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Study of Different IRIS Recognition Methods

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***Abstract*— Iris is an internally protected organ whose texture is stable from birth to death. So it is very reliable as IRIS texture is unique in each individual, and its probability of two iris images to be same is 1/1051 proved by Dr. J. Doughman. By this we can say that it is one of most secure mechanism when security is concerned. The iris recognition technique consists of iris localization, normalization, encoding and comparison .In this paper various IRIS recognition algorithms are analyzed and it is concluded that the Doughman's approach given highest efficiency of 99.9% and Kaushik Rai's approach using SVM given 99.56% of overall efficiency.**

***Index Terms*—Encoding, Iris Recognition System, Localization and SVM.**

I. INTRODUCTION

In all of the biometric identification systems Iris is taking too much attention because of its reliable and secure identification measures. The human iris is an annular region between the pupil (generally darkest portion of the eye) and sclera. It has many interlacing minute characteristics such as freckles, coronas, stripes, furrows, crypts and so on[21]. These minute patterns in the iris are unique to each individual and are not invasive to their users. These properties make iris recognition particularly promising solution to society.

A. Biometric Identification System

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 the one presented in this thesis, the iris [1].

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 normalized, 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.

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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.

B. Comparison of Various Biometric Techniques:

The comparison of various recognition systems shows that IRIS recognition system is the most stable, precise and the fastest biometric authentication method. Computer vision-based techniques that recognize human features such as faces, finger prints, palms, and eyes have many applications in surveillance and security.

C. Steps of IRIS Recognition System[4]:

It is the process of acquiring high definition iris images either from iris scanner or precollected images. These images should clearly show the entire eye especially iris and pupil part. Then Major steps are followed:-

1) Segmentation

A technique is required to isolate and exclude the artifacts as well as locating the circular iris region. The inner and the outer boundaries of the iris are calculated.

2) Normalization

Iris of different people may be captured in different size, for the same person also size may vary because of the variation in illumination and other factors. 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.

3) Feature extraction

The significant features of the iris must be encoded so that comparisons between templates can be made. Most iris recognition systems make use of a band pass decomposition of the iris image to create a biometric template. Iris provides abundant texture information. a feature vector is formed which consists of the ordered sequence of features extracted from the various representation of the iris images.

***4)** Matching of an Image*

To authenticate via identification (one-to-many template matching) or verification (one to- one template matching), a template created by imaging the iris is compared to a stored value template in a database. If the Hamming distance is below the decision threshold, a positive identification has effectively been made e.g. a hamming distance of 0 would result in a perfect match.

The test of statistical independence is implemented using a Boolean XOR and then a hamming distance is computed to determine how similar two irises are.
Figure 1. Shows some basic steps for the complete analysis of IRIS recognition are as follows:-

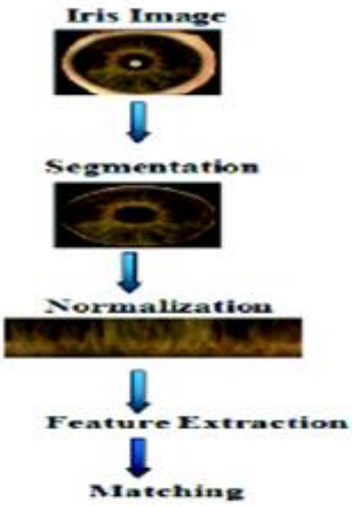

Figure 1. IRIS Recognition System

II. IRIS IMAGE DATASETS

The accuracy of the iris recognition system depends on the image quality of the iris images. Noisy and low quality images degrade the performance of the system. UBIRIS database is the publicly available database [9]. It consists of images with noise, with and without cooperation from subjects. The UBIRIS database has two versions with images collected in two distinct sessions corresponding to enrolment and recognition stages. The second version images were captured with more realistic noise factors on non-constrained conditions such as at-a-distance, on-the-move and visible wavelength. CASIA iris image database images are captured in two sessions [18]. CASIA-IrisV3 contains a total of 22,051 iris images from more than 700 subjects. It also consists of twins' iris image dataset. ND 2004-2005 database is the superset of Iris Challenge Evaluation (ICE) dataset, uses an Iridian iris imaging system for capturing the images [16]. The system provides voice feedback to guide the user to the correct position. The images are acquired in groups of three called as shot. For each shot, the system automatically selects the best image of the three and reports values of quality metrics and segmentation results for that image. For each person, the left eye and right eye are enrolled separately.

III. IRIS RECOGNITION METHODS

A. Phase-based method

1) Daugman integrodifferential operator

The phase based method recognize iris patterns based on phase information. Phase information is independent of imaging contrast and illumination. J.Daugman [11, 12] designed and patented the first complete, commercially available phase-based iris recognition system in 1994. The eye images with resolution of 80-130 pixels iris radius were captured with image focus assessment performed in real time. The pupil and iris boundary was found using integrodifferential operator given in Equation

$$\max_{r,x0,y0} \left| G(r) * \frac{d}{dr} \int_{r,x0,y0} \frac{I(x,y)}{2\pi r} ds \right| \quad (1)$$

where I(x,y) is the image in spatial coordinates, r is the radius, (x0,y0) are centre coordinates, the symbol * denotes convolution and Gσ(r) is a Gaussian smoothing function of scale σ. . The centre coordinates and radius are estimated for both pupil and iris by determining the maximum partial derivative of the contour integral of the image along the circular arc. The eyelid boundaries are localized by changing the path of contour integration from circular to arcuate. The iris portion of the image I(x, y) is normalized to the polar form by the mapping function I(x(r, θ), y(r, θ)) → I(r, θ) where r lies on the unit interval [0,1] and θ is the angular quantity in the range [0,2π]. The representation of iris texture is binary coded by quantizing the phase response of a texture filter using quadrature 2D Gabor wavelets into four levels. Each pixel in the normalized iris pattern corresponds to two bits of data in the iris template. A total of 2,048 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 256- byte template, which allows for storage and comparison of iris.
The recognition in this method is the failure of a test of statistical independence involving degrees of freedom. Iris codes are different for two different samples. The test was performed using Boolean XOR operator applied to 2048 bit phase vectors to encode any two iris patterns, masked (ANDed) by both of their bit vectors. From the resultant bit vector and mask bit vectors, the dissimilarity measure between any two iris patterns is computed using Hamming Distance (HD) given in Equation (2).

$$HD = \frac{(codeA \otimes CodeB) \odot maskA \odot maskB}{maskA \odot maskB} \quad (2)$$

Where codeA, codeB are two phase code bit vectors and maskA, maskB are mask bit vectors. The HD is a fractional measure of dissimilarity with 0 representing a perfect match. A low normalized HD implies strong similarity of iris codes. The work by Xianchao Qui [13] used 2D Gabor filters for localization.

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The filter response vectors were clustered using vector quantization algorithms like k-means. The experiments were conducted on CASIA-Biosecure iris database consisting of images captured from Asian and non-Asian race groups. The support vector machine was used for the two class ethnic classification. In Martin's method, the iris circumference parameters are obtained by maximizing the average intensity differences of the five consecutive circumferences. In Masek's method, the segmentation was based on the Hough transform. The phase data from 1D Log-Gabor filters was extracted and quantized to four levels to encode the unique pattern of the iris into a bit-wise biometric template. Xiaomei Liu [16] reimplemented Masek's algorithm in C that was originally written in Matlab. Continuing the Daugman's method, Karen vollingsworth [17] has developed a number of techniques for improving recognition rates. These techniques include fragile bit masking, signal-level fusion of iris images, and detecting local distortions in iris texture. The bits near the axes of the complex plane shift the filter response from one quadrant to adjacent quadrant in presence of noise. In the fragile bit masking method, such bits called as the fragile bits are identified and masked to improve the accuracy. The signal-level fusion method uses image averaging of selected frames from a video clip of an iris. Local texture distortions occurs with contact lenses with a logo, poor-fit contacts and edges of hard contact lenses, segmentation inaccuracies and shadows on the iris. These are detected by analyzing iris code matching results. The 20x240 normalized images were covered with 92 windows each of size 8x20. Fractional HD was computed for each window. The location of windows with highest fractional HD was identified and removed from further calculations. The effect of dilation was studied by collecting datasets of images with varying degrees of dilation. The data was divided into subsets with small pupils, medium pupils and large pupils. The subset of data with large pupils showed worst performance with EER at an order of magnitude greater compared to that of small pupil data set. The visibility in the iris area is reduced and greater part of iris is occluded by eyelids which provide less information for iris code generation.

B. Texture-analysis based method

1) Laplacian of Gaussian Filters

In order to encode features, the Wildes et al. system decomposes the iris region by application of Laplacian of Gaussian filters to the iris region image. The filters are given as

$$\nabla G = -\frac{1}{2\pi\sigma^4}\left\{1-\frac{\rho^4}{2\sigma^2}\right\}e^{-\rho^2/2\sigma^2} \qquad (3)$$

where σ is the standard deviation of the Gaussian and ρ is the radial distance of a point from the centre of the filter. The filtered image is represented as a Laplacian pyramid which is able to compress the data, so that only significant data remains. Details of Laplacian Pyramids are presented by Burt and Adelson [24].

A Laplacian pyramid is constructed with four different resolution levels in order to generate a compact iris template. The method for iris identification by Emine Krichen [21] use a hybrid method for iris segmentation, Hough transform for outer iris boundary and integrodifferential operator for inner iris boundary. The iris code was produced using wavelet packets. The whole image is analyzed at different resolutions. 832 wavelets with 4 scales are used to generate 1664 bits code. The iris database consisted of 700 images acquired with visible light. An improvement of 2% FAR and 11.5% FRR was obtained relative to Daugman method. It was observed that by considering colour information, overall improvement of 2% to 10% was obtained according to threshold value.

2) Zero-Crossing representation method

Boles and Boashash [8] make use of 1D wavelets for encoding iris pattern data. The mother wavelet is defined as the second derivative of a smoothing function θ(x).

$$\psi(x) = \frac{d^2\theta(x)}{dx^2} \qquad (4)$$

The zero crossings of dyadic scales of these filters are then used to encode features. The wavelet transform of a signal f(x) at scale s and position x is given by

$$W_s f(x) = f * \left\{s^2\frac{d^2\theta(x)}{dx^2}\right\}(x) \qquad (5)$$

$$= s^2\frac{d^2(f*\theta_s)(x)}{dx^2} \qquad (6)$$

where

$$\theta_s = W_s(1/s)\theta(x/s)$$

$W_s f(x)$ is proportional to the second derivative of f(x) smoothed by $\theta_s(x)$, and the zero crossings of the transform correspond to points of inflection in $f*\theta_s(x)$. The motivation for this technique is that zero-crossings correspond to significant features with the iris region.

The method developed by Boles [22] represents features of the iris at different resolution levels based on the wavelet transform zero-crossing. The algorithm is translation, rotation and scale invariant. The input images are processed to obtain a set of 1D signals and its zero crossing representation based on its dyadic wavelet transform. The wavelet function is the first derivative of the cubic spline. The centre and diameter of the iris is calculated from the edge-detected image. The virtual circles are constructed from the center and stored as circular buffers. The information extracted from any of the virtual circles is normalized to have same number of data points and a zero crossing representation is generated. The representation is periodic and independent from the starting point on iris virtual circles. These are stored in the database as iris signatures. The dissimilarity between the iris of the same eye images was smaller compared to the eye images of different eyes.

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The advantage of this function is that the amount of computation is reduced since the amount of zero crossings is less than the number of data points. But the drawback is that it requires the compared representations to have the same number of zero crossings at each resolution level.

C. Approach based on intensity variations

1) Hough Transform

The Hough transform is a standard computer vision algorithm that can be used to determine the parameters of simple geometric objects, such as lines and circles, present in an image. The circular Hough transform can be employed to deduce the radius and centre coordinates of the pupil and iris regions. An automatic segmentation algorithm based on the circular Hough transform is employed by Wildes et al. [7], Kong and Zhang [15], Tisse et al. [19], and Ma et al. [16]. Firstly, an edge map is generated by calculating the first derivatives of intensity values in an eye image and then thresholding the result. From the edge map, votes are cast in Hough space for the parameters of circles passing through each edge point. These parameters are the centre coordinates x_c and y_c, and the radius r, which are able to define any circle according to the equation

$$X_c^2+Y_c^2-r^2=0 \qquad (7)$$

A maximum point in the Hough space will correspond to the radius and centre coordinates of the circle best defined by the edge points. Wildes et al. and Kong and Zhang also make use of the parabolic Hough transform to detect the eyelids, approximating the upper and lower eyelids with parabolic arcs, which are represented as

$$\left(-(x-h_j)\sin\Theta_j+(y-k_S)\cos\Theta_j\right)^2=\left((x-h_S)\cos\Theta_j+(y-k_S)\sin\Theta_j\right)$$
(8)

where a_j controls the curvature, $(h_j, k_j)$is the peak of the parabola and θ_j is the angle of rotation relative to the x-axis.

In performing the preceding edge detection step, Wildes et al. bias the derivatives in the horizontal direction for detecting the eyelids, and in the vertical direction for detecting the outer circular boundary of the iris. The motivation for this is that the eyelids are usually horizontally aligned, and also the eyelid edge map will corrupt the circular iris boundary edge map if using all gradient data. Taking only the vertical gradients for locating the iris boundary will reduce influence of the eyelids when performing circular Hough transform, and not all of the edge pixels defining the circle are required for successful localization. Not only does this make circle localization more accurate, it also makes it more efficient, since there are less edge points to cast votes in the Hough space.

There are a number of problems with the Hough transform method. First of all, it requires threshold values to be chosen for edge detection, and this may result in critical edge points being removed, resulting in failure to detect circles/arcs. Secondly, the Hough transform is computationally intensive due to its 'brute-force' approach, and thus may not be suitable for real time applications.

D. Approach using Independent Component Analysis

The iris recognition system developed by Hamed Ranjzad [2] adopts Independent Component Analysis (ICA) to extract iris texture features. Image acquisition is performed at different illumination and noise levels. The iris localization is performed using integrodifferential operator and parabolic curve fitting. From the inner to outer boundary of iris, fixed number of concentric circles n with m samples on each circle is obtained. This is represented as a matrix n x m for a specific iris image which is invariant to rotation and size. The independent components are uncorrelated, determined from the feature coefficients. The feature coefficients are non-Gaussian and mutually independent. The basis function used is kurtosis. The independent components are estimated and encoded. The centre of each class is determined by competitive learning mechanism which is stored as the iris code for a person. The average Euclidean distance classifier is used to recognize iris patterns.

E. Iris authentication based on Continuous Dynamic Programming

Pupil extraction begins by identifying the highest peak from the histogram which provides the threshold for lower intensity values of the eye image. All the connected components in sample eye image less than threshold intensity value are labeled. By selecting the maximum area component we arrive at pupil area of the eye. Normalized bounding rectangle is implemented using centre of pupil to crop iris. Continuous dynamic programming is used with the concept of comparing shape characteristics part wise. The acceleration plot is segmented and parts of acceleration curve are used to verify with input's acceleration curve. For iris samples, rate of change of gray level intensities within bounding box forms acceleration feature plot. The implementation is based the concept of accumulated minimum local distances between a reference template and input sample. The reference template is obtained using leave one out method. The distance measure is the count of directional changes in acceleration plot. The local distances are directional changes in respective segmented slots of the acceleration plot.

F. New Inverse Laplacian Filter Bank

Performance of this new filter bank is similar to Laplacian pyramid in opposite direction in frequency domain it is named as Inverse Laplacian filter bank. In Laplacian filter bank the bandwidths of band pass filters are increased with increasing the frequency center of them.

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Since texture detail information exists in high frequencies more than in low frequencies, these filter banks cannot analysis texture information exactly. In these filter banks high frequency information of texture cannot be extracted exactly because wide widths of filters in high frequency, mixes in band frequency information with each other [4].

To overcome to this problem we have designed a new filter bank which can extract texture information more exactly than previous filter banks. The bandwidth of our new filter bank are reduced in high frequencies, then extracted features with new filter bank can describe texture information more exactly than wavelet and Laplacian pyramids .It is observable that new filter bank behavior in frequency domain is similar to previous filter banks but in opposite direction so we have named this new filter bank as inverse Laplacian filter bank. Since texture information in high frequency is more important than low frequencies, this new filter bank can extract texture information efficiently [2].

Lower and upper bands of k'th band pass filter are determined by

$$L_{bpf} = \frac{w}{2} + x\frac{1-\left(\frac{1}{2}\right)^{(k-1)}}{1-\left(\frac{1}{2}\right)} \qquad (9)$$

$$H_{bpf} = \frac{w}{2} + x\frac{1-\left(\frac{1}{2}\right)^{(k)}}{1-\left(\frac{1}{2}\right)} \qquad (10)$$

Where L_{bpf} and H_{bpf} are lower and upper bands of k'th band pass filter. So in spatial domain inverse Laplacian filter bank is determined by relation

$$H_k(x,y) = \begin{cases} H(x,y)_{\uparrow 2} & k = 1 \\ H(x,y)_{\uparrow \frac{2(2^{(l-1)}-1)}{2^{(l)}-2^{(l-k)}-1}} - H(x,y)_{\uparrow \frac{2(2^{(l-1)}-1)}{2^{(l)}-2^{(l-k+1)}-1}} & k > 1 \end{cases} \qquad (11)$$

Where H(x,y) is 2-D signal, Hk(x,y) is 2-D output signal, after applying inverse Laplacian filter bank at Level *k*, *l* is total number of band pass filters and ↑ is a indicator for up sampling operation.

G. Multiclass SVM based Approach.

The support vector machine (SVM) is a well-accepted approach for pattern classification due to features and promising performance. Support vector classifiers devise a computationally efficient way of learning good separating hyper plane in a high dimensional feature space. In this work, we apply multi class SVM to classify the iris pattern due to its outstanding generalization performance. Here, the SVM is employed as an iris pattern classifier because of its advantageous features over other classification scheme and also because of its promising performance as a multiclass classifier. In an SVM, a few important data point called support vectors (SV) are selected on which a decision boundary is exclusively dependent.

The SVM is also well suited for the case where the sample proportion between two classes is poorly balanced [17].

In this method, three basic kernel functions are used for experimentation, and the most favorable one is selected for prediction purpose. The adjustment of C and the kernel parameters are also important to improve the generalization performance. A careful selection of a training subset and a validation set with a small number of classes is required to avoid training the SVM with all the classes and evaluate its performance on the validation set due to its high computational cost when the number of classes is higher. An modified approach proposed in [12] is applied here to reduce the cost of selection procedure as well as to tune the parameters of SVM. Here, the Fisher discriminate function is used with a low computation cost for each class. After careful selection of C, and kernel parameters, the whole training set with all classes are trained.

IV. COMPARISON RESULTS:

As given in the references [3][4][8][11][12][17]The algorithms were implemented in MATLAB. These algorithms have been tested on the CASIA Iris Image Database [22] A**s** this is the only database available in public domain. The database includes 756 iris images from 108 individuals. For each eye, 7 images are there which have been captured in two sessions; three samples are collected in

TABLE 1. IRIS RECOGNITION METHODOLOGIES

Group	EER	FAR/FRR	Overall Accuracy
Wildes et al.	1.76	2.4/2.9	95.10
Avila	3.38	0.03/2.08	97.89
Tisse	5.94	1.84/8.79	96.61
Li Ma	4.73	0.02/1.98	98.00
Daugman	0.95	0.01/0.09	99.9
Boles	8.13	0.02/1.98	94.33
Hamed Ranjzad	2.1	1.6/1.2	98.1
Kaushik Rai	0.92	0.03/0.02	99.5

the first session and four in the second session. Three images for training purpose and rest of the four for testing are taken. The performance results are based on error rates: False Acceptance Rate (FAR) and False Rejection Rate (FRR); Equal Error Rate (EER) and the overall accuracy. The percentage accuracy based on FAR and FRR of the implemented algorithms is shown in Table 1. This table shows that the Daugman's algorithm [15] gives the maximum accuracy among the Eight with respect to FRR and FAR,0.01/0.09% and overall accuracy 99.9% second highest accuracy is 99.5% given by SVM based approach proposed by Kaushik Rai.

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V. CONCLUSION

Available IRIS recognition algorithm of almost every domain is studied in this paper. Generally algorithm is divided into four steps, viz. Localization, Normalization, Feature Extraction and Matching. Doughman's approach is there with highest accuracy of 99.9% and Kaushik Rai's approach with 99.5% is available now the only thing that can be done is to decrease the computational time and no. of features to obtain the same efficiency. By which one can overcome the deficiency of existing algorithms.

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