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Biometric Identification System Using Fusion at decision level of Human Iris

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Abstract - *Biometric identification system based on the pattern of the human iris is well suited to a high level of security systems. Iris recognition is must reliable and precise biometric system. This paper proposes iris recognition system that implements a fusion of two iris images at decision level. The Gabor filtering and wavelet transform are used in order to extract the deterministic patterns in a person's iris. A CASIA iris database of iris images has been used in the implementation of the iris recognition system. The results show that proposed method is quite effective.*

Keywords: *Iris recognition, Iris Localization, decision level fusion*

I. Introduction

I.1 Biometric Technology

A biometric system provides automatic recognition of an individual based on some type of unique feature or characteristic possessed by the individual.

Biometric systems have been developed based on fingerprints, facial features, voice, hand geometry, handwriting, and the iris.

Biometric systems work by first capturing a sample of the feature, such as recording a digital sound signal for voice recognition, or taking a digital color image for face recognition. The sample is then transformed using some sort of mathematical function into a biometric template. The biometric template will provide a normalised, efficient and highly discriminating representation of the feature, which can then be objectively compared with other templates in order to determine identity. Most biometric systems allow two modes of operation. An enrolment mode for adding templates to a database, and an identification mode, where a template is created for an Individual and then a match is searched for in the database of pre-enrolled templates. A good biometric is characterized by use of a feature that is; highly unique – so that the chance of any two people having the same characteristic will be minimal, stable – so that the feature does not change over time, and be easily captured – in order to provide convenience to the user, and prevent misrepresentation of the feature.

I.2 Iris 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 digitized 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 with the other templates stored in a database until either a matching template is found and the subject is identified, match is found and the subject remains unidentified.

Although prototype systems had been proposed earlier, it was not until the early nineties that Cambridge researcher, John Daugman, implemented a working automated iris recognition system. The Daugman system is patented [5] and the rights are now owned by the company Iridian Technologies. Even though the Daugman system is the most successful and most well known, many other systems have been developed. The most notable include the systems of Wildes et al., Boles and Boashash , and Noh et al.

The Daugman system has been tested under numerous studies, all reporting a zero failure rate. The Daugman system is claimed to be able to perfectly identify an individual, given millions of possibilities. The prototype system by Wildes et al. also reports flawless performance with 520 iris images.

Compared with other biometric technologies, such as face, speech and finger recognition, iris recognition can easily be considered as the most reliable form of biometric technology. However, there have been no independent trials of the technology, and source code for systems is not available. Also, there is a lack of publicly available datasets for testing and research, and the test results published have usually been produced using carefully imaged irises under favorable conditions.

I.3 Objective

The objective will be to implement an open-source iris recognition system in order to verify the claimed performance of the technology. The development tool used will be MATLAB®, and emphasis will be only on the software for performing recognition, and not hardware for capturing an eye image. A rapid application development (RAD) approach will be employed in order to produce results quickly. MATLAB® provides an excellent RAD environment, with its image processing toolbox, and high level programming methodology. To test the system, two data sets of eye images will be used as inputs; a database of 150 grayscale eye images courtesy of The Chinese Academy of Sciences – Institute of Automation (CASIA).

The system is to be composed of a number of sub-systems, which correspond to each stage of iris recognition. These stages are segmentation – locating the iris region in an eye image, normalization – creating a dimensionally consistent representation of the iris region, and 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. For an overview of the components of the system see Appendix B.

II. Proposed Iris recognition system

Block diagram of the proposed iris recognition system is as shown in Figure 1 that contains the typical stages of iris recognition system.

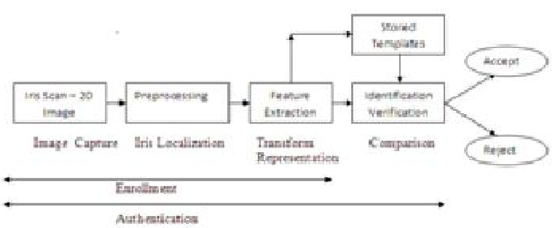

Fig.1. Proposed iris recognition system

The initial stage concerns about the segmentation of the iris. This consists in localize the iris inner (pupillary) and outer (scleric) boundaries, assuming either circular or elliptical shapes for each border. Additionally, it is used to detect regions of the iris derived from inside the limbus (the border between the sclera and the iris) and outside the pupil. If the eyelids are occluding part of the iris, then only that portion of the image without the eyelids should be included. For the localization of iris first any random circular contour is formed which contains iris + pupil region to eliminate the remaining portion of the eye .A circular pseudo image is formed of desired diameter. The inside region of the circle is set at gray level '1'(white) and the outside region to '0'(black). The diameter

texture occluded by any other type of data, as eyelids, eyelashes, glasses or hair. Extracted iris image are normalised and using Log Gabor transform features are extracted. These extracted features are stored in the database during enrollment. While matching features of the query image are correlated with the feature vectors of templates in the database and decision is formulated.

a) Image acquisition: The system captures eye images with the iris diameter typically between 100 and 200 pixels from a distance of 15–46 cm using a 330-mm lens.

b) Iris localization: Image acquisition of the iris cannot be expected to yield an image containing only the iris. It will also contain data derived from the surrounding eye region. Therefore, prior to iris pattern matching, it is important to localize that portion of the image

selected is such that the circular contour will encircle the entire iris. This diameter selection is crucial as it should be common for all iris images. Thus when the product of the gray levels of the circular pseudo image and the original iris image are taken, the resultant image will have the circular contour enclosing the iris patterns and the outside of the circular contour will be at gray level '0'(black). This circular contour is moved such that it is concentric with the pupil. So before pattern-matching, alignment is carried out. Firstly, we use point image processing techniques such as threshold and gray-level slicing (without the background) on the resultant localized image to eliminate every other feature except the pupil of the eye. The pupil of the eye is set at gray level '0' and rest of the region is at '255'(white) . Next step involves determining the center of the pupil is obtained by finding the row and column having the maximum number of pixels of gray level '0' (black), which corresponds to the center of the pupil. Knowing the center of the pupil, we now shift the center of the circular contour to the center of the pupil. The resultant image will have the pupil and the iris regions concentric with the circular contour and the localized iris image to the center of frame is performed. Pupil diameter is known to us and to find iris diameter binary image of semi circular iris using image point processing operators, mainly gray level slicing with and without the background and a digital negative, we obtain only the iris at gray level '0'(black) and the remaining portion of the image is at gray level '255'(white) . The shape of the iris in this case can be considered to be semi-circular. Now scanning row-wise, a counter determines the number of pixels having gray level '0' (white) in each row and the maximum count can be considered as the diameter of the iris along the row. Now scanning column-wise, a counter determines the number of pixels having gray level '0' (white) in each column and the maximum count can be considered as the radius of the iris. Doubling gives the diameter of the iris along the column. Taking the average of the two, we get the average iris diameter. Final Result of iris localization eye with iris and pupil are circled correctly.

III. Feature extraction

Once the iris region is successfully segmented from an eye image, the next stage is to transform the iris region so that it has fixed dimensions in order to allow The normalization process will produce iris regions, which have the same constant dimensions. The homogenous rubber sheet model devised by Daugman [8] remaps each point within the iris region to a pair of polar coordinates (r, θ) where r is on the interval [0, 1]

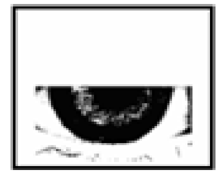

Fig.2 (a) Binary Semi –Iris Image

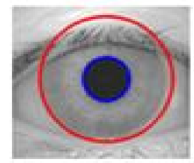

Fig.2 (b) Localized Iris

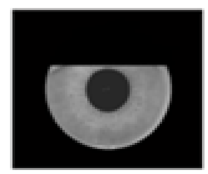

Fig.2 (c) Image Removing Eyelids

Removing the portion of the iris occluded by the eyelids is carried out next. The eyelids are occluding part of the iris, so only that portion of the image below the upper eyelids and above the lower eyelids are included. This is achieved by changing the gray level above the upper eyelids and below the lower eyelids to '0'

comparisons. The dimensional inconsistencies between eye images are mainly due to the stretching of the iris caused by pupil dilation from varying levels of illumination. Other sources of inconsistency include, varying imaging distance, rotation of the camera, head tilt, and rotation of the eye within the eye socket. and θ is angle [0,2π].

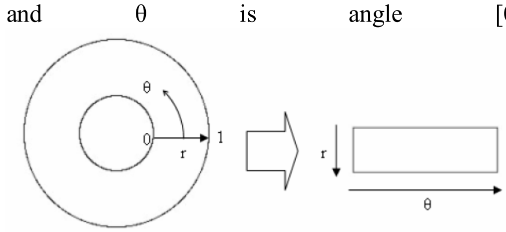

Fig.3 Daugman's Rubber Sheet Model.

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The remapping of the iris region from (x, y) Cartesian coordinates to the normalized non-concentric polar representation is modeled as Eq. 1.

$$I(x(r,\theta)\ y(r,\theta)) = I(r,\theta) \qquad (1)$$

with

$$x(r,\theta) = (1-r)\, xp(\theta) + r\, xi(\theta)$$
$$y(r,\theta) = (1-r)\, yp(\theta) + r\, yi(\theta)$$

Where I(x, y) is the iris region image, (x, y) are the original Cartesian coordinates, (r,θ) are the corresponding normalized polar coordinates, and xp, yp and xi, yi are the coordinates of the pupil and iris boundaries along the θ direction. The rubber sheet model takes into account pupil dilation and size inconsistencies in order to produce a normalized representation with constant dimensions. In this way the iris region is modeled as a flexible rubber sheet anchored at the iris boundary with the pupil centre as the reference point.

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

For normalization of iris regions a technique based on Daugman's rubber sheet model was employed. The centre of the pupil was considered as the reference point, and radial vectors pass through the iris region, as shown in Figure 4. A number of data points are selected along each radial line and this is defined as the radial resolution. The number of radial lines going around the iris region is defined as the angular resolution. Since the pupil can be non-concentric to the iris, a remapping formula is needed to rescale points depending on the angle around the circle. This is given by Eq.2.

$$r' = \sqrt{\alpha\beta} \pm \sqrt{\alpha\beta^2 - \alpha - r_I^2} \qquad (2)$$

with

$$\alpha = O_x^2 + O_y^2$$

and

$$\beta = COS(\pi - \arctan(\frac{O_x}{O_y}) - \theta)$$

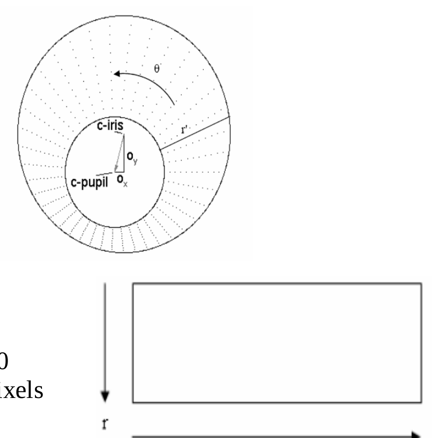
where displacement of the centre of the pupil relative to the centre of the iris is given by $O_{x,}O_y$, and r' is the distance between the edge of the pupil and edge of the iris at an angle, θ around the region, and rI is the radius of the iris as shown in Figure 4. The remapping formula first gives the radius of the iris region 'doughnut' as a function of the angle θ.

A constant number of points are chosen along each radial line, so that a constant number of radial data points are taken, irrespective of how narrow or wide the radius is at a particular angle. From the 'doughnut' iris region, normalization produces a 2D array with horizontal dimensions of angular resolution and vertical dimensions of radial resolution. Another 2D array was created for marking reflections, eyelashes, and eyelids detected in the segmentation stage. In order to prevent non-iris region data from corrupting the normalized representation, data points which occur along the pupil border or the iris border are discarded.

The normalization process proved to be successful, a constant number of points are chosen along each radial line, here 20 pixel points are chosen as number of radial data points are taken, and 240 pixel points for angular data points are selected to create a 2D array, as shown in fig. 5.

Normalization produces a 2D array with horizontal dimensions of angular resolution and vertical dimensions of radial resolution as shown in figure 6. Another 2D array for marking reflections, eyelashes, and eyelids to prevent non-iris region data from corrupting the normalized representation, as shown in figure 7 below.

Feature Encoding: After iris region is segmented, to provide accurate recognition of individuals, the most discriminating information present in an iris pattern must be extracted to create a biometric template. Only the significant features of the iris must be encoded so that comparisons between templates can be made.



20 pixels

2
40 Pixels

Fig. 4 Normalization process with radial resolution of 20 pixels, and angular resolution of 240 pixels.

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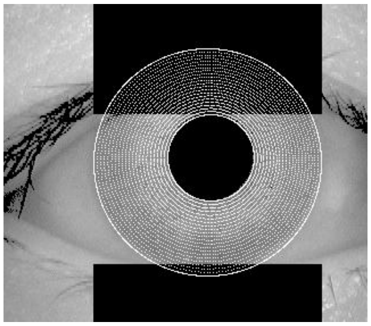

Fig. 5 Radial and angular pixel from iris region

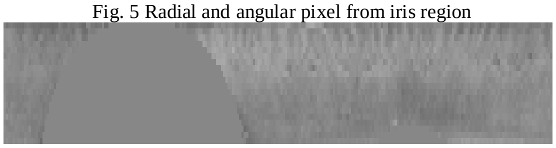

Fig.6 Normalized Iris (Polar array)

Fig.7 Mask for normalized iris (Polar Mask)

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 localization in both space and frequency, since a sine wave is perfectly localized in frequency, but not localized in space. Modulation of the sine with a Gaussian provides localization in space, though with loss of localization 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 in order to encode iris pattern data. A 2D Gabor filter over the an image domain (x,y) is represented as Eq.3.

$$G(x,y)=e^{-\pi[(x-x_o)^2/\alpha^2+(y-y_o)^2/\beta^2]}e^{-2\pi i[u_o(x-x_o)+v_o(y-y_o)]} \quad (3)$$

where (xo,yo) specify position in the image, (α,β) specify the effective width and length, and (uo, vo) specify modulation, which has spatial frequency $\omega=\sqrt{u_o^2+v_o^2}$.

Daugman demodulates the output of the Gabor filters in order to compress the data. This is done by quantizing the phase information into four levels, for each possible quadrant in the complex plane, phase information, rather than amplitude information provides the most significant information within an image. Taking only the phase will allow encoding of discriminating information in the iris, while discarding redundant information such as illumination, which is represented by the amplitude component.
These four levels are represented using two bits of data, so each pixel in the normalized iris pattern corresponds to two bits of data in the iris template. A total bits are calculated for the template, and an equal number of masking bits are generated in order to mask out corrupted regions within the iris. This creates a compact template, which comparison of irises. The Daugman system makes use of polar coordinates for normalization, therefore in polar form the filters are given as Eq. 4

$$H(r,\theta)=e^{-i\omega(\theta-\theta_o)}e^{-(r-r_o)^2/\alpha^2}e^{-i(\theta-\theta_0)^2/\beta^2} \quad (4)$$

Where (α, β) are the same as in Eq. 3 and (r0, θ0) specify the centre frequency of the filter.
The demodulation and phase Quantization process can be represented as Eq. 5

$$h_{(\mathrm{Re,Im})}=\mathrm{sgn}_{(\mathrm{Re,Im})}\int_\rho \int_\phi I(\rho,\phi)e^{-i\omega(\theta_o-\phi)}e^{-(r_o-\rho)^2/\alpha^2}e^{-(\theta_o-\phi)^2/\beta^2}\rho d\rho d\phi \quad (5)$$

where $h_{(\mathrm{Re,Im})}$} can be regarded as a complex valued bit whose real and imaginary components are dependent
on the sign of the 2D integral, and is the raw iris image in a dimensionless polar coordinate system.
A disadvantage of the Gabor filter is that the even symmetric filter will have a DC component whenever the bandwidth is larger than one octave .However, zero DC component can be obtained for any bandwidth by using a Gabor filter which is Gaussian on a logarithmic scale, this is known as the Log-Gabor filter. The frequency response of a Log-Gabor filter is given as;

$$G(f)=\exp\left(\frac{-(\log(f/f_o))^2}{2(\log(\sigma/f_o^2))}\right) \quad (6)$$

Where f_o represents the centre frequency, and σ gives the bandwidth of the filter. ‘

d) Matching

In comparing the bit patterns X and Y, the Hamming distance, HD, is defined as the sum of disagreeing bits (sum of the exclusive-OR between X and Y) over N, the total number of bits in the bit pattern as given in Eq. 7.

$$HD = \frac{1}{N}\sum_{j=1}^{N} X_j (XOR) Y_j \tag{7}$$

For matching, the Hamming distance was chosen as a metric for recognition, since bit-wise comparisons were necessary. The Hamming distance algorithm employed also incorporates noise masking, so that only significant bits are used in calculating the Hamming distance between two iris templates. Now when taking the Hamming distance, only those bits in the iris pattern that corresponds to '0' bits in noise masks of both iris patterns will be used in the calculation. The Hamming distance will be calculated using only the bits generated from the true iris region, and this modified Hamming distance formula is given as Eq. 8.

$$HD = \frac{1}{N - \sum_{k=1}^{N} Xn_k (OR) Yn_k} \sum_{j=1}^{N} X_j (XOR) Y_j (AND) Xn'_j (AND) Yn'_j \tag{8}$$

Where Xj and Yj are the two bit-wise templates to compare, Xnj and Ynj are the corresponding noise masks for Xj and Yj, and N is the number of bits represented by each template.

In order to account for rotational inconsistencies, when the Hamming distance of two templates is calculated, one template is shifted left and right bit-wise and a number of Hamming distance values are calculated from successive shifts. This bit-wise shifting in the horizontal direction corresponds to rotation of the original iris region by an angle given by the angular resolution used. This method is suggested by Daugman, and corrects for misalignments in the normalized iris pattern caused by rotational differences during imaging. From the calculated Hamming distance values, only the lowest is taken, since this corresponds to the best match between two templates.

Used Algorithms:-

Algorithm

1) Image Acquisition: Acquire the iris image by a Iris scanner Acquire the two images one after another of same eye.
2) Perform the step number 3 to 6 on both images
3) Segmentation: Separate out the iris image from the acquired image using the following steps
   - Edge detection is to be performed on the image
   - *Circles for Iris and Pupil Boundary are* to be detected using Hough transform
   - Eyelid are to be detected are remove from the iris image.
4) Normalization: the region between the iris and pupil is to be normalized like the rubber sheet model.
5) From the normalized image Feature are to be extracted by using LOG Gabor transform and Encoded
6) Matching distance: Hamming distance is to be obtained between the test and Query image.
7) Fusion: Two hamming distances D1 and D2 are obtained. If D1 or D2 is less than Threshold the image is recognized. Otherwise it is rejected.

IV. Fusion of Decision level

Two iris images are used to find the two Hamming distances of test images with Query. Two hamming distances are given by D1 and D2. If D1 or D2 is less than Threshold the image is recognized. Otherwise it is rejected. This makes the robust to accept the person under query.

Result: The result obtained after experimentation are calculated. The percentage Accuracy Based on FAR (False Acceptance Ratio), FRR (False Reject Ratio) and RAR (Right Acceptance Ratio) of the implemented algorithm is given in Table gives the result for Fusion of Iris at decision level as given below.

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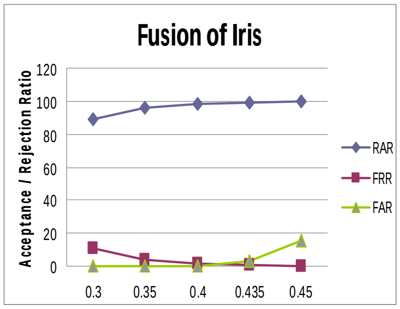
Threshold	RAR	FRR	FAR
0.3	89.36	10.64	0
0.35	96.1	3.9	0
0.4	98.65	1.35	0.04
0.435	99.30	0.7	2.87
0.45	100	0	15.41

Table I Result interms of RAR, FRR, FAR for Multiple Iris image



Performance rate

Percentage performance rate of the system calculated for threshold value 0.3 and for 0.45. So genuine acceptance rate of identification,

RAR = (NCi X 100) / Ti

RAR- Right acceptance rate

NCi – No of correct accepted images

Ti – Total no of images in database.

For threshold value of 0.3 RAR is 89.33 % and that of for 0.45 performance rate of the sytem is 100 %.

Errors - 1 - The false reject rate (FRR) is known as Type I error, measures the probability of an enrolled individuals not being identified by the system.

FRR = (NRi X 100) / Ti

FRR – False reject rate (Type I error)

NRi – No of false rejected images

Ti – Total no of images in database.

For threshold 0.3 type I error rate is 10.66 % and that of for 0.45 is 0 %.

2 - The false accept rate (FAR) is known as type II error. It measures the probability of an individual being wrongly identified as another individual.

FAR = (Nai X 100) / ((Ti – 3) X Ti)

FAR – False accept rate (Type II error)

Nai – No of false accepted images

Ti – Total no of images in database.

For threshold 0.3 type II error rate is 0 % and that of for 0.45 is 15.41 %.

Separation point will affect the FAR & FRR. Since lower the threshold will decreases FAR while increases FRR and vice versa. Thus threshold or separation point is important to consider both error rates.

TABLE II Computational Complexity

Method	Feature Extraction (ms)	Matching (ms)	Feature extraction + matching (ms)
Existing	737.87	4.8	742.67
Proposed (Multiple Snaps)	1475.7	9.6	1485.34

V. Conclusion

The developed system of Biometrics using fusion at decision level for person identification is tested and the results are all described earlier, shows a good separation of intra-class and inter-class for different persons. If selected threshold is changed according to determined Hamming Distances such that if we select the maximum Hamming distance of that particular Person, and considering same as threshold for decision it can improve decision making accuracy. The computaional complexity of the proposed system is more as we use the non othrogonal transform (Gabor Transform) for extracting the features. As menstioned in result the recognition rate gets improved due to the fusion of multiple iris images. The results obtained are more robust in multmodal system as compared to single biometrics system.

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