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IRIS Recognition: A Review

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Abstract: Iris recognition can be considered as one of the most reliable and accurate method of biometric technology when compared with other biometric technologies such as face, fingerprint and speech recognition. The iris is an externally visible, yet protected organ whose unique epigenetic pattern remains stable throughout adult life. These characteristics make it very attractive for use as a biometric for identifying individuals. Image processing techniques can be employed to extract the unique iris pattern from a digitised image of the eye, and encode it into a biometric template, which can be stored in a database. This biometric template contains an objective mathematical representation of the unique information stored in the iris, and allows comparisons to be made between templates. When a subject wishes to be identified by iris recognition system, their eye is first photographed, and then a template created for their iris region. This template is then compared by hamming distance with the other templates stored in a database until either a matching template is found and the subject is identified, or no match is found and the subject remains unidentified.

Key words: DWT-DCT domain, Hamming Distance, Normalization, Segmentation

INTRODUCTION

The need for infallible security systems has become a vital aspect in public security. Iris recognition is one of the important techniques and compared with other biometric features (such as face, voice, etc.), the iris is more stable and reliable for identification [1]. Iris recognition is the analysis of the coloured ring that surrounds the pupil [1]. The iris has unique structure and these patterns are randomly distributed, which can be used for identification of human being.

Biometric Technology

Biometric Technology refers to the identification of humans by their characteristics or traits. Biometrics is used in computer science as a form of identification. It is also used to identify individuals in groups that are under surveillance. Biometric identifiers are the distinctive, measurable characteristics used to label and describe individuals [10]. A good biometrics is one which uses a feature that is highly unique. This reduces the chances of any two people having the same characteristics to the minimal. The feature should also be stable so that it does not change over the period of time.

The Human Iris

The iris is a thin circular anatomical structure in the eye. The iris's function is to control the diameter and size of the pupils and hence it controls the amount of light that progresses to the retina. Figure1 shows front view of the iris. To control the amount of light entering the eye, the muscles associated with the iris (sphincter and dilator) either expand or contract the centre aperture of the iris known as the pupil.

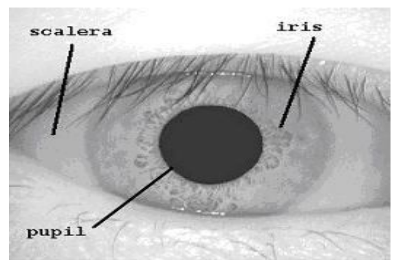

Figure 1 – A front view of the Human Iris [6]

Iris Recognition

The iris is a well-protected organ that is externally visible and whose epigenetic patterns are very unique and remain stable throughout most of a person's life [4]. Its high uniqueness and stability makes it a good biometrics that can be used for identifying individuals. The stages involved in most iris recognition systems consist of five basic modules leading to a decision as shown in Figure 2.

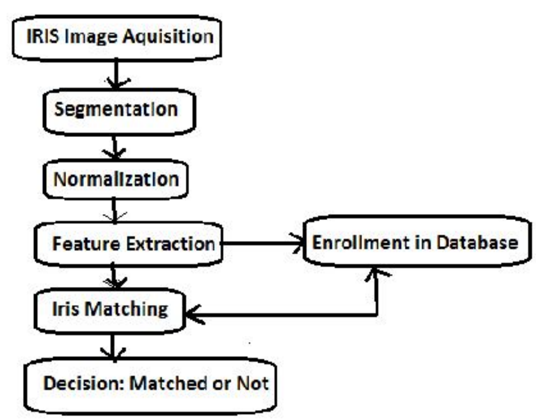

Figure 2: Typical iris recognition schemes

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SEGMENTATION

The color image is converted into shade of gray. That is brightness or luminance of color image is converted into gray shade by using formula [11]

$$Y=0.3RED+0.59GREEN+0.11BLUE \quad (1)$$

The first stage of iris recognition is to isolate the actual iris region in a digital eye image. The iris region, shown in Figure 1, can be approximated by two circles, one for the iris/sclera boundary and another, interior to the first, for the iris/pupil boundary. The eyelids and eyelashes normally occlude the upper and lower parts of the iris region. Also, specular reflections can occur within the iris region corrupting the iris pattern.Figure3 shows a technique or design to isolate and exclude these artefacts as well as locating the circular iris region

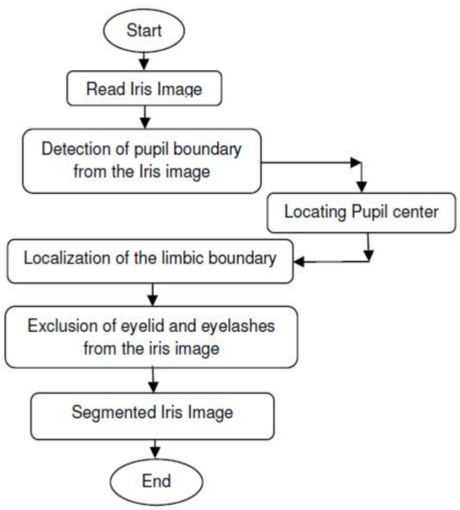

Figure 3: The design of iris segmentation

Pupil Detection

The inner boundary of the iris can be detected by finding the pupil, which is assumed to be the darkest portion of the eye and Algorithm used to detect the pupil because of the smaller pixel intensity values which are not uniformly distributed across the pupil [9].

Enhanced pupil boundary detection

Algorithm**:**

Step 1: Transform the original grey scale eye image into a binary image.This threshold computes the constant of the threshold using the image space; transforming an image *f* to a binary image *g* as thus,

$$g(x,y) = \begin{cases} 1 & \text{for } f(x,y) \geq T \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

T is the threshold value.

Step 2: Inversion of the dark colour pupil to white to make it visible since it is the area of interest.

Step 3: Smoothen the blurred circular boundary of the pupil image by applying averaging filter for easy detection of the pupil boundary.

Step 4: Find the center of the Pupil by using next algorithm

The pupil center is located using the following procedure:

Finding Pupil Center

Algorithm:

Step 1: Scan through the binary image starting from the top left horizontally, using 8-neighbour moving left to right, mark the first and last 8-neigbour encountered whose value is 1, that should form a vertical bisector of the pupil circle at 0°and 180° respectively as shown in figure 4(a)

Step 2: Scan vertically through the image this time, using the same connected component in the same direction, also mark the first and last 8-neighbour encountered whose value is 1 that should form a vertical bisector of the pupil circle at 270°and 90°respectively as shown in figure 4(a)

Step 3: Connect these two opposite point becomes the assumed center of the pupil and half of the length of the opposite connected pixel is an assumed radius of the pupil.

Step 4: Use the assumed center and radius detected to localize the pupil circular shape as shown in figure 4(c)

(a) **(b)** **(c)**

Figure 4: (a) Four points of the assumed detected pupil circle image. (b) Detected binarised image boundary. (c) Detected pupil image boundary [2]

Detecting the Iris (Limbic) Boundary Using Hough Transform

The Hough transform can be used to determine the parameters of a circle when a number of points that fall on the perimeter are known. And when these parameters are known it makes the computational speed faster. A circle with radius r and center (a, b) is defined by the parametric equations:

$$x = a + r\cos(\theta)$$
$$y = b + r\sin(\theta) \quad (3)$$

When the angle θ sweeps through the full 360 degree range,the points (x, y) traces the perimeter of a circle.It is a bit more difficult to detect the outer boundary of the iris because of the similar intensity pixels values between the iris and sclera, but we can localise the iris boundary.

Detecting Iris Boundary

Algorithm:

Step 1: Remove the noise on the eye image by applying minimal blurring to avoid making the boundary difficult to visualize.

Step 2: Apply 5 by 5 average filter for smoothing the image on the original intensity image.

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Step 3: Feed the pupil center parameter as detected,to circle Hough transform to detect the iris boundary.

Exclusion Of The Eyelids And Eyelashes

Having located the assumed center of the pupil , the eyelid is excluded with the following procedure as below.
Detection And Removal Of The Eyelids
Algorithm
Step 1: Apply canny edge operator on the eye image.
Step 2: Locate four different edge point pixels on the top (left and right) and bottom (left and right) respectively lying on the edge map of the eyelids detected by canny edge operator.
Step 3: Use the center of the pupil which is also the center of the iris, to excluded it from the iris. The eyelashes detected are removed from the iris by using following steps.

Detection And Removal Of The Eyelashes
Algorithm:
Step 1: Search for pixel values that are lower than the iris pixel values at the top and bottom of the iris image.
Step 2: Set the pixel values to the same value of the iris pixels in the neighbourhood
Step 3: Repeat the two steps above until all the eyelashes will remove.

NORMALIZATION

Once the segmentation module has estimated the iris's boundary, the normalization process will produce iris regions, which have the same constant dimensions, so that two photographs of the same iris under different conditions will have characteristic features at the same spatial location [8]. We can be using Daugman's Rubber Sheet Model for normalization. This model transforms the iris texture from Cartesian to polar coordinates. The process, often called iris unwrapping, yields a rectangular entity that is used for subsequent processing. The normal cartesian to polar transformation is recommended which maps the entire pixels in the iris area into a pair of polar coordinates (r, θ), where r and θ represents the intervals of [0 1] and[0 2π] as shown in figure 5.

Daugman's Rubber Sheet Model for Normalization

Normalization has advantages like, It accounts for variations in pupil size due to changes in external illumination that might influence iris size, It ensures that the irises of different individuals are mapped onto a common image domain in spite of the variations in pupil size across subjects etc.

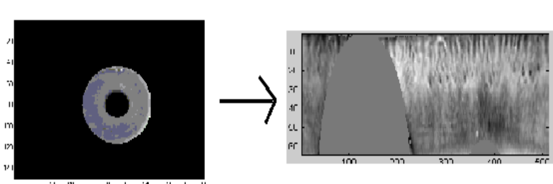

Figure 5: Normalized Iris

Histogram Equalization

Histogram equalization is done on each iris template to generate an image whose intensity also covers the entire range of intensity levels. The normalized iris image has very low contrast and it could have a non-uniform brightness in different parts of the image due to the light applied at the acquisition time. This makes the iris texture seem to be with less contrast than it really is. The contrast enhancement of the image is accomplished by means of histogram equalization in order to use the full spectrum of gray levels, hence the textures are highlighted as shown in figure 6. Further, filtering operation can be applied to remove noisy components.

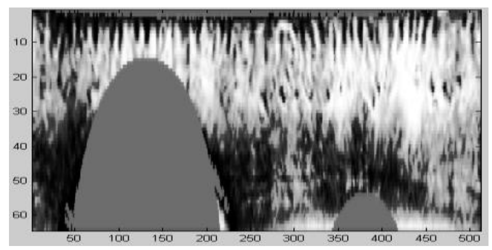

Figure 6: Enhancement of the iris normalized image.

ENCODING/FEATURE EXTRACTION

Each isolated iris pattern is then encoded using DWT-DCT method to extract its binary information.

Binary Image Template Formed Using Energies in DWT-DCT Domain

In encoding stage, two level Discrete Wavelet Transformation (DWT) is applied on the above segmented and normalized iris region to get approximation and detail coefficients as shown in figure 7.The two-dimensional DWT leads to a decomposition of approximation coefficients at level j in four components: the approximation at level $j + 1$, and the details in three orientations (horizontal, vertical, and diagonal) [2].

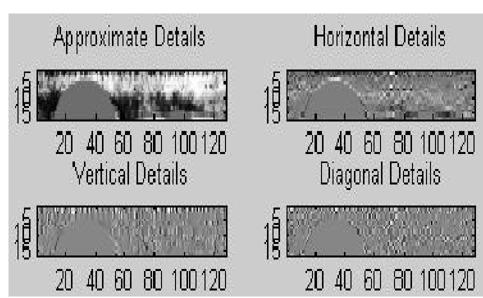

Figure 7: Approximation and detail coefficients of the normalized iris image.

In encoding stage, unique iris texture features are extracted from both second level horizontal detail subband CH2 and vertical detail subband CV2. Both subbands are first segmented into non-overlapping 8x8

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non-overlapping blocks. If size of both subbands is NxM, then

$$CH2=(ch2(1),ch2(2),\ldots\ldots\ldots,ch2(Nb)) \quad (4)$$

$$CV2=(cv2(1),cv2(2),\ldots\ldots\ldots,cv2(Nb)) \quad (5)$$

where,ch2(i) is i^{th} block of CH2 subband,cv2(i)is i^{th} block of CV2 subband and N_b=(NxM/64) is total number of blocks in each subbands at level 2 of wavlet decomposition.

Apply Discrete Cosine Transform (DCT) to each of the 8x8 block of both subbands. The energy-compaction characteristics of DCT in both sub-bands are used further to capture iris texture variations [2].

Calculate the energy of each 8x8 DCT block for both the subbands

$$HE_k = \frac{1}{Nk}\sum_{i=1}^{Nk-1} \circ \|DHk\|^2 \quad (6)$$

$$VE_k = \frac{1}{Nk}\sum_{i=1}^{Nk-1} \circ \|DVk\|^2 \quad (7)$$

Where, HE_k is energy of k^{th} DCT block of Horizontal detail wavlet subband, VE_k is energy of k^{th} DCT block of Vertical detail wavlet subband and Nk=64 is total number of DCT coefficients in each block vector.

Form binary image template using both subband energy vectors representing iris texture variations using the following criteria.

For a k^{th} block, if HE_k is greater than VE_k then set all pixels of corresponding 8x8 block of binary template as 255 i.e. all white pixels.

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

Figure 8: Binary image template formed using energies in DWT-DCT domain.

Form final binary bit stream/unique code B corresponding to above binary iris image template using following rule, If all pixels of 8x8 block is marked as 0 then corresponding bit will set as 0 else corresponding bit will set as 1 as shown in figure 9.

```
000000100100001000011111000111111111111111111111
011110111111111110001111111110100011111100000000
111111110000001111111111111111111111111111111110
000010000000000000111101111101111111111111111111
111000000000000000000000000000010010000011000011
011111111111110000000000100100110000001000000011
01100000000000000100011111000000000011111110011 0
```

Figure 9: Sample Unique Binary Bit Pattern

$$B=(b(1),b(2),\ldots..,b(Nb)) \quad (8)$$

This bit pattern will be stored in database for recognition purpose. So the size of overall database is reduced as only binary bit stream of Nb bits is stored instead of NxM sized binary image template. This also increases the computational speed of searching the code during matching process.

Iris Template Matching Process

The matching algorithm consists of all the image processing steps that are carried out at the time of enrolling the encoded iris template in database. Once the bit encrypted bit pattern B' corresponding to binary image formed is extracted, it is tried to match with all stored encrypted bit patterns B using simple boolean XOR operation[2]. The dissimilarity measure between any two iris bit patterns is computed using Hamming Distance (HD) which is given as,

$$HD=\frac{1}{Nl}\sum_{l=1}^{Nl} \circ X_l(XOR)Y_l \quad (9)$$

Where, Nl=total number of bits in each bit pattern. As HD is a fractional measure of dissimilarity with 0 representing a perfect match, a low normalized HD implies strong similarity of iris codes.

CONCLUSION

The iris recognition system that was developed proved to be a highly accurate and efficient system that can be used for biometric identification. Iris recognition is one of the most reliable methods available today in biometrics field. The accuracy achieved by the system was very good and can be increased by the use of more stable equipment and conditions in which the iris image is taken. The applications of the iris recognition system are innumerable and have already been deployed at a large number of places that require security or access control.

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