Iris Recognition using Orthogonal Transforms

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***Abstract*— Iris Recognition is a biometric recognition technique in which features of the iris are used to uniquely identify individuals. Iris recognition has over the years emerged as one of the most accurate biometric techniques as opposed to other biometric techniques like face, signature and fingerprint. First, the iris image is pre processed using canny edge detector using a Gaussian filter. The iris edge and the pupil edge are extracted using image morphological operation, image opening. After normalization of red, green and blue components of the colour iris using Euclidean distance method, they are combined to form the localized colour iris. For feature vectors extraction, orthogonal transforms like discrete cosine transform, discrete sine transform and discrete Fourier transform have been considered. The proposed iris recognition system is very time efficient and it takes less than 1 second to grant authentication.**

Keyword- Image processing, Discrete Cosine transform Transform, Discrete Sine Transform, Discrete Fourier Transform.

I. Introduction

Biometrics is term for a variety of methods of capturing a person's unique biological data that differentiate him or her from another individual for identification purposes. A biometric system provides automatic recognition of an individual based on some sort of unique feature or characteristic possessed by the individual. Biometric systems have been developed based on fingerprints, facial features, voice, hand geometry, handwriting, the retina, and human iris.

Biometric systems work by first capturing biometric template, such as recording a voice signal for voice recognition. The template can then be objectively compared with other test templates in order to determine identity or to grant authentication. Most biometric systems allow two modes of operation. An enrolment mode for adding templates to a database, and a verification mode, where a template is created for an individual and then a match is searched for in the database of enrolled templates ([1]-[3]).

Most of the current research in biometrics is based on finger print and face. One of the many ways for automatic identification or verification is by comparing selected facial features from the image and a facial database. This technique is typically used in security systems. The reliability of personal authentication using face is currently low due to the problem of pose, lighting, orientation and gesture. Finger print identification is widely used in personal identification as it works well in most cases. However it is difficult to acquire finger print features i.e. minutiae for some class of persons as manual labourers, elderly people etc. As a result, other biometric characteristics are receiving increasing attention [1], [2].

A. *The Human Iris*

The iris is a thin circular diaphragm, which lies between the cornea and the lens of the human eye as shown in Figure 1. The function of the iris is to control the amount of light entering through the pupil. The average diameter of the iris is 12 mm, and the pupil size can vary from 10% to 80% of the iris diameter [3], [4].

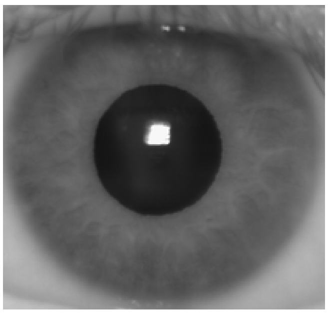

Fig 1 The Human Iris

Formation of the iris begins during the third month of embryonic life. The unique pattern on the surface of the iris is formed during the first year of life, and pigmentation of the stroma takes place for the first few years. The only characteristic that is dependent on genetics is the pigmentation of the iris, which determines its colour. Due to the epigenetic nature of iris patterns, the two eyes of an individual contain completely independent iris patterns, and identical twins possess uncorrelated iris patterns ([3]-[7]). The iris is also not subject to the effects of aging which means it remains in a stable form from about the age of one until death. The use of glasses or contact lenses (coloured or clear) has little effect on the representation of the iris and hence does not interfere with the recognition technology [5].

B. Iris Recognition

The iris is an externally visible, whose unique epigenetic pattern remains stable throughout adult life ([3]-[5]). These characteristics make it very useful 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 transform 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 person wishes to be identified by iris recognition system, his iris is scanned and then a template is created for his iris region. This template is then compared with the other templates stored in a database until either a matching template is found and the person is identified, or no match is found and the person remains unidentified.

II. LITERATURE REVIEW

In early nineties Cambridge researcher, John Daugman [4], [5], implemented an automated iris recognition system. Even though the Daugman system is the most successful and most well known, many other systems have been developed. M. M. Gifford et al. discussed iris recognition system which is used for computer based login system [6]. The most notable include the systems of Wildes [8] et al, Boles and Boashash, Lim et al, and Noh et al. The algorithms by Lim et al. are used in the iris recognition system developed by the Evermedia and Senex companies. Also, the Noh et al algorithm is used in the 'IRIS 2000' system, sold by IriTech. Kazuyuki Miyazawa et al. [9] presents an implementation of iris recognition algorithm using phase-based image matching ,an image matching technique using phase components in 2D Discrete Fourier Transforms (DFTs) of given images. A neural network based iris recognition system was implemented by Y. Wang et al. [10]. 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 because there is a lack of publicly available databases for testing and research, and the test results published have usually been produced using carefully imaged irises under favourable conditions. The block diagram of the proposed system for iris recognition is shown in fig 2.

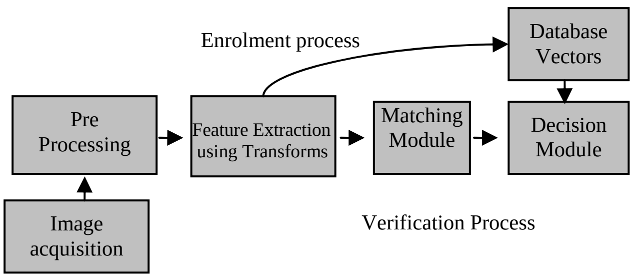

Fig 2. Proposed block diagram for IRIS Recognition

Iris recognition proceeds in three major steps [11] .The first step is image acquisition, which yields an image of the subject's eye region. The second step is pre processing which consists of iris localization to separate the iris from the eye image. The third step is pattern matching, which produces a decision. For authentication, the decision is an accept or reject response relative to a particular database entry; for identification, the decision is a record that has been indexed relative to a larger set of entries.

III. IMPLEMENTATION

The implementation of IRIS recognition requires the following steps during the enrolment phase.

- Image Acquisition
- Iris Localization
- Iris Normalization
- Feature Vector extraction using Orthogonal transforms
- Storing the feature vectors in the database for future reference

A. Image Acquisition:

This step involves obtaining the image of the iris. This is achieved by means of a high resolution camera which is positioned in front of the person's eye. Some standard cameras include the CASIA Iris Scanner and the OKI IRISPASS-h; these cameras simply click the photograph and store the image in the destination folder. More advanced equipment may also be used such as the TOPCON TRC50IA optical device in connection with any standard digital camera; such devices may photograph the eye and then automatically segment the area around the eyeball and then store the modified image in the destination folder. These types of images were found in Michael's Dobes and Libor Machala database ([12]-[14]).

The main features of this database are

- The database contains 3 x 128 iris images (i.e. 3 x 64 left and 3 x 64 right)
- The images are: 24 bit - RGB, 576 x 768 pixels, file format: PNG
- The irises were scanned by TOPCON TRC50IA optical device connected with SONY DXC-950P 3CCD camera.

B. Iris Localization [9]:

An iris image contains parts like eyelid, sclera, pupil, etc. Also, the size of an iris may vary depending on camera-to-eye distance and lighting condition. Therefore, the original image needs to be normalized and segmented out. This step involves the elimination of any unnecessary information from the acquired image. In case of database formed using standard equipment, segmentation deals with the elimination of information such as skin, eyelashes, eyelids etc and retains only the iris itself. To do this, we first need to detect the edge between the pupil and the iris as well the edge between the sclera and the iris. We use Canny Edge detection method to detect these edges [15]. The Canny edge detection algorithm is known as the optimal edge detector. The canny edge detector, first smoothes the image to eliminate noise. For smoothing, it uses a Gaussian filter. The resultant image is the convolution of the original image with a Gaussian filter as shown in equation 1. Gaussian filter is used to reduce the noise and unwanted details and textures.

$$Y(u,v) = H_\sigma(x,y) * f(x,y) \qquad (1)$$

where $Y(u,v)$ is the smoothed image and $f(x,y)$ is the original noisy image. The impulse response of the Gaussian filter is given by

$$H_\sigma(x,y) = \frac{1}{\sqrt{2\pi}\sigma}\exp(-[\frac{x^2+y^2}{2\sigma^2}]) \qquad (2)$$

It then finds the image gradient to highlight regions with high spatial derivatives using equation 3.

$$M(x,y) = \sqrt{Y_x{}^2(u,v) + Y_y{}^2(u,v)} \qquad (3)$$

where $Y_x\ (u,v)$ is the x gradient and $Y_y\ (u,v)$ is the y gradient of the smoothed image.

The gradient array is now further reduced by hysteresis. Hysteresis is used to track along the remaining pixels that have not been suppressed. Hysteresis uses two thresholds T_1 and T_2 and if the magnitude is below the first threshold T_1, it is set to zero (made a non edge). If the magnitude is above the high threshold T_2, it is made as an edge. If the magnitude is between the two thresholds in such a way $T_{1 \le M \le T2}$, then it is set to zero unless there is a path from this pixel to a pixel with a gradient above the second threshold. However, all the edges in the images get detected including noise in the iris and pupil region as shown in fig 3. This presents a hurdle since it is only the iris-pupil edge and the iris-sclera edge that should be detected. Any other edges represent noise. Hence we have to eliminate this unwanted noise. For this, we use a morphological function called image opening [16]. Very simply, an image opening is defined as erosion followed by a dilation using the same structuring element for both operations as shown below.

$$A \circ B = (A \ominus B) \oplus B \qquad (4)$$

where $\ominus$ and $\oplus$ denote erosion and dilation, respectively. Dilation, in general, causes objects to dilate or grow in size; erosion causes objects to shrink. The amount and the way that they grow or shrink depend upon the choice of the structuring element. Together with closing, the opening serves in computer vision and image processing as a basic method of morphological noise removal. Opening removes small objects from the foreground of an image, placing them in the background, while closing removes small holes in the foreground, changing small islands of background into foreground. After image opening, the noise and unwanted edges are removed and we can see the iris edge and pupil edge very clearly as shown in fig 4.

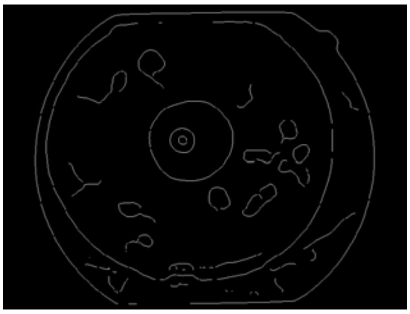

Fig 3. Result of Canny Edge detection

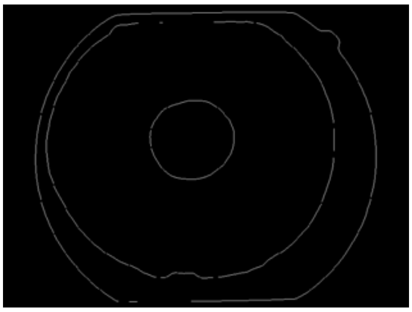

Fig 4. Iris after Image opening

C. Iris Normalization

An important step in this stage is determining the centre and radius of the pupil as well as outer iris circle. We have assumed that the pupil centre and iris centre are the same and they are concentric circles. In real, the two circles are not always concentric, but for simplicity sake we make this assumption. In reality the centres might differ by a few pixels. By computing the Euclidian distance from any non-zero point to the nearest zero valued point, an overall spectrum can be found. This spectrum shows the largest filled circle that can be formed within a set of pixels. Since the pupil is the largest filled circle in the image, the overall intensity of this spectrum will peak in it. In the pupil circle, the exact centre will have the highest value. This is due to the simple fact that the centre is the one point inside the circle that is farthest from the edges of the circle. Thus the maximum value must correspond to the pupil centre, and furthermore the value at that the centre must be equal to the pupil radius.

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 comparisons. The dimensional inconsistencies between eye images are mainly due to the stretching of the iris caused by pupil dilation from varying levels of lighting conditions. Other sources of inconsistency include, varying imaging distance, rotation of the camera, head tilt, and rotation of the eye within the eye socket. 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.

D. Feature Encoding and Matching

Having localized the iris, features/patterns of the iris have to be extracted for matching purposes and stored in a database. Each iris image has an entry in the database corresponding to feature vectors extracted from the iris. In the enrolment stage, multiple templates are grouped together and used as one common database of feature-encoded iris images. In the verification stage, the template so formed is then compared with every template in the database until a match is found. If no match is found then verification has failed; if a match is found, verification has succeeded.

IV. TRANSFORMS UNDER CONSIDERATION

We have implemented the system using sinusoidal orthogonal transforms like discrete Fourier transform, discrete cosine transform and discrete sine transform ([16]-[19]).

A. Discrete Fourier Transform (DFT)

The Fourier transform is simply a method of expressing a function in terms of the sum of its projections onto a set of basis functions. The DFT is a specific kind of discrete transform, used in Fourier analysis. It transforms one function into another, which is called the frequency domain representation, or simply the DFT, of the original function (which is often a function in the time domain). The DFT requires an input function that is discrete. The discrete transform F of a two dimensional image is calculated using equation 5.

$$F(k,l) = \frac{1}{\sqrt{MN}} \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} f(m,n) e^{-j2\pi(\frac{mk}{M}+\frac{nl}{N})} \qquad (5)$$

Where $f(m,n)$ is the original image and $F(k,l)$ is the image after transform.

B. Discrete Sine Transform (DST)

DST is a well-known signal analysis tool used in compression due to its compact representation power. The sine transform is real symmetric and orthogonal. The sine transform is not the imaginary part of discrete Fourier transform. It is related to DFT of its anti symmetric extension. It transforms a signal or image from the spatial domain to the frequency domain with very good energy compaction property. The general equation for a 2D (N data items) DST is defined by the following equation:

$$F(u,v) = \frac{2}{N+1}\sum_{i=0}^{M-1} f(i,j) \bullet \sin\left(\frac{(u+1)(i+1)\pi}{M+1}\right) \bullet \sum_{i=0}^{N-1} \cos\left(\frac{(v+1)(j+1)\pi}{N+1}\right) \quad (6)$$

where $f(i,j)$ is the original image and $F(u,v)$ is the image after transform.

C.Discrete Cosine transform (DCT)

In particular, a DCT is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry. THE DCT is a fast transform and it is often used in signal and image processing, especially for lossy data compression, because it has a strong "energy compaction" property for highly correlated data. Hence most of the signal information tends to be concentrated in a few low-frequency components of the DCT, approaching the Karhunen-Loève transform. DCT helps separate the image into parts of differing importance. The general equation for 2D (N data items) DCT is defined by the following equation:

$$F(u,v) = \alpha(u) \bullet \alpha(v) \sum_{i=0}^{M-1} f(i,j) \bullet \cos\left(\frac{u(2i+1)\pi}{2M}\right) \bullet \sum_{i=0}^{N-1} \cos\left(\frac{v(2j+1)\pi}{2N}\right) \quad (7)$$

where,

$$\alpha(u) = \alpha(v) = \begin{cases} \frac{1}{\sqrt{N}} & \text{for } u,v = 0 \\ \frac{2}{\sqrt{N}} & \text{otherwise} \end{cases}$$

$f(i,j)$ *is the image*

V. Results and Discussions

The Michael’s Dobes and Libor Machala dadabase consists of three left Iris images and 3 right iris images in the database for ever user. Out of these, we have used two left Iris images and two right iris images during the enrolment process and one left iris image and one right iris image during verification process. Since we are dealing with colour iris database, before feature extraction, we have separated the red component, green component and Blue component of the iris after identifying the centre using Euclidean method as shown in fig 5.

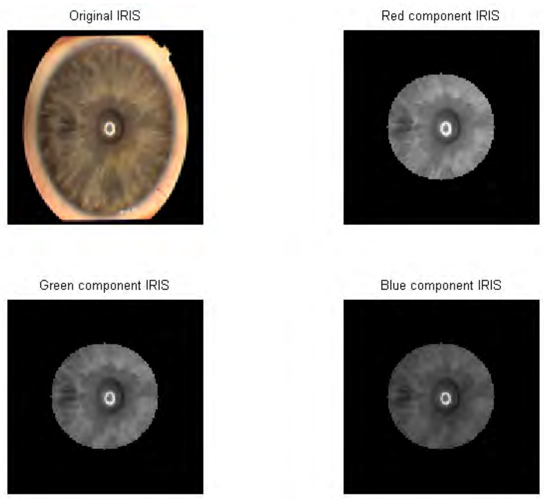

Fig 5. RGB components of coloured IRIS

Now these three images are combined and the localized iris image is reconstructed as shown in fig 6.Using orthogonal transforms, feature vectors are extracted from this image and stored in the database .During verification stage, the same procedure is repeated on the test iris image and feature vectors are generated.

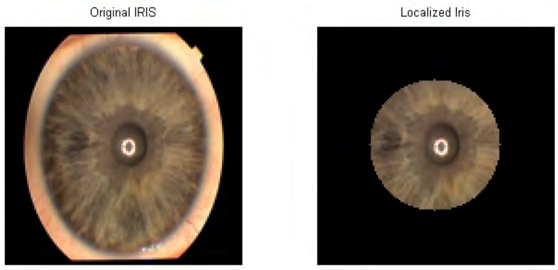

Fig 6.Localized Colour Iris

In matching process, the feature vectors from the test iris image are compared with the feature vectors of database images and match score is generated, If the match score satisfies the pre determined threshold, authentication is granted otherwise , it is rejected. For comparing the performance we have calculated the true acceptance rate (TAR) which is ratio between the number of true users accepted and the total number of users. Since we have considered 60 users, the database consists of a total of 240 iris images (60 x 2 for left iris and 60 x 2 for right iris). For verification, we have a 120 iris images, two from each user. Hence, 120 match scores are generated for every test iris using the Euclidean distance and these scores are sorted out to decide the winner. The results are shown in table 1 and the TAR for various coefficients is plotted as shown in fig 7.

Table 1 Results of Iris Recognition system

Transform	No. of Coeff.	TAR in %	Training period in secs	Testing period in secs
DCT	64	96	18.29	0.289
	128	97	18.30	0.29
	256	97	19.12	0.30
	512	94	19.15	0.33
DST	64	96	18.54	0.29
	128	97	18.67	0.30
	256	96	17.85	0.32
	512	94	17.90	0.34
DFT	64	95	17.95	0.28
	128	98	18.00	0.29
	256	97	18.96	0.3
	512	96	18.22	0.48

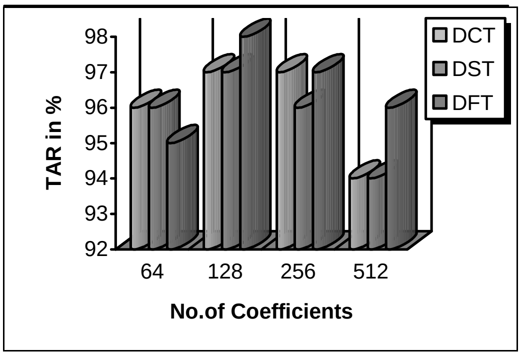

Fig 7. Performance Comparison

VI. Comparison with existing Iris recognition algorithms

The first Iris recognition system proposed by Daugman was based on frequency approach. He proposed the use of Gabor filters for feature vector extraction and hamming distance for matching score generation ([20] – [23]). Wilds [8] proposed the Iris recognition system based on high contrast edges. He used gradient operation and Hough transform for better segmentation. He used Gaussian filters for feature extraction and matching was done based on normalized correlation. Ma et al. [24] used canny edge detection for iris segmentation and similarity function for match score generation. Monro et.al used one dimensional discrete cosine transform for feature extraction [25]. He used Hamming distance for match score generation. In the proposed method, Image segmentation is done using canny edge detector. The detected edges are enhanced using the combination of gradient operation and morphological operations like image opening and closing. Iris normalization was done using Euclidean distance approach. This approach uses the two dimensional orthogonal transforms like DCT, DST and DFT for feature vector extraction. Since these transforms are having good energy compaction, the entire system works very faster with only 128 feature vectors. While most of the earlier systems used many iris images as training images, the performance evaluation of the proposed approach was done with two iris images as training images.

VII. Conclusion

An iris recognition system using orthogonal transforms DCT, DFT and DST has been proposed. The entire work was implemented in MATLAB 7.1 and we have used Intel i3 processor with 2.40 GHz speed. The Michael's Dobes and Libor Machala database is considered for evaluating the performance of the system. In the pre processing stage, the iris is localized, normalized and then feature vectors are extracted. 60 individuals are considered in the system with three left iris images and three right iris images (a total of 360 iris images). Two left eye iris images and two right eye iris images were used to generate the training feature vectors and one left iris image and one right iris images were used for testing. Hence we had 240 training iris images and 120 test iris images. During the feature extraction phase, we have considered 64, 128, 256 and 512 feature vector coefficients for comparison. The results show that the true acceptance rate reaches its maximum when 128 coefficients are considered as feature vectors. The system is quite simple to implement .Also it is found out that the performance of all these transforms is almost same and the average testing time during the verification stage is less than one second. In our future work, we will focus on larger databases and try to validate the robustness of the system performance. Since the system is implemented in MATLAB, which is an interpreted language, the system performance can be improved using the other languages like C++ and Java.

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