A Study on Iris Recognition System

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Abstract: A Biometric system provides automatic identification of an individual, based on a unique possessed feature or characteristic. Iris recognition is regarded as the most reliable and accurate biometric system available. Characteristics of the iris make it very attractive for use as a biometric. The unique iris pattern from a digitized image of the eye is encoded into a biometric template, and then stored in a database. A Biometric template contains an objective mathematical representation of the unique information stored in the iris and allows comparisons between templates. Existing algorithms based on extracting and matching features from iris have reported very high recognition rates on clean data sets. We have implemented an Iris Recognition System using Sparse Recognition which appears as another paper in this journal, entitled “Iris Recognition System through Sparse modeling”.

I. INTRODUCTION

1.1 Biometric in general
In this modern era, when internet has reached its peak and forms the basis for all modern banking and business systems [1], the accurate verification for accessing accounts is also becoming a necessity.

1.2 Iris biometric

![Iris Image](image.png)

Figure 1.1: Image of an eye representing the iris, pupil and sclera.  

The iris biometric deals with identifying a human being by his/her iris pattern extracted from the images of his/her eye. As shown in Figure 1.1, the human eye consists of 3 major parts: pupil (the innermost black part), iris (the colored part) and sclera (the white part). The iris and pupil are said to be non-concentric [2]. The radius of inner border of the iris i.e. it’s border with the pupil is also not constant since the size of pupil increases and decreases depending on the amount of light incident to the pupil. Every individual has a unique pattern of iris [2].

1.3 Iris compared to other biometrics
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 three-dimensional (3-D) object whose image varies with viewing angle, pose, illumination, accoutrements, and age [3]. It has been shown that, for “mug shot” images taken at least one year apart, even the best current algorithms can have error rates of 43%–50%. 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. 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 [4]. In addition, as an internal (yet externally visible) organ of the eye, the iris is well protected from the environment and stable over time [8]. Its complex pattern can contain many distinctive features such as arching ligaments, furrows, ridges, crypts, rings, corona, freckles, and a zigzag collarette. Iris color is determined mainly by the density of melanin pigment in its anterior layer and stroma, with blue irises resulting from an absence of pigment.

1.4 Emerging Opportunities
We categorize issues of iris recognition systems in two broad classes namely those related to iris template security and those associated with iris recognition performance.

A. Iris Template Security
1) Biometric Key Release: These are the systems where biometrics along with cryptographic keys are used for authentication and communication.
2) Cancelable Biometrics: Cancelable biometric systems apply some transformation on the
biometric template to secure the template [9], [10]. The transformation function must be non-invertible so that a compromised transformed template cannot be translated to the original template [11]. In addition, the secret can easily be revoked by applying a different transformation to the original template resulting in a new transformed template [23], [24].

B. Iris Recognition Performance

1) A System for Iris Recognition at a Distance

Conventional iris recognition systems impose constraints with regard to a subject’s proximity to the device as well as their movement. Recent innovations in iris acquisition systems and recognition algorithms have aimed to relax these constraints. [12]

2) Iris Recognition under Alcohol Influence

A new system for matching iris images captured before and after alcohol consumption provides opportunity for research. Due to alcohol consumption, the pupil dilates/constricts which causes deformation in iris pattern, possibly affecting iris recognition performance. This change is dynamic and varies from person to person. This is similar to disguise covariate in face recognition where the appearance can be changed provisionally. This covariate can be viewed as a vulnerability of iris recognition systems. [5]

3) Lenses

Around the world, approximately 125 million people use contact lenses. Therefore, iris recognition systems should be flexible enough to accommodate these large numbers of people. Designers of iris recognition algorithms claim that recognition performance of their systems is not affected by the use of contact lenses. But, recently, Baker et al [35] come up with a study showing that every type of lens negatively affects iris recognition performance [13].

II. IRIS RECOGNITION PROCESS

2.1 Localization or Segmentation

The iris region is approximated by a ring, defined by the iris/sclera boundary and the iris/pupil boundary. Thus, in this step, we should be able to detect these boundaries and isolate the part of the image within [17]. In 1993, John Daugman [14] proposed one of the most significant approaches in iris recognition, which became the basis of many functioning systems today. Daugman applies an integro-differential operator to isolate the boundaries.

2.2 Normalization

In order to allow comparisons between different irises, we should transform the extracted iris region so that it has fixed dimensions, and hence removing the dimensional inconsistencies between eye images due to the stretching of the iris caused by the pupil dilation from varying levels of illumination [15]. Therefore, this normalization process will produce irises with same fixed dimensions so that two photographs for the same iris under different lighting conditions will have the same characteristic features.

2.3 Feature extraction

After being able to localize the iris, it is time to extract the most discriminating feature in its pattern so that a comparison between templates can be done. The iris pattern provides two types of information: The amplitude information and the phase information. Extraction of the iris patterns takes into account the correlation between adjacent pixels. 1D Log-Gabor filters are used to convolve the image because: They provide phase information; they are constructed by modulating sines and cosines waves with a Gaussian filter which makes them useful for localizing in space and frequency.

2.4 Sparse Representation

Sparse approximation is the problem of estimating a sparse vector, satisfying a linear system of equations given high-dimensional observed data and a design matrix. It is applied for selection and recognition of iris images [6]. We have L distinct classes and a set of n training images per class [6]. The sparse solution can be recovered by solving the $l_1$ minimization problems.

III. SEGMENTATION

3.1 Image acquisition

Early research into iris recognition was obstructed by the lack of iris images. Now several free databases exist on the internet for testing usage. A well known database is the CASIA Iris Image Database (version 1.0) [16] provided by the Chinese Academy of Sciences. The CASIA Iris Image Database includes 756 iris images from 108
eyes collected over two sessions. The images, taken in almost-perfect imaging conditions, are noise-free.

3.2 Segmentation Methods

Different approaches have been used in detecting the outer and inner contours of the iris boundary. Daugman uses an integro-differential operator on the raw image (doesn’t apply feature detectors) to isolate the iris [18], whereas Wildes uses the circular Hough transform on the binary edge map [19]. Other approaches have been proposed, such as Active Contour Models, and simple Circular Summation [20, 21].

3.2.1 Integro-Differential Function

The integro-differential function finds for an image \( I(x,y) \), the maximum of the absolute value of the convolution of a smoothing function \( G_o \) with the partial derivative, with respect to \( r \), of the normalized contour integral of the image along an arc \( ds \) of a circle \( C(x_o,y_o), r \) [17].

\[
\max_{r,x_0,y_0} |G_o(r)| \frac{\partial}{\partial r} \oint_{r,x_0,y_0} \frac{I(x,y)}{2\pi r} ds,
\]

This integro-differential operator serves to find the both boundaries of the iris. The operator is applied iteratively with the amount of smoothing progressively reduced in order to attain precise localization [22].

The operator searches for the circular path where there is maximum change in pixel values, by varying the radius ‘\( r \)’ and the center (x, y) of the circular contour. Assuming that the variables x, y and \( r \) belong to the ranges [0; X], [0; Y], [0; R] respectively, this method has the computational complexity of order \( [X \times Y \times R] \). Thus, at every pixel, a total of \( R \) scans are necessary to compute the circle parameters using this approach.

![Figure 1.3: The black boxed line represents one pixel wide iris border at a certain radius ‘\( R \)’ (not to scale) at the centre coordinate and the blue boxed line represents one pixel wide circle at the same center coordinate at radius ‘\( R+1/2 \)’][3]

A search over the entire image (of an eye) is done, pixel by pixel. At every pixel, the normalized sum of all circumferential pixel values, at increasing radius is found. At every level of increased radius, the difference between the normalized sums of pixel intensity values at adjacent radii circle (see Figure 1.3) is noted.

3.2.2 Hough Transform

The Hough transform can be described as a transformation of a point in the x,y-plane to the parameter space. The parameter space is defined according to the shape of the object of interest. A straight line passing through the points (\( x_1, y_1 \)) and (\( x_2, y_2 \)) can in the x,y-plan be described by: \( y = ax + b \). This is the equation for a straight line in the Cartesian coordinate system, where \( a, b \) represent the parameters of the line. The Hough transform for lines does not use this representation of lines, since lines perpendicular to the x-axis will have value of infinity. This will force the parameter space \( a, b \) to have infinite size. Instead a line is represented by its normal which can be represented by an angel \( \theta \) and a length \( \rho \), \( \rho = x \cos(\theta) + y \sin(\theta) \). The parameter space can now be spanned by \( \theta \) and \( \rho \), where \( \theta \) will have a finite size, depending on the resolution used. The distance to the line \( \rho \) will have a maximum size of two times the diagonal length of the image [26]. The circle is actually simpler to represent in parameter space, compared to the line, since the parameters of the circle can be directly transferred to the parameter space. The equation of a circle is \( r^2 = (x-a)^2 + (y-b)^2 \). As it can be seen the circle has got three parameters, \( r, a, b \). Where \( a, b \) are the center of the circle in the x and y direction respectively and where \( r \) is the radius (see Figure 1.4). The parametric representation of the circle is \( x = a + r \cos(\theta); y = b + r \sin(\theta) \). Thus the parameter space for a circle will belong to \( R^3 \) whereas the line only belonged to \( R^2 \). As the number of parameters needed to describe the shape increases, as well as the dimension of the parameter space \( R \) increases, so do the complexity of the Hough transform. Therefore, the Hough transform in general is only considered for simple shapes with parameters belonging to \( R^2 \) or at most \( R^3 \). In order to simplify the parametric representation of the circle, the radius can be held as a constant or limited to number of known radii.

![Figure 1.4: The parameter space used for Circular Hough Transform][4]

![Figure 1.5: Circular HT from the x, y-space (left) to the parameter space (right), for a constant radius][5]
The process of finding circles in an image using Circular Hough Transform is: First, we find all edges in the image. This step has nothing to do with Hough Transform and any edge detection technique of your desire can be used. It could be Canny, Sobel or Morphological operations[26],[25].

When every edge point and every desired radius is used, we can turn our attention to the accumulator. The accumulator will now contain numbers corresponding to the number of circles passing through the individual coordinates. Thus the highest numbers (selected in an intelligent way, in relation to the radius) correspond to the center of the circles in the image (see Figure 1.5) [27], [28]. Multiple circles with the same radius can be found with the same technique (see Figure 1.6).

Daugman’s operator applied to such images detects the intensity change at this reflection affected white regions to be the maximum change in sum of circumferential pixels intensity values. Hence due to this element of light reflection the iris and pupil borders are incorrectly identified as shown in figure. This complemented image is then processed by the morphological operator ‘imfill’ that fills in this dark region (the light affected region in the original image) with intensity similar to that of its neighborhood. Using ‘imcomplement’ again reverses the dark region into lighter region and vice versa. This command removes specular reflections due to light in the image [36].

The circles in parameter space intersect at the (a, b) that is the center in geometric space. Both Hough’s Transform and Daugman’s Integro-Differential Operator are both computationally intensive. However, removal of noise and other occluding issues are handled with more ease when Daugman’s approach is adopted.

### 3.3 The enhancement of an eye image before the application of the Daugman’s operator

#### 3.3.1 Countering the effect of light reflection on images

Light reflections in the eye images negatively affect iris border detection by means of Daugman’s algorithm. These light reflections cover the parts of the eye image causing hindrance in the iris detection process. It can be observed that the ‘light reflection affected region’ is a region consisting of the pixels with high intensity values (since it is a white region). The region surrounding it is a region consisting of the pixels with low intensity values (since it is a darker region). Therefore the original information of this part of the image has been lost. Secondly, there is an observable difference in intensity values between this ‘light affected region’ and its surrounding darker region.

IV. NORMALIZATION AND FEATURE EXTRACTION

#### 4.1 Normalization and Unwrapping

We should transform the extracted iris region so that it has a fixed dimensions, and hence removing the dimensional inconsistencies between eye images due to the stretching of the iris caused by the pupil dilation from varying levels of illumination [29]. However an important note we must take care of when normalizing the doughnut shaped iris region to have to have constant radius, is that, as clearly shown in Figure 1.10, the centers of the iris and the pupil are not concentric[17].

**Figure 1.6:** Each point in geometric space (left) generates a circle in parameter space(right).

**Figure 1.7:** Light reflection affected eye image

**Figure 1.8:** Iris and pupil wrongly detected for light reflection affected image (see Figure 1.7)

**Figure 1.9:** Output for the input image as shown in Figure 1.8 after the morphological operation

**Figure 1.10:** The centre of the Pupil and Iris are not concentric
4.1.1 Daugman’s Rubber Sheet Model

In fact, the homogeneous rubber sheet model devised by Daugman remaps each point within the iris region to a pair of polar coordinates where the radius r is on the interval \([0,1]\), and the angle is on the interval \([0,2\pi]\). Then the normalized iris region is unwrapped into a rectangular region.

Figure 1.11 illustrates the mechanism of this model [30].

The remapping (normalization) of the iris region from Cartesian coordinates \((x,y)\) to normalized non-concentric polar representation is modeled as:

\[
I(x(r, \theta), y(r, \theta)) \rightarrow I(r, \theta)
\]

where,

\[
x(r, \theta) = (1 - r)x_p(\theta) + rx_I(\theta)
\]
\[
y(r, \theta) = (1 - r)y_p(\theta) + ry_I(\theta)
\]

After getting this normalized polar representation of the iris region; this region is unwrapped by choosing a constant number of points along each radial line irrespective of how narrow or wide the radius is at a particular angle, and thus producing a 2D array with vertical dimensions of radial resolution and horizontal dimensions of angular resolution (see Figure 1.12). Now in order to prevent non-iris region data from corrupting the normalized representation, another 2D array is created for marking reflections, eyelashes, and eyelids detected in the segmentation stage, and data points which occur along the pupil border or the iris border are discarded.

4.2 Feature Encoding

Constructing the iris code is our final process. After being able to localize the iris, it is time to extract the most discriminating feature in its pattern so that a comparison between templates can be done. The iris pattern provides two types of information: The amplitude information and the phase information. As shown by Oppenheim and Lim, and because of the dependence of the amplitude information on many extraneous factors, only phase information is used to generate the iris code [31]. Wavelets can be used to decompose the data in the iris region into components that appear at different resolutions, allowing therefore features that occur at the same position and resolution to be matched up.

4.2.1 Gabor Filter

Let \(\mathcal{O}(x, y)\) be any chosen generic 2D wavelet that can be called a mother wavelet from which we can
generate a complete self similar family of parameterized daughter wavelets

\[ \Psi_{\text{specify wavelet}}(x, y) = 2^{-2m} \Psi(x', y') \]

Where

\[ x' = 2^{-m}[x \cos(\theta) + y \sin(\theta)] - p \]
\[ y' = 2^{-m}[-x \sin(\theta) + y \cos(\theta)] - q \]

x' and y' incorporate dilations in the wavelet in size by 2m, translations in position (p,q), and rotations through angle \( \theta \) [32], [33].

An interesting and useful choice for \( \Phi(x, y) \) is the complex valued Gabor wavelet which is defined as follow:

\[ \Psi(x, y) = e^{-\pi[(x-x_0)^2/v_0^2 + (y-y_0)^2/v_0^2]} e^{-2 \pi i [u(x-x_0) + v(y-y_0)]} \]

where, \((x_0, y_0)\) specify wavelet position \((\alpha, \beta)\) specify effective width and length, \((u_0, v_0)\) specify a modulation wave vector which has spatial frequency \( \omega = \sqrt{u_0^2 + v_0^2} \)

Because these wavelets are complex valued, it is possible to use the real and imaginary parts of their convolution with an image \( I(x, y) \) (which is in this case the iris pattern) to extract a description of the image in terms of amplitude and phase. The amplitude modulation function is defined as follow:

\[ A(x, y) = \sqrt{\text{Re}\{\Psi(x, y) * I(x, y)\}^2 + \text{Im}\{\Psi(x, y) * I(x, y)\}^2} \]

And the phase modulation function is defined as:

\[ \phi(x, y) = \tan^{-1} \left( \frac{\text{Im}\{\Psi(x, y) * I(x, y)\}}{\text{Re}\{\Psi(x, y) * I(x, y)\}} \right) \]

As we said before, the phase angle can be quantized to construct the iris code. This quantization is illustrated in Figure 1.13.

By demodulating the iris pattern using 2 D Gabor wavelet, the pattern is encoded into 256 bytes (2048 bits) iris code. Each resulting phasor angle is quantized to one of four quadrants, setting therefore two bits of information. This operation is repeated for each local element all across the iris with many wavelet sizes, frequencies, orientations, to extract the 2048 bits.

The Daugman system makes use of polar coordinate for normalization; therefore the Gabor filter is given as:

\[ H(r, \theta) = e^{-i\omega(\theta-\theta_0)} e^{-(r-r_0)^2/\alpha^2} e^{-i(\beta-\beta_0)^2/\delta^2} \]

where \((\alpha, \beta)\) are the same as before, and \((r_0, \theta_0)\) specify the center frequency of the filter [34].

As a result, the iris code can be constructed by demodulating the iris pattern using complex valued 2 D Gabor wavelets to extract the structure of the iris as a sequence of phasors whose phase angles are mapped or quantized into bits that construct the iris code. The angle quantization is furthermore described by the following conditional integrals where the iris image pixel data is given in the dimensionless pseudo polar coordinate system \( I(\rho, \phi) \) [32].

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REFERENCES

[5] Sunpreet S. Arora, Mayank Vatsa, Richa Singh and Anil Jain “Iris Recognition under Alcohol Influence: A Preliminary Study”, IIIT Delhi, Michigan State University
[12] Eagle-Eyes™: A System for Iris Recognition at a Distance Faisal Bashir, Pablo Casaverde, David Usher, Marc Friedman - Retica Systems, Inc., 201 Jones Road, Waltham, MA 02451.
[16] Chinese Academy of Sciences, Institute of Automation. CASIA Iris Image Database (version 1.0). Available at : www.idealtest.org/dbDetailForUser.do?id=1
[21] “A Robust Iris Localization Method Using an Active Contour Model and Hough Transform” - Jaehan Koh, Venu Govindaraju, and Vipin Chaudhary Department of Computer Science and Engineering, University at Buffalo (SUNY)


