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# Iris Recognition System: A Review

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**Abstract:**
Biometrics has become important in security applications. In comparison with many other biometric features, iris recognition has very high recognition accuracy because it depends on iris which is in a place that still stable throughout human life and the probability to find two identical irises is close to zero. In Iris Recognition a person is identified by the iris which is the part of eye using pattern matching or image processing. The aim is to identify a person in real time, with high efficiency and accuracy by analyzing the random patters visible within the iris if an eye from some distance. The identification system consists of several stages including segmentation stage which is the most serious and critical one. The current segmentation methods still have limitation in localizing the iris due to circular shape consideration of the pupil. Daugman method is done to investigate the segmentation techniques. Eyelid detection is another step that has been included in this study as a part of segmentation stage to localize the iris accurately and remove unwanted area that might be included. The obtained iris region is encoded to construct iris code, which contains most discriminating feature in iris pattern.

**Keywords:** Iris, Biometric, segmentation, template matching

## I. INTRODUCTION

Biometrics refer to the automatic recognition of individuals based on their physiological and behavioral characteristics. Biometric recognition can be used as a form of identification and access control. A biometric recognition system is used to identify individual in a group that are under surveillance. Biometric identifiers are often classified as physiological characteristics and behavioral characteristics.

- Physiological characteristics are those related to the shape of the body like fingerprint, DNA, palm veins, iris recognition, face recognition and so on.
- The second category includes the pattern behavior of an individual like voice, signature etc.

Among biometric technologies, iris-based authentication systems bear more advantages than any other biometric technologies as it offers an excellent recognition performance. Iris patterns are believed to be unique due to the complexity of the underlying environmental and genetic processes that influence the generation of iris pattern. These factors result in extraordinary textural patterns that are unique to each eye of an individual and is even distinct between twins.

**Iris anatomy**

Iris is the colored ring of tissue around the pupil through which light enters the interior of the eye. It is located in front of the crystalline lens, and divides the anterior aqueous into the anterior and posterior chambers. The pigmented fibro vascular tissue known as stroma characterizes the iris. Its role is to help in regulating the amount of light that enters the eye. The iris made up of smooth muscle fibers known as sphincter and dilator, adjust the pupil size with the purpose of controlling the amount of light passing through the pupil. The sclera often referred to as white or white of the eye, is the outer white coat of connective tissue and blood vessels that surround the iris. Together with internal fluid pressure, it maintains the eye shape and cares for its delicate internal components. The structure of iris is shown in figure 1.

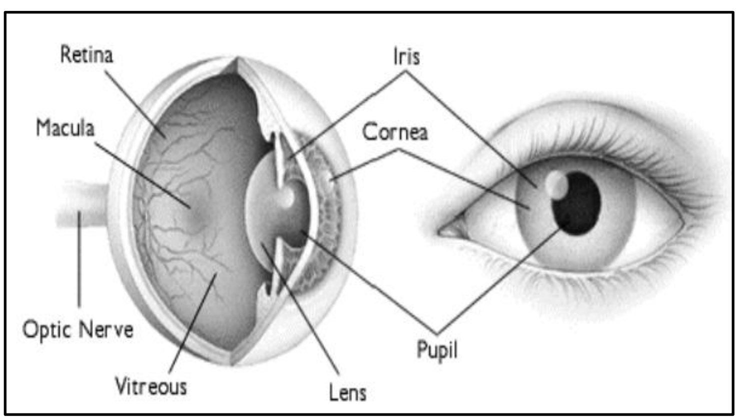



**Figure.1. Structure of iris**

The iris is an overt body that is available for remote assessment with the aid of a machine vision system to do automated iris recognition.

**A.** Iris recognition technology combines computer vision, pattern recognition, statistical inference, and optics.

**B.** The spatial patterns that are apparent in the human iris are highly distinctive to an individual.

• Clinical observation

• Developmental biology

Although the coloration and structure of the iris is genetically linked, the details of the pattern are not. The iris develops during prenatal growth through a process of tight formingand folding of the tissue membrane. Prior to birth, degeneration occurs, resulting in the pupil opening and the random, unique patterns of the iris. Although genetically identical, an individual's irises are unique and structurally distinct, which allows for it to be used for recognition purposes. This is like a living password for an individual that cannot be forgotten or copied as well as cannot be altered surgically. Iris recognition, a reliable method for identity authentication, plays an important role in many mission-critical applications such as access control and border checkpoints due to several reasons:

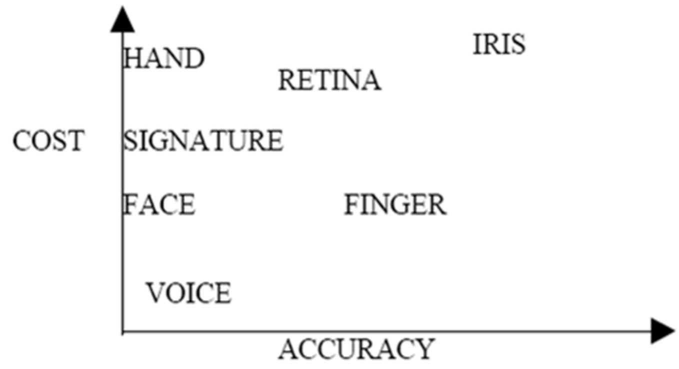
- Iris is an internal organ of the eye, physically protected from external environment by the cornea. This makes it more consistent than fingerprints that are more susceptible to worn out due to age or manual labour.

- Iris starts to develop in the third month of gestation and the structures creating its pattern reach completion mainly by the eighth month and does not vary throughout one's lifetime. Furthermore, the formation of iris depends on the initial environment of the embryo. Therefore, the texture patterns of the iris do not correlate with genetic determination. Consequently, even irises of genetically identical twins are extremely distinct. Actually, the left and the right irises of the same person are unique

- Since iris is stable, iris-based technologies have demonstrated high levels of performance Moreover, surgical modification of the pigmentation and/or color of the iris without unacceptable risk to damage the vision is also impossible.

- The physiological reaction of the iris to light sources provides one of the easiest aliveness detection practices against spoofing attacks.

- Glasses or contact lenses rarely hinder Iris recognition efficacy. In addition, the non-contact acquisition procedure used in Improved Biometric Authentication System Using Multimodal Cue Integration 163 capturing iris images makes it more convenient than fingerprints, which mostly use optical touch based sensors.
- Among biometrics, iris has one of the smallest outlier populations, where few people cannot use or enroll using this technology. Despite the aforementioned advantages of using iris recognition, the acquisition of satisfactory quality iris images for iris recognition is a critical yet challenging step. It may act very poorly when deployed in realtime applications, especially for recognition at a distance. Besides, the iris is usually located at the back of a curved and reflecting surface, typically covered by eyelashes and partially occluded by eyelids. The biometric comparison list is shown in figure 2.




| 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 | 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 |

**Figure .2. Biometric Comparison List**

## II. PROPOSED METHOD

Iris recognition is nowadays considered as one of the most accurate biometric recognition techniques. Iris recognition is user friendly since the iris can be captured from a certain distance. Critical step in the recognition process is the segmentation of the iris pattern in the input eye image. This process must deal with the fact that the iris region of the eye is a relatively small area, wet and constantly in motion due to involuntary eye movements. Moreover, eyelids, eyelashes and reflections are occlusions of the iris pattern that can cause errors in the segmentation process. As a result, an incorrect segmentation can produce errors in biometric recognitions and seriously reduce the final accuracy of the system. Iris recognition techniques identifies a person by mathematically analyzing the unique random patterns that are visible within the iris and making comparisons with an already existing database. The basic block diagram of iris recognition system is as shown in figure 3.

**The different stages in the implementation of the system consist of**

✓ Segmentation
✓ Normalization
✓ Feature Extraction
✓ Matching

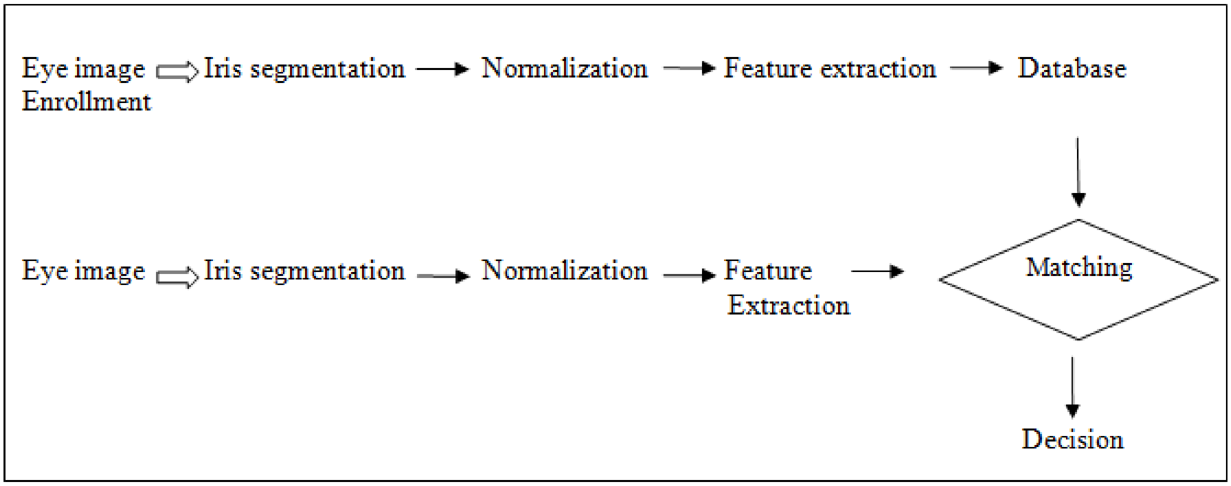



**Figure.3. general steps for iris recognition**

**In identifying one's iris there are two methods:**

- **Active method:** It requires the user be anywhere between 6 to 14 inches away from camera.
- **Passive method:** this method allows the user to be anywhere between 1 to 3 feet away from camera that locates the focus on iris.

The system is to be composed of several sub-systems, which correspond to each stage of iris recognition. These stages are:

- Image acquisition-capturing eye image
- Segmentation – locating the iris region in an eye image
- Normalization – creating a dimensionally consistent representation of the iris region
- Feature encoding – creating a template containing only the most discriminating features of the iris.

The input to the system will be an eye image, and the output will be an iris template, which will provide a mathematical representation of the iris region. It is shown in figure 4.

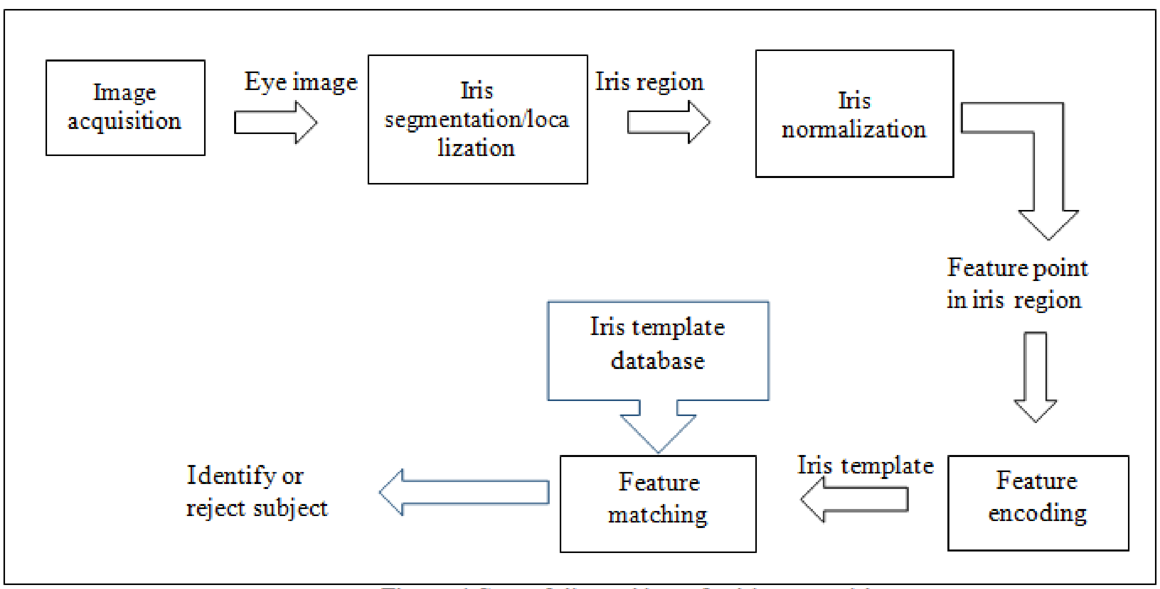



**Figure.4. Steps followed here for iris recognition**

The iris image should be rich in iris texture as the feature extraction stage depends upon the image quality. Image acquisition deals with capturing sequence of iris images from the subject using cameras and sensors with High resolution and good sharpness. One of the major challenges of automated iris recognition is to capture a high-quality image of the iris while remaining noninvasive to the human operator. Given that the iris is a relatively small (typically about 1 cm in diameter), dark object and that human operators are very sensitive about their eyes, and the matter requires careful engineering. Several points are of concern. The captured image is shown in figure 5.

**First,** it is desirable to acquire images of the iris with sufficient resolution and sharpness to support recognition.

**Second,** it is important to have good contrast in the interior iris pattern without resorting to a level of illumination that annoys the operator, i.e., adequate intensity of source ($W/cm^2$) constrained by operator comfort with brightness ($W/sr\text{-}cm^2$).

**Third,** these images must be well framed (i.e., centered) without unduly constraining the operator (i.e., preferably without requiring the operator to employ an eye piece, chin rest, or other contact positioning that would be invasive).

**Further,** as an integral part of this process, artifacts in the acquired images (e.g., due to specular reflections, optical aberrations.) should be eliminated as much as possible.

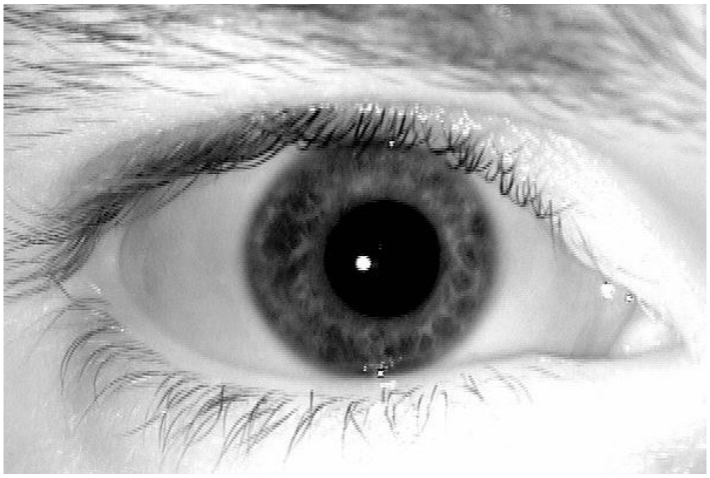


**Figure.5. Captured eye image**

After image acquisition is done the pre-processing stage requires the localization of the iris which generally involves the detection of the edge of the iris as well as that of the pupil. Since varying levels of illumination can result in dimensional inconsistencies between eye images due to the stretching of the iris, normalization needs to be performed so that iris region is transformed to have fixed dimensions. After unwrapping the normalized iris region into a rectangular region, it is encoded to generate the iris code. In the recognition stage, hamming distance is used for comparison of the iris code, the most discriminating feature of the iris pattern, with the existing iris templates.

1. Without placing undue constraints on the human operator, image acquisition of the iris cannot be expected to yield an image containing only the iris.
2. Rather, image acquisition will capture the iris as part of a larger image that also contains data derived from the immediately surrounding eye region.
3. Therefore, prior to performing iris pattern matching, it is important to localize that portion of the acquired image that corresponds to an iris.
4. In particular, it is necessary to localize that portion of the image derived from inside the limbus (the border between the sclera and the iris) and outside the pupil.
5. Further, if the eyelids are occluding part of the iris, then only that portion of the image below the upper eyelid and above the lower eyelid should be included.
6. Typically, the limbic boundary is imaged with high contrast, owing to the sharp change in eye pigmentation that it marks.
7. The upper and lower portions of this boundary, however, can be occluded by the eyelids. The pupillary boundary can be far less well defined. The image contrast between a heavily pigmented iris and its pupil can be quite small.
8. Further, while the pupil typically is darker than the iris, the reverse relationship can hold in cases of cataract: the clouded lens leads to a significant amount of backscattered light.
9. Like the pupillary boundary, eyelid contrast can be quite variable depending on the relative pigmentation in the skin and the iris.
10. The eyelid boundary also can be irregular due to the presence of eyelashes. Taken in tandem, these observations suggest that iris localization must be sensitive to a wide range of edge contrasts, robust to irregular borders, and capable of dealing with variable occlusion.
11. For the reduction of the computational complexity, the iris images are first converted into gray scale images.
12. For localization, the assumption that summation of the pixel values in the iris region will be less compared to other region is used.
13. This leads to the use of the threshold technique based on the color of the iris.
14. The gray level values of the iris pixels for a dark iris will be lesser when compared to light iris. Two threshold values can be set to determine the iris region using the histogram of the eye image. For creation of the knowledge base, eye images of both the groups have been used so that threshold value has been computed for the extreme cases.

For boundary detection both Daugman and Wildes at el iris recognition system performs iris localization. Both of these systems make use of first derivatives of image intensity to signal the location of edges that correspond to the borders of the iris. Here, the notion is that the magnitude of the derivative across an imaged border will show a local maximum due to the local change of image intensity. Also, both systems model the various boundaries that delimit the iris with simple geometric models. They both model the limbus and pupil with circular contours. The Wildeset al. system also explicitly models the upper and lower eyelids with parabolic arcs, whereas the Daugman system simply excludes the upper- and lower-most portions of the image, where eyelid occlusion is expected to occur.Iris segmentation stages is shown in figure 6.

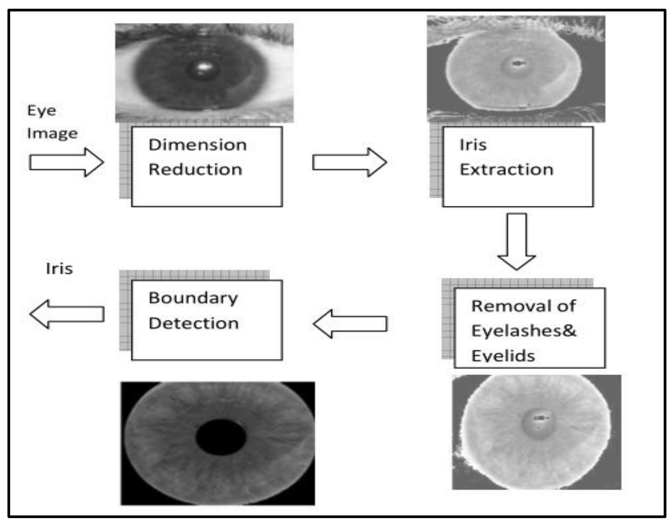



**Figure 6 Iris segmentation stages**

Next stage is the removal of unwanted information, such as eyelashes and eyelids. This can be done using sobel operator or canny edge detector.

**The Sobel operator**, which performs a 2D spatial gradient measurement on an image, helps in detection of the edges of eyelids and eyelashes. An edge is characterized by a noticeable change in the intensity and the Sobel operator returns edges at those points where there is maximum gradient of the image. The two 3 x 3 masks Gx and Gy of the operator, are given in Equations respectively.

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$G_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

Applying the masks to the image and computing its magnitude as in Equation above approximates the gradient.

$$G[I(i,j)] = |G_x| + |G_y|$$

To compute the gradient for the pixel $P_i$(I,j), of the input image, I is given as follows

$$I(i,j) = \begin{bmatrix} I(i-1,j-1) & I(i-1,j) & I(i-1,j+1) \\ I(i,j-1) & I(i,j) & I(i,j+1) \\ I(i+1,j-1) & i(i+1,j) & I(i+1,j+1) \end{bmatrix}$$

Following equations evaluates Gx and Gy respectively. Determination of the Gradient magnitude at each pixel and comparison with some threshold determines whether it is an edge pixel or not. Sobel operator is less sensitive to noise due to its large convolution masks.

$$G_x(i,j) = \begin{cases} [I(i-1,j+1) + 2 * I(i,j+1) + I(i+1,j+1)] \\ -[I(i-1,j-1) + 2 * I(i,j-1) + I(i+1,j-1)] \end{cases}$$

$$G_y(i,j) = \begin{cases} [I(i-1,j-1) + 2 * I(i-1,j) + I(i-1,j+1)] \\ -[I(i+1,j-1) + 2 * I(i+1,j) + I(i+1,j+1)] \end{cases}$$

For boundary detection, the Centre pixel of the eyelash removed iris image is determined and a circular strip is extracted based on the Centre co-ordinates of the pupil. For detecting the inner and outer boundary ($B_{in\ or\ out}$) of the iris, **Integro-Differential operator** can be used. The operator searches for the circular path where there is maximum change in the pixel value, by varying the radius and Centre x and y position of the circular contour. To understand how these searches proceed, let I(x,y) represent the image intensity value at location (x,y) and let circular contours (for the limbic and pupillary boundaries) be parameterized by center location ($X_c$, $Y_c$) and radius r. The Daugman system fits the circular contours via gradient ascent on the parameters ($X_c$,$Y_c$, r) so as to maximize

$$\left| \frac{\partial}{\partial r} G(r) * \oint_{r,x_c,y_c} \frac{I(x,y)}{2\pi r}\, ds \right|$$

where is a radial Gaussian $G(r) = (1/\sqrt{2\pi}\sigma)e^{-((r-r_0)^2/2\sigma^2)}$ with center $r_0$ and standard deviation $\sigma$ that smooths the image to select the spatial scale of edges under consideration, * symbolizes convolution, ds is an element of circular arc, and division by $2\pi$r serves to normalize the integral.

In order to incorporate directional tuning of the image derivative, the arc of integration ds is restricted to the left and right quadrants (i.e., near vertical edges) when fitting the limbic boundary. This arc is considered over a fuller range when fitting the pupillary boundary; however, the lower quadrant of the image is still omitted due to the artifact of the specular reflection of the illuminant in that region. In implementation, the contour fitting procedure is discretized, with finite differences serving for derivatives and summation used to instantiate integrals and convolutions. More generally, fitting contours to images via this type of optimization formulation is a standard machine vision technique, often referred to as active contour modeling. The operator is applied iteratively in order to attain precise localization.

**The Wildes et al. system** performs its contour fitting in two steps.

I. The image intensity information is converted into a binary edge-map.

II. The edge points vote to instantiate particular contour parameter values. The edge map is recovered via gradient-based edge detection.

This operation consists of thresholding the magnitude of the image intensity gradient i.e, $|\nabla G(x,y) * I(x,y)|$ where $\nabla \equiv (\partial/\partial x, \partial/\partial y)$, while

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{(x-x_0)^2+(y-y_0)^2}{2\sigma^2}}$$

is a two-dimensional Gaussian with center ($X_0$, $Y_0$) and standard deviation $\sigma$ that smooths the image to select the spatial scale of edges under consideration.

The voting procedure is realized via Hough transforms on parametric definitions of the iris boundary contours. In particular for the circular limbic or pupillary boundaries and a set of recovered edge points ($X_j$, $Y_j$), j = 1,2,…..n a Hough transform is defined as

$$H(x_c, y_c, r) = \sum_{j=1}^{n} h(x_j, y_j, x_c, y_c, r)$$

where

$$h(x_j, y_j, x_c, y_c, r) = \begin{cases} 1, & \text{if } g(x_j, y_j, x_c, y_c, r) = 0 \\ 0, & \text{otherwise} \end{cases}$$

with

$$g(x_j, y_j, x_c, y_c, r) = (x_j - x_c)^2 + (y_j - y_c)^2 - r^2.$$

For each edge point ($X_i$, $Y_i$) , $g(x_j, y_j, x_c, y_c, r) = 0$ for every parameter triple $(x_c, y_c, r)$ that represents a circle through that point. Correspondingly, the parameter triple that maximizes H is common to the largest number of edge points and is a reasonable choice to represent the contour of interest. In implementation, the maximizing parameter set is computed by building $H(x_c, y_c, r)$ as an array that is indexed by discretized values for Xc, Yc and r. Once populated, the array is scanned for the triple that defines its largest value. Contours for the upper and lower eyelids are fit in a similar fashion using parameterized parabolic arcs in place of the circle parameterization $g(x_j, y_j, x_c, y_c, r)$ Just as the Daugman system relies on standard techniques for iris localization, edge detection followed by a Hough transform is a standard machine vision technique for fitting simple contour models to images.

1. Both approaches to localizing the iris have proven to be successful in the targeted application.

2. The histogram-based approach to model fitting should avoid problems with local minima that the active contour model's gradient descent procedure might experience.
3. By operating more directly with the image derivatives, however, the active contour approach avoids the inevitable thresholding involved in generating a binary edge-map.
4. Further, explicit modeling of the eyelids (as done in the Wildes et al. system) should allow for better use of available information than simply omitting the top and bottom of the image.
5. However, this added precision comes with additional computational expense.
6. More generally, both approaches are likely to encounter difficulties if required to deal with images that contain broader regions of the surrounding face than the immediate eye region.
7. Such images are likely to result from image-acquisition rigs that require less operator participation than those currently in place.
8. Here, the additional image "clutter" is likely to drive the current, relatively simple model fitters to poor results.
9. Solutions to this type of situation most likely will entail a preliminary coarse eye localization procedure to seed iris localization proper.
10. In any case, following successful iris localization, the portion of the captured image that corresponds to the iris can be delimited.

Once the iris region has been successfully segmented from an eye image, it is transformed so that it has fixed dimensions in order to allow comparisons. Since variations in the eye, like optical size of the iris, position of pupil in the iris, and the irisorientation change person to person, it is required to normalize the iris image, so that the representation is common to all, with similar dimensions. Most normalization techniques are based on transforming iris into polar coordinates, known as unwrapping process. The normalization process will produce iris region, which have the same constant dimensions, so that two photographs of the same iris under different conditions will have same characteristics features. It is done using Daugman's Rubber sheet model. It is shown in figure 7.

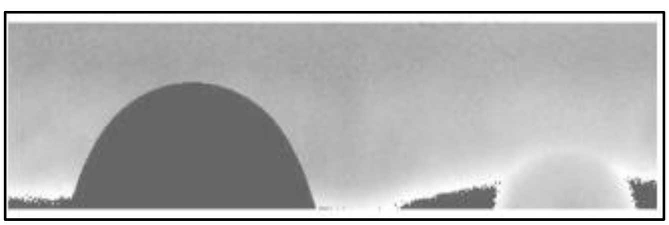


**Figure 7 Image normalization**

Homogenous rubber sheet model devised by Daugman remaps each point (x,y) within the iris region to a pair of polar co-ordinates (r,θ), where r is on the interval (0,1) and θ is angle (0,2π). Then the normalized iris region is unwrapped into a rectangular region as shown in figure 8.

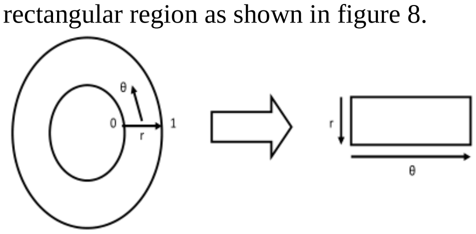



**Figure 8 Unwrapping-Daugman's rubber sheet model**

The normalized remapping of iris region from Cartesian co-ordinates (x,y) to non-concentric polar representation is given by equation

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

Where

$$x(r,\theta) = (1-p) \times x_p(\theta) + p \times x_i(\theta)$$

$$y(r,\theta) = (1-p) \times y_p(\theta) + p \times y_i(\theta)$$

Where;

I(x, y), refers to iris image.

(x & y), are the actual coordinates.

(r & θ), are the corresponding polar coordinates.

($x_p$ & $y_p$) and ($x_i$ & $y_i$), are the coordinates of pupil and iris boundaries respectively along the θ direction.

After getting the 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. Thus, a 2D array is produced with vertical dimensions of radial resolution and horizontal dimension of angular resolution. In order to provide accurate recognition of individuals, the most discriminating information present in an iris pattern has been extracted. Only the significant features of the iris have been encoded so that comparison between templates is done. It is shown in figure 9.

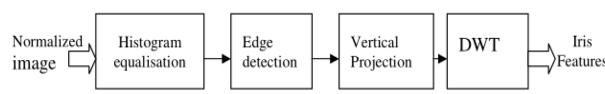



**Figure 9 Steps for feature encoding**

In the feature extraction stage, first histogram equalization is done to enhance the iris texture in the normalized image. After this, the canny edge detector [8] is used to extract iris texture from the normalized image. This edge detected is a 2D image and hence to reduce the dimension of feature it is converted into a 1D energy signal. Vertical projection is the method used for the conversion from 2D to 1D signal. Discrete wavelet transform is applied to this 1D energy signal. As a result a set of low frequency and high frequency coefficients are obtained. Since the high frequency coefficients do not contain any information, it is omitted and the low frequency coefficients each of which has a dimension of 64 bytes are taken as the iris templates. The following are required:

1. This method usually increases the local contrast of many images.

2. Through this adjustment, the intensities can be better distributed on the histogram.

3. This allows for areas of lower local contrast to gain a higher contrast without affecting the global contrast.

4. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. The image obtained after histogram equalization is shown in Figure 10. The domes in the unwrapped image are due to the eyelid occlusion.

**Figure 10 Histogram equalized image**

**Edge Detection process is described below:**

1. After histogram equalization iris texture will be enhanced in the normalized image.
2. Edge detection is performed to extract the iris texture from this enhanced image. Though several edge detection techniques such as Sobel, Canny, Prewitt etc. are available, it was observed that Canny edge detection technique is able to extract most of the iris texture from the enhanced image.
3. The Canny operator, an optimal edge detector, takes grayscale image as input producing an image showing the positions of tracked intensity discontinuities. The Canny operator works in a multi-stage process. After smoothing the image by Gaussian convolution, a simple 2-D first derivative operator (somewhat like the Roberts Cross) is applied to highlight regions of the image with high first spatial derivatives. Edges give rise to ridges in the gradient magnitude image. The algorithm then tracks along the top of these ridges and sets to zero all pixels that are not actually on the ridge top to give a thin line in the output, a process known as nonmaximal suppression. The tracking process exhibits hysteresis controlled by two thresholds: T1 and T2, with T1 > T2. Tracking can begin only at a point on a ridge higher than T1 and it continues in both directions out from that point until the height of the ridge falls below T2. This hysteresis helps to ensure that noisy edges are not broken up into multiple edge fragments. The effect of the Canny operator is determined by three parameters - the width of the Gaussian kernel used in the smoothing phase and the upper as well as lower thresholds used by the tracker. Increasing the width of the Gaussian kernel reduces the detector's sensitivity to noise, at the expense of losing some of the finer details in the image. The localization error in the detected edges also increases slightly as the Gaussian width is increased. Usually, the upper tracking threshold can be set quite high and the lower threshold quite low for good results. Setting the lower threshold too high will cause noisy edges to break up while setting the upper threshold too low increases the number of spurious and undesirable edge fragments appearing in the output. The Gaussian smoothing in the Canny edge detector fulfils Improved Biometric Authentication System Using Multimodal Cue Integration 173 two purposes: first, it can be used to control the amount of detail that appears in the edge image and second, it can be used to suppress the noise.
4. The Canny method finds edges by looking for local maxima of the gradient of I(I,j). The gradient is calculated using the derivative of a Gaussian filter.
5. The method uses two thresholds, to detect strong and weak edges, and include the weak edges in the output only if they are connected to strong edges.
6. This method is therefore less likely than the others to be fooled by noise, and more likely to detect true weak edges. Figure 11 shows the edge detected image using canny operator.

**Figure .10. Canny edge detected image**

**Vertical projection is done in the following way:**

1. Vertical projection is a method used to convert the 2D signal to 1D signal. This is done to reduce the system complexity.
2. For vertical projection, energy of each row of the edge detected image is calculated and is converted into a row vector.
3. The generalized equation is shown in equation below. The dimension of normalized image is m x n and is taken as 128 x 512 . Hence, after vertical projection its dimension is m, which is equal to 128.

i. $$\begin{pmatrix} X_{11} & \cdots & X_1 n \\ \vdots & \ddots & \vdots \\ Xm_1 & \cdots & Xmn \end{pmatrix} \rightarrow [\sum_{i=1}^{n}|X_1 i|^2 \ldots \quad |Xmi|^2]$$

***b. Discrete wavelet transform***

4. At low data rates, the Discrete Cosine Transform (DCT), suffer from a blocking effect due to the unnatural block partition that is required in the computation.
5. Other drawbacks include mosquito noise, a distortion that appears as random aliasing occurring close to the object's edges, and aliasing distortions.
6. Due to the shortcomings of DCT, discrete wavelet transform (DWT) has become increasingly important.
7. The main advantage of DWT is that it provides space-frequency decomposition of images, in comparison to the DCT and Fourier transform that only provide frequency decomposition.
8. By providing space-frequency decomposition, the DWT allows energy compaction at the low-frequency sub-bands and the space localization of edges at the high-frequency sub-bands.
9. Furthermore, the DWT does not present a blocking effect at low data rates. Wavelets are functions that integrate to zero, waving above and below the x-axis.
10. Like sine and cosine in the Fourier transform, wavelets are used as the basis functions for signal and image representation. Such basis functions are obtained by dilating and translating a mother wavelet c(x) by amounts k and τ, respectively as given in following Equation.

$$\Psi_{\tau,s}(x) = \left\{\Psi\left(\frac{x-\tau}{s}\right), (\tau, s) \in R \times R^{+}\right\}$$

The translation τ and dilation k allow the localization of wavelet transform in time and frequency. The discrete wavelet transform (DWT) decomposes the signal into mutually orthogonal set of wavelets [113]. The DWT of signal x is calculated by passing it through a series of filters. The samples are passed through a low pass filter with impulse response g resulting in a convolution as given in Equation. and is simultaneously decomposed using a high pass filter h.

$$\boldsymbol{Y}[\boldsymbol{n}] = (\boldsymbol{x} * \boldsymbol{g})[\boldsymbol{n}] = \sum_{k=-\infty}^{\infty} \boldsymbol{x}[\boldsymbol{k}]\, \boldsymbol{g}[\boldsymbol{n}-\boldsymbol{k}]$$

The signal is also decomposed simultaneously using a high pass filter h[n]. The outputs give the detail coefficients (from the high pass filter) and approximation coefficients (from the low pass filter) whose dimension will be 64 bytes each, since the dimension of 1D signal is 128 bytes. It is important that two filters are related to each other and they are known as a quadrature mirror filter. Here Haar wavelet is used for wavelet transform. After wavelet transform, a set of low frequency coefficients and high frequency coefficients each of dimension 64 bytes is obtained. After DWT, it is observed that approximation coefficients contain information and detailed coefficients do not have any information. Hence approximation coefficients with dimensions 64 bytes is selected as feature vector and stored in database. The following steps are followed for matching:

1. In recognition stage the features of the input eye image is compared with that of the features that is already stored in the database and if it matches, the corresponding eye image is identified otherwise it remains unidentified. Since a bitwise comparison is necessary Hamming distance was chosen for identification.
2. Having localized the region of an acquired image that corresponds to the iris, the final task is to decide if this pattern matches a previously stored iris pattern.
3. This matter of pattern matching can be decomposed into four parts:

➢ bringing the newly acquired iris pattern into spatial alignment with a candidate data base entry;
➢ choosing a representation of the aligned iris patterns that makes their distinctive patterns apparent;
➢ evaluating the goodness of match between the newly acquired and data base representations;
➢ deciding if the newly acquired data and the data base entry were derived from the same iris based on the goodness of match.

The Hamming distance gives a measure of how many bits are the same between two patterns. It is used for the comparison of iris templates in the recognition stage. Hamming distance D is given by

$$D = \frac{1}{n}\sum_{k=1}^{n} x_k \oplus y_k$$

where x and y are the two bit patterns of the iris code while n indicates the number of bits. Hamming distance D gives out the number of disagreeing bits between x and y.

**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.

✓ Ideally, the hamming distance between two iris codes generated for the same iris pattern should be zero;
✓ however this will not happen in practice due to fact that normalization is not perfect.
✓ The larger the hamming distances (closer to 1), the more the two patterns are different and closer this distance to zero, the more probable the two patterns are identical.
✓ By properly choosing the threshold upon which we make the matching decision, one can get good iris recognition results with very low error probability.
✓ 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.
✓ If two bits patterns are completely independent, such as iris templates generated from different irises, the Hamming distance between the two patterns should equal to 0.5.
✓ This occurs because independence implies the two 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.
✓ In order to account for rotational inconsistencies, when the Hamming distance of two templates is calculated, one template is shifted left and right bitwise and a number of Hamming distance values are calculated from successive shifts. The shifting process for one shift is illustrated in following figure.
✓ One shift is defined as one shift left, and one shift right of a reference template. In this example one filter is used to encode the templates, so only two bits are moved during a shift.
✓ The lowest Hamming distance, in this case zero, is used since this corresponds to the best match between the two templates.

The process is shown in figure 12.

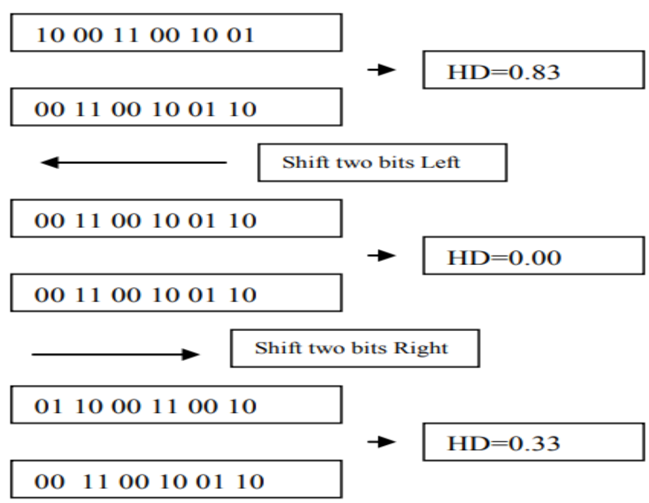



**Figure 12Shifting process**

Identification and verification modes are two main goals of every security system based on the needs of the environment.

1. In the verification stage, the system checks if the user data that was entered is correct or not (e.g., username and password) .
2. 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.

**The key disadvantages of iris recognition are the following:**

1. **Expensive**: Iris scanners are relatively higher in cost compared to other biometric modalities. As one of the leading and latest technology of the modern times, the cost of the iris devices are fairly high. Large companies, agencies or Governments can afford that price, but the general public can't afford to pay that price. Some say that it costs five times higher than fingerprint scanning which is more readily available to the general public.
2. **Distance**: Iris is small in size and can't be located from a few meters distance. A person needs to be in close distance with the iris scanning device to be enrolled on the system properly. So, a proper setup is needed for initiating an iris recognition process.
3. **Movement**: A person has to be steady in front of the device to be enrolled by iris scanners. It means this device can't be used like face recognition devices to scan anybody, regardless of their movements. Sometimes it is quite difficult to be steady enough to complete the scanning process in first attempt.
4. **Reflection**: In some cases, it is hard to perform an iris scanning due to the presence of reflections. It could happen in case of eyelashes, lenses, and anything in general that would cause a reflection. These aren't very uncommon in our society, so people would face some difficult during iris scanning process.
5. **Infrared light**: The constant use of this system may cause harm to the iris because it is constantly being scanned with infrared light.
6. **Location**: The placement of iris is somewhat bizarre. It is situated behind a curved, wet, reflecting surface.
7. A lot of memory is required for the data to be stored and later accessed.
8. **Obscure**: It is obscured by eyelashes, lenses and reflections, which create a problem, more often than not.
9. **Eyelids**: Iris is partially blocked by eyelids which is difficult to control by individuals due to frequent blinking.
10. **Transformation**: Iris may deform non-elastically as the pupil may change its size due to medical or other conditions.

Iris recognition technology is being used in banks and financial organizations, replacing the cumbersome and time taking, pin based, and password based systems. The use of iris recognition is expected to improve standards of financial services as the bankers will become free from time consuming document processing for identity proofs. This in turn will give them ample time and opportunity to concentrate on other important areas such as customer service.Since banks generally crunch large amount of financial data and witness a large number of footfalls, data security assumes critical importance. Iris recognition systems thus become the most reliable and the most secure security systems for banks. The healthcare industry faces is plagued with the persistent problem of establishing accurate patient identification. Healthcare management applications are turning towards biometric iris recognition technology. With its high accuracy and ease of use, iris recognition technology provides an option to identify proper insurance status that prevents fraudulence and duplicate medical records. The patients will benefit as well by getting correct treatments. Furthermore, the use of iris recognition technology helps to implement effective authentication and authorization mechanisms in various areas of healthcare which include –

- Tracking the patient registration
- Treatment or passageways to different departments
- Repetitive treatment
- Checkup arrangement and scheduling
- Supporting national or private Health Insurance Cards
- Ambulant treatment document

Biometric technology has a long history with law enforcement agencies and many important identity management innovations have sprouted from this beneficial relationship. For more than a century law enforcement has been using biometric technology to track and identify criminals, helping to enhance public safety and facilitate justice. The performance of iris acceptance algorithm is validated using F1 score, precision and recall. In pattern recognition and information retrieval with binary classification, precision, or positive predictive value, is the fraction of retrieved instances that are relevant, while recall or sensitivity is the fraction of relevant instances that are retrieved. Table below shows the condition and test outcome to calculate F1 score for performance measurement. Both precision as well as recall are therefore based on an understanding and measure of relevance. Precision can be seen as a measure of exactness or quality, whereas recall is a measure of completeness or quantity. Table 1 shows the analysis.

**Table.1. Performance measure for F1 score**

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Condition</td><td rowspan="2"></td></tr>
<tr><td>Condition positive(cp)</td><td>Condition negative(cn)</td></tr>
<tr><td rowspan="2">Test outcome</td><td>Test outcome positive (top)</td><td>True positive(tp)</td><td>False positive(fp) (Type I error)</td><td>$precision = \frac{\sum tp}{\sum top}$</td></tr>
<tr><td>Test outcome negative (ton)</td><td>False negative(fn) (Type II error)</td><td>True negative(tn)</td><td>$Negative\ predictivity = \frac{\sum tn}{\sum ton}$</td></tr>
<tr><td colspan="2"></td><td>$sensitivity = \frac{\sum tp}{\sum cp}$</td><td>$specificity = \frac{\sum tn}{\sum cn}$</td><td>$Accuracy = \frac{\sum tp + \sum tn}{\sum Total\ population}$</td></tr>
</table>

In a classification task, the precision for a class is the ratio of the number of true positives to the total number of elements labelled as belonging to the positive class or say the sum of true positives and false positives. Recall is defined as the ratio of number of true positives to the total number of elements that actually belong to the positive class, say the sum of true positives and false negatives, which are items not labelled as belonging to the positive class but should have been. In statistical analysis of binary classification, the F1 score (also F-score or F-measure) is a measure of a test's accuracy. It considers both the precision and the recall of the test to compute the score as in Equation below.

$$F_1 = 2\frac{precision * recall}{precision + recall}$$

## III. CONCLUSION

Iris recognition technology is durable, quantifiable, recordable and reliable. It thus fulfills the basic tenets of an ideal biometric system. The stored biometric template can be used for a person's whole life as iris patterns are not susceptible to change, remaining stable for long periods of time. Enrolment is required only once in a lifetime, saving both time and money. Biometric iris recognition systems are easy to use and create a hassle free security environment. Iris scanners can be used to protect high value locations by denying access to unwarranted visitors. Business and governmental organizations across the board have recognized the benefits of this system and have gone about implementing iris recognition based authentication systems in a big way. Iris images are segmented and projected into 1D signal by the vertical projection and the 1D signal features are extracted by the Haar wavelet transform. The complexity of feature extraction method for iris recognition is low and achieves a considerable computational reduction while keeping good performance. It can be observed that the canny operator is best suited for extracting most of the edges to generate the iris code for comparison. Wavelet, Gabor filter and the range of hamming distance for Haar wavelet is less for robust and fast matching for healthcare application for patient identification.

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