θ direction, respectively. (See Figure 4) shows polar transformation.

3) Feature Extraction

The most important step in automatic iris recognition is the ability of extracting some unique attributes from iris, which help to generate a specific code for each individual. Gabor and wavelet transforms are typically used for analysing the human iris patterns and extracting features from them, Steps for feature Extraction:

i. The Gabor Filter is applied to the obtained rubber sheet model (from Cartesian to polar conversion step). For this first both the image and filter are changed into different domain and then convolved to get result. This enhances the iris image (See Figure 5 (d)).
ii. The result is both real and imaginary. This when convolved with the resulted rubber sheet model, it gives values between -1 to 1.
iii. These values are converted in first binary, i.e. if>0 then 1 if<0 then 0, and then in turn to logical arrays, each signifying a specific pattern.
iv. These logical vectors are then stored in the compiled database, for faster future access.

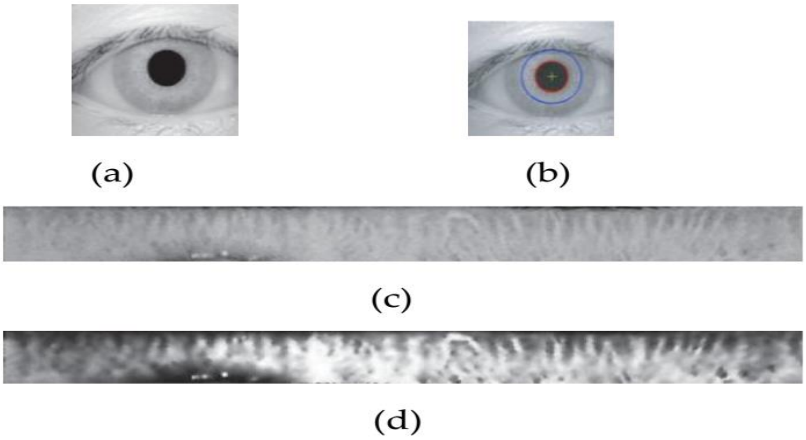


Figure 5: (a) Original image; (b) localized iris; (c) normalized iris and (d) enhanced iris.

4) Pattern Matching

The pattern is matched using Hamming Distance. The Hamming distance (HDs) between input images and images in each class are calculated, then the two different classifiers are being applied as follows.

i. In the first classifier, the minimum HD between input iris code and codes of each class is computed.
ii. In the second classifier, the harmonic mean of the n HDs that have been recorded yet is assigned to the class.

$$HM = \frac{length(code)}{\sum_{i=1}^{length(code)} (1/code(i))} \text{ --- (5)}$$

Steps for matching using hamming distance:

- Compare feature vector of database images with feature vector of query image.
- Calculate the hamming distances for each database feature vector.
- Find out the minimum hamming distance.

The iris codes in the database are used to find out which iris codes come from the same eye. Hamming distance is chosen because of its speed in calculating dissimilarity between binary codes. Hamming distance two Boolean as shown in (6).

$$HD=\frac{1}{N}\sum_{i=1}^{N} X_I \otimes Y_I \text{ --------(6)}$$

Where N is the number of bits in the feature vector, Xi is the itch feature of the tested iris, and Yi is the itch feature of the iris template. If two bit patterns are completely independent, such as iris templates generated from different irises, the Hamming distance the two patterns will be close to 1. If two patterns are derived from the same iris, the Hamming distance between them will be close to 0, since they are highly correlated and the bits should agree between the two iris codes. The maximum Hamming distance that exists between two irises belonging to the same person is 0.32. Thus, when comparing two iris images, their corresponding binary feature vectors are passed to a function responsible of calculating the Hamming distance between the two. The decision of whether these two images belong to the same person depends upon the following result:

- If HD >= 0.88 decide that it is same person
- If HD < 0.88 decide that it is different person (See Figure7)

Fast matching : Configurable matching speed varies from 50,000 to 150,000 comparisons per second . The highest speed still preserves nearly the same recognition quality.

5) IDENTIFICATION AND VERIFICATION

Identification and verification modes are two main goals of every security system based on the needs of the environment. In the verification stage, the system checks if the user data that was entered is correct or not (e.g., username and password) but in the identification stage, the system tries to discover who the subject is without any input information. Hence, verification is a one-to one search but identification is a one-to-many comparison.

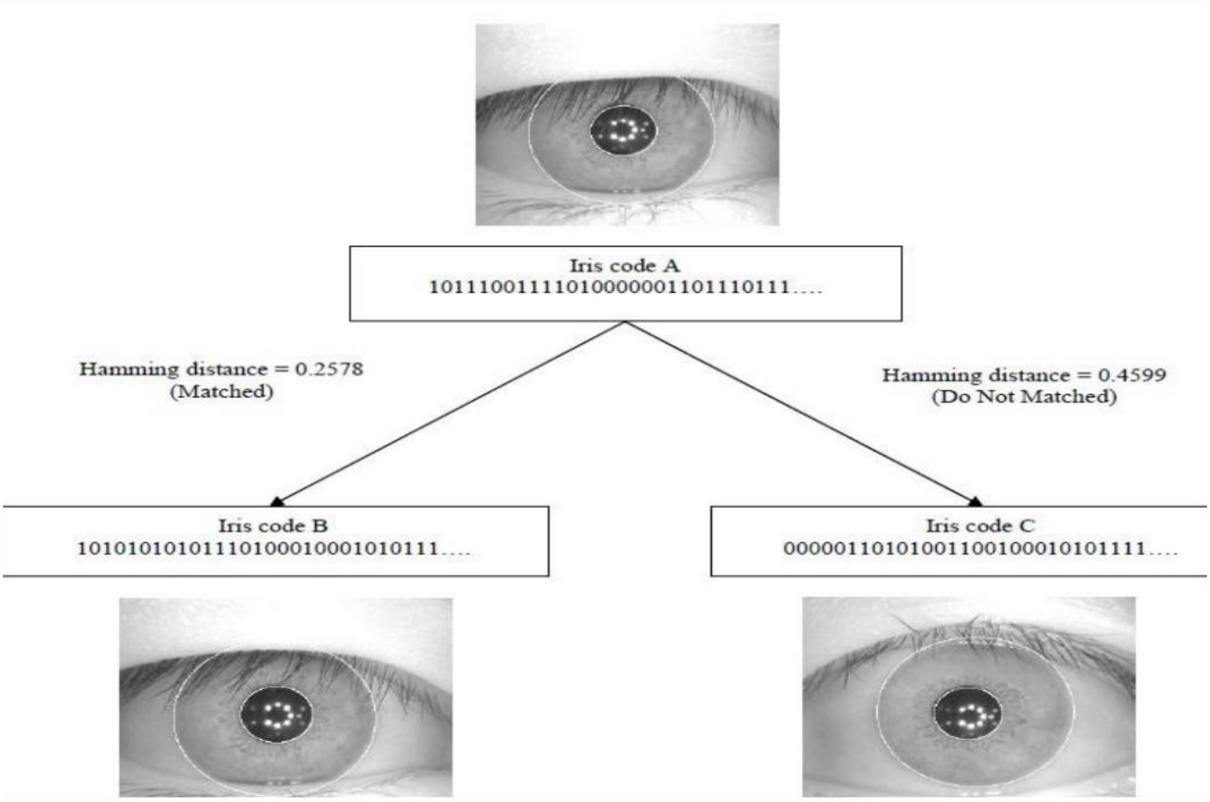


Figure 7: iris code matching process

MATLAB Code Analysis

Various functions are made and used in MATLAB for IRIS RECOGNITION. These functions follow the algorithm mentioned before. The MATLAB files along with their usage is described in Table 3

S.No	MATLAB File	Function Usage
1	Fileop34	To generate the Database (Containing all bincodes of all images of database)
2	Thresh	Used for Iris Segmentation & Finding Centres and Radii of iris & pupil.
3	DrawCircle	Used to draw circle with centre C & radius r (Used in segmentation)
4	Lineint	Implementation of Dougman's Integro Differential Operator using Line Integration
5	Search	To search for centres and radii of iris & pupil (Used in segmentation)
6	Partiald	To smoothen & blur images for better segmentation
7	Test3	GUI made in MATLAB to enhance user interface & ease of use
8	Pathdef	It helps in setting default path for MATLAB

Table 2

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