COMPARATIVE ANALYSIS OF SELECTED FEATURE EXTRACTION TECHNIQUES FOR IRIS RECOGNITION SYSTEM

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Abstract: The complexity of features extraction has a great influence on the program and processing speed of iris recognition system. Inappropriate feature extraction methods use in the representation of iris images may affect the classification accuracy of iris recognition system. It is important in iris recognition technology to look into different feature extraction techniques. This paper addresses the challenge of how to deduce the effectiveness of some feature extraction methods by carrying out comparative analysis on selected feature extraction techniques: Gabor Wavelet Transform, Scale Invariant Feature Transform (SIFT) and Haar Wavelet Transform. The experimental evaluation of the feature extraction techniques based on CASIA iris dataset gave different results of each technique. Finally, it was showed that the Gabor Wavelet Transform technique outperformed the other two techniques in term of recognition accuracy, training and testing time.

Keywords: Gabor wavelet transform, Haar wavelet transform

Introduction

Iris recognition is a method of biometric authentication that uses pattern recognition techniques based on high resolution images of the irises of an individual's eyes. The Iris recognition is a dependable approach that visually recognize persons when the imaging can be done at distances not more than 1 meter and quite useful in situations in which a large database will need to be searched for such recognition while ensuring there are minimal or no false matches (Daugman, 2009). Recently, the human iris has attracted the attention of biometric-based recognition research and development (Pithadia & Nimavat, 2015). Iris is a coloured and muscular portion within the eye size of the pupil, controlling the amount of light that passes into eye (Shirke & Gupta, 2013). The iris is so distinct in nature that no two irises of individuals are like even for identical twins (Jain, Ross & Pankanti, 2006).

The iris represents an annular point between pupil and white sclera, it has extraordinary structure which provides many interlacing of fine and unique features such as freckles, stripes, corona, furrows, crypts, rings, zigzag, collarets, radial, which are collectively referred to as texture of the iris (Pithadia & Nimavat, 2015). The iris features are unique and distinguishable for different people, the unique features of the anatomical structure of iris makes it possible to differentiate individuals (Homayon, 2015). The uniqueness of iris pattern is such that the left and right eye of the same person is entirely different (Chouhan & Shukla, 2010). This makes the technology very important in biometric authentication system compared to other techniques like retina, finger, face, palm-print, odour and nose (Thyaneswaran & Padma, 2014).

In pattern recognition method such as iris recognition system, the extraction of features from iris region is considered to be most important process because best features is required to be obtained with minimum classification and low running time (Shah *et al.*, 2013). Feature extraction is a process that involves the transformation of data into a set of feature or feature vector (Kumari & Sharma, 2014). In iris recognition, a feature extraction can be seen as the extraction of unique features of the iris that encodes them into a code which is a set of mathematical parameters usually called a template, the template is then stored in the database for matching an iris with those in the database (Abikoye *et al.*, 2014; Sharma & Singh, 2014).

The feature extraction represents one of the most important phases of iris recognition due to the direct dependency of accuracy of any iris model on the level of extracted features from iris region (Abhineet Kumar, Potnis & Singh, 2016). Several feature extraction methods such as Haar Wavelet Transform, SIFT, Gabor Wavelet Transform have been applied by researchers to extract iris texture in iris recognition system (Adegoke *et al.*, 2013). The feature extraction based on Gabor-filters have been widely employed in iris and fingerprint recognition (Khaladkar & Ganorkar, 2012). A multi-channel Gabor wavelet is a set of filter banks with different orientations and scales, which is used to obtain textures of various densities and piece them together for a formation of iris image texture feature coding (Mude & Patel, 2015).

Haar Wavelet Transform applies a pair of low-pass and high-pass filters for decomposition of image (Sinkar *et al.*, 2017) . This technique of iris feature extraction captures both local and global features details in an iris (Ibrahim, 2014). A Scale Invariant Feature Transform (SIFT) is a feature extraction technique with efficient method for describing local properties of an image. In SIFT technique some important parts are insensitive to illumination, rotation and scale changes (Gandhi & Kulkarni, 2014). This is useful in determining salient, stable feature points in an image. In every image point, it provides a set of features that describe a small image region around the point. These features are invariant to scale and rotation.

Bansal *et al.* (2016) developed a statistical feature extraction technique based on correlation between adjacent pixels. Hamming distance was applied for matching. The performance of the system was measured by recording false acceptance rate (FAR) and false rejection rate (FRR) at different threshold in the distance metrics. Results obtained from experiments based on the different set of statistical features of iris images showed significant improvement in equal error rate (ERR) when number of statistical parameters for feature extraction was increased from three to six.

Ashwini *et al.* (2015) presented a multi-algorithmic approach in enhancing the accuracy of iris recognition system. In this system, features are extracted from the iris using various feature extraction algorithms, namely Local Pattern Quantization (LPQ), Local Binary Pattern (LBP), Gabor Filter, Haar, Daubechies8 and Daubechies16. Based on the experimental results, it was demonstrated that Mutli-algorithms Iris Recognition System performed better than the unimodal system. The accuracy improvement offered by the proposed approach also showed that using more than two feature extraction algorithms in extracting the iris system might decrease the system performance. This is due to redundant features. The system presented a detailed description of the experiments and provided an analysis of the performance of the proposed method.

Abikoye *et al.* (2014) proposed a method for extraction of iris using fast wavelet transform; a mathematical algorithm designed to turn a signal in the time domain into a sequence of coefficients based on an orthogonal basis of wavelets. The transform was used for the iris multidimensional image such that the time domain was replaced with space domain. The study converted the localized iris image which was in a Cartesian coordinate system to one in a polar coordinate system. They reported that the algorithm was fast and has a lower complexity rate.

Chirchi and Waghmare (2013) proposed a system of feature extraction based by using a five level decomposition technique implemented with Haar, db2 and db4. The proposed method has a comparative accuracy of 99.97%, its speed was faster and equal error rate smaller than existing systems it was compared with such as (Daugman, 1993; Ma & Wang, 2002).

Jain *et al.* (2012) came up with an efficient iris recognition algorithm using method of moments. Fast Fourier transform was employed for conversion of image from spatial domain to frequency domain and also filtered noise in the image giving more precise information. The moments served as area descriptors used to characterize the size and shape of the image. The moment's values were invariant to scale transformation. Finally Euclidean distance formula was used for image matching.

Materials and Methods

The proposed system of comparison of selected feature extraction methods of iris recognition system involved several phases. The first phase of this study started with acquisition of iris images from CASIA database (Chinese Academy of Sciences' Institute of Automation). The second phase is the segmentation process, this process isolated the iris region of an eye image by locating pupil, two eyelids and eye lashes that cover some areas of the iris texture. After segmentation of the iris region in an eye image, the next step is to unwrap it into rectangular block of fixed dimensions. A Daugman Rubber Sheet method was used to fix dimensions. The next phase which is the real focus of this work, considered three feature extraction methods; Haar Wavelet Transform, Gabor Wavelet Transform and Scale Invariant Feature Transform (SIFT) for extraction of feature texture from iris images. The different extracted features were passed to Hamming Distance for matching of iris image. A comparative performance analysis was conducted on each feature extraction methods.

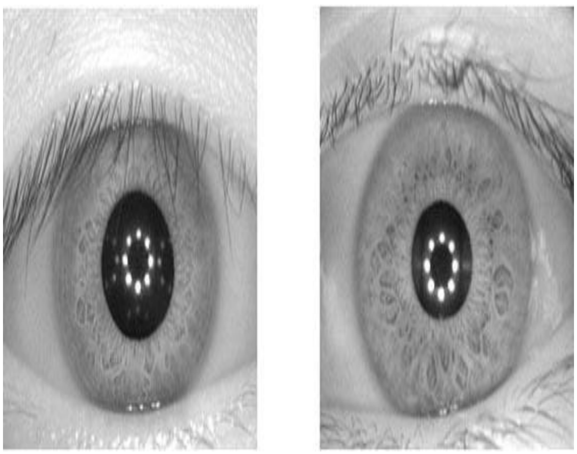

Fig. 1: Sample of iris image (CASIA database)

Iris image dataset

The CASIA iris image database was selected to evaluate the iris proposed comparison analysis of feature extraction methods. Currently, the database is one of the largest iris datasets available in the public domain.

Setting of parameters for iris database

For each individual, the study used six data sets for training, and two data set which comprises of the left and right iris for testing. The total number of training sets is sixty, testing sets is 24 and it consist of 10 classes. Four out of the testing image were impostors that are the images were not found in the database. This phase allows the database parameters to be set before carrying out the experimental evaluation on developed system as shown in Table 1.

Table 1: Database parameter settings

Parameters	Value
Total number of training sets	60
Total number of Testing Sets	24
Total Iris Per subject	6
Total Number of Class (subjects)	10
Training Iris Per Class	6
Testing Iris Per Subject	2
Imposter	4
Total Iris Images	88

Iris image processing

This study applied image processing methods to demarcate area of interest (ROI) from input image containing an eye. The image processing module contains two major tasks: Iris Segmentation and Iris Normalization. The Daughman's Integro-differential operator was employed to segment the iris portion accordingly. Daugman's rubber sheet model was applied to normalize the iris annular region to a rectangular region.

Feature extraction algorithms

The extraction of iris pattern was done using some selected iris feature extraction algorithms: Gabor wavelet Transform, Haar Wavelet Transform and Scale Invariant Feature Transform (SIFT).

(i) Algorithm of scale invariant feature transform (SIFT) for iris feature extraction

The four major steps were used for the computation of the feature extraction using SIFT, these are Scale Space Extrema Detection, Keypoint Localization, orientation Assignment and Keypoint Descriptor, which are detailed as follows:

Step 1: Scale space extrema detection

This step finds the entire scale and image location. The Difference of Gaussian function is used to identify the keypoints from annular iris image. The scale space of an input iris image I(x, y) is defined as a function of L(x, y, σ) which is convolved with Gaussian kernel G(x, y, σ) and defined as:

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{\frac{(-x^2 - y^2)}{2\sigma^2}} \quad (5)$$

$$L(x, y, \sigma) = G(x, y, \sigma) * I(x, y) \quad (6)$$

Where * is the convolution operation in x and y. σ defines the width of the Gaussian filter. The Difference of Gaussian images are computed from the difference of two nearby scales separated by a constant multiplicative factor k.

$$D(x, y, \sigma) = L(x, y, k\sigma) - L(x, y, \sigma) \quad (7)$$

Step 2: Keypoint localization

The candidate keypoint was obtained by comparing two nearby pixel; the next step performed the detailing to the candidate keypoint to eliminate the points which are poorly localized. The Difference of Gaussian images were used to detect the interest points using local maxima and minima at different scales using local maxima and minima at different scales.

Step 3: Orientation assignment

This stage assigns the orientation to the each selected keypoints which result rotation invariance. Direction of the gradient and the magnitude of each keypoints are collected and the most prominent orientation is a taken as the keypoint in that region. Then the keypoint orientation is determined by computing the gradient orientation histogram. Then select the Gaussian smoothed image from the scale of keypoint. For each Gaussian smoothed image L(x, y), magnitude (m (x,y)) and orientation (θ (x,y)) are computed as m(x,y)= θ (x,y)= tan-1 An orientation histogram is formed for all pixels around the keypoint, in which 360 degrees of orientation are split it into 36 bins and each sample is weighted by gradient magnitude and Gaussian weighted circular window with σ = 1.5 times of scale of keypoint before adding it to histogram. Histogram peaks corresponds to the orientation and any other local peak that is within 80% of the highest peak is used to create keypoint with that orientation. Thus for location with multiple peaks of similar magnitudes will have multiple keypoints created at the same location and scale but with different direction. This will contribute to increase the stability during the matching.

Step 4: Keypoint descriptor computation

The feature descriptor is computed as a set of orientation histogram on 4×4 pixel neighbourhoods. For that a 16×16 neighbourhood around the keypoint was taken, divided into 16 sub-blocks of 4×4 size. For each sub-block, 8-bin orientation histogram was created. So a total of 4×4×8=128 bins values. These 128 numbers form the feature vector and the keypoint was uniquely identified by this feature vector.

(ii) Algorithm of Haar wavelet transform for feature extraction

Step 1: Decompose a given iris image with 2-D wavelet transform into four sub-images, as indicated in Fig. 2 , where LL represents low frequency vectors (approximate), HL represents high frequency vectors in horizontal direction. LH represents high frequency vectors in vertical direction, HH represents diagonal high frequency vectors. After first decomposition, LL quarter (i.e. the approximate sub band) is submitted for next decomposition, as indicated in Fig. 2 and Fig. 3.

LL1	LH1
HL1	HH1

Fig. 2: One-level wavelet decomposition

<table>
<tr><td>LL2</td><td>LH2</td><td rowspan="2">LH1</td></tr>
<tr><td>HL2</td><td>HH2</td></tr>
<tr><td colspan="2">HL1</td><td>HH1</td></tr>
</table>

Fig. 3: Two-level wavelet decomposition

Step 2: For each decomposed image including LH1, HL1, and HH1 generated in the first pass and LL2, HL2, and HH2 which are generated during the second transform pass.

Step 3: Divide each sub-image into overlapping blocks.

Step 4: Compute the energy of each block belong to wavelet sub band using the following equation.

$$E=\sum_{X=XS}^{X-2} \sum_{Y=YS}^{Y2-1} Wavelet\ (i,j)^2 \quad (8)$$

Where (Xs, Ys) are the range of coordinates of the tested image, wavelet (i, j) is the wavelet sub bands.

Step 5: For the decomposed image including LL1 in the first wavelet pass and LL2 after the second.

Step 6: Repeat **Step 3**

Step 7: Extract the set of iris features

Step 8: Stop

(iii) Algorithm for Gabor Wavelet Transform

The feature extraction using Gabor-filters contains following steps:

Step 1: Image transformation

The superior and inferior cones of iris are eliminated. Differences in the size of the iris are compensated through a polar sampling of image, obtaining J as a result. The equation for transformation is as follows:

$$J(\rho,\phi) = I_E\ (x_0 + r cos\ \theta, y_0 + r sin\ \theta) \quad (9)$$

Where

$$r = r_i + (\rho - 1)\Delta_{r,} \forall\rho \in N: \rho\ \leq \frac{r_e - r_i}{\Delta_r} \quad (10)$$

(10)

$$v = \begin{cases} \frac{-\pi}{4} + (\Phi - 1) \times\ \Delta_\theta & if\ \phi\ \leq \frac{\pi}{2\Delta_0} \\ \frac{3\pi}{4} + (\phi - 1) \times\ \Delta_\theta & if\ \phi\ > \frac{\pi}{2\Delta_0} \end{cases} \quad (11)$$

where: I_E represents the gray level of the iris image with the sclera and pupil extracted r_i and r_e are the inner and outer radius. $(x_0\ y_0)$ is the center of the pupil, and Δ_r and $\Delta_{0,}$ are the sample intervals in magnitude and angle.

Step 2: Iris image preprocess

J is weighted with imaginary part of Gabor filter with orientations $(0, \frac{\pi}{4}, \frac{\pi}{2} and\ \frac{3\pi}{4})$. To perform this task, the image is divided in squared section and the following equation is used:

$$C(i\ j) = \sum_{x=1}^{N} \sum_{y=1}^{M} j\left(i + x - \frac{N}{2}, j + y - \frac{M}{2}\right) \times g(x, y, \varphi_k, \lambda) \quad (12)$$

Where: $g(x, y, \varphi_k, \lambda) = exp\ \left\{ \exp\ -(\frac{x\ cos\ \psi_k + y \sin \psi_k}{{\sigma_x}^2})^2 + (-\ (\frac{-x \sin x_\varphi}{{\sigma_y}^2})^2) \right\} X\ sin \left\{ \frac{2\pi(x cos \varphi_k + y\ sin \varphi_k)}{\lambda} \right\} \quad (13)$

The dimension of filter is N × M, (i, j) is the centre of each section and $x,\ \lambda, \sigma_{x,}\ \sigma_y$ are parameters of filter.

Testing and matching using hamming distance

The Hamming distance gives a measure of how many bits are the same between two bit patterns. Using the Hamming distance of two bit patterns, a decision can be made as to whether the two patterns generated from different irises or from the same one. In comparing the bit patterns X and Y, the Hamming distance, HD, is defined in Equation (14)

$$HD = \frac{1}{N} \sum_{J-1}^{N} X_j (XOR) Y_j \quad (14)$$

HD is the sum of disagreeing bits (sum of the exclusive OR between X and Y) over N .where N is the total number of bits in the bit pattern. The result of this computation was used as the goodness of match with smaller values indicating better matches.

Performance evaluation of the developed system

The performance evaluations of the proposed feature extraction techniques were carried out using the following confusion matrix parameters; True Positive (TP), True Negative (TN), False Negative (FN), False Positive (FP). From this, the precision, sensitivity and accuracy then computed by applying the following equations.

$$Precision = \frac{TP}{TP+FP} \quad (15)$$

$$Sensitivity = \frac{TP}{TP+FN} \quad (16)$$

$$Specificity = \frac{TN}{TP+FP} \quad (17)$$

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (18)$$

Results and Discussion
The experimental results of the study are comprehensively described in this section. After the image processing of iris image, the processed iris image were passed separately to three selected feature extraction techniques; Gabor Wavelet Transform, SIFT and Haar Wavelet Transform. The extracted features were match using Hamming distance measure with threshold value set to ≤ 0.3732 as shown in following Tables 2 – 7.

Table 2: Result of extracted iris features using Gabor wavelet transform

S/N	Class	Index of image recognized	Hamming distance (m)	Testing Time (secs)	Matching Status
1	1	1	0.2541	5.5567	Matched
2	1	3	0.2279	5.4991	Matched
3	2	2	0.1347	5.5254	Matched
4	2	2	0.1620	5.2367	Matched
5	3	1	0.2541	5.3485	Matched
6	3	3	0.2279	5.4863	Matched
7	4	2	0.1347	6.4831	Matched
8	4	2	0.1620	6.3880	Matched
9	5	2	0.1620	6.3616	Matched
10	5	1	0.2541	4.9278	Matched
11	6	1	0.2541	4.5416	Matched
12	6	1	0.2541	5.4471	Matched
13	7	3	0.2279	4.6760	Matched
14	7	2	0.1347	5.2055	Matched
15	8	2	0.1620	5.4618	Matched
16	8	1	0.2541	5.4533	Matched
17	10	3	0.4279	5.4833	Mismatched
18	9	2	0.1347	5.4022	Matched
19	10	2	0.1620	5.0313	Matched
20	1	2	0.1620	5.1632	Matched

Table 3: Result of extracted features using Gabor wavelet transform (impostor)

S/N	Class	Index of image recognized	Hamming distance	Testing Time (secs)
21	No Class	No Image	No Value	5.1822
22	No Class	No Image	No Value	5.8061
23	3	1	0.1347	5.0359
24	No Class	No Image	No Value	6.2378

Table 4: Result of extracted features using SIFT

S/N	Class	Index of image recognized	Hamming distance	Testing time (secs)	Matched
1	1	1	0.3421	6.7894	Matched
2	1	3	0.3579	5.7869	Matched
3	2	2	0.2277	6.3241	Matched
4	2	2	0.2150	5.6765	Matched
5	3	1	0.3641	6.0897	Matched
6	3	3	0.3467	6.9845	Matched
7	4	2	0.2456	5.7685	Matched
8	4	2	0.2520	6.7876	Matched
9	5	2	0.2345	7.6765	Matched
10	5	1	0.3478	5.6876	Matched
11	6	1	0.3675	6.7576	Matched
12	6	1	0.3967	6.7809	Mismatched
13	7	3	0.3324	4.9084	Matched
14	7	2	0.2543	6.1111	Matched
15	8	2	0.2765	6.7856	Matched
16	8	1	0.3846	5.1123	Mismatched
17	10	3	0.3452	4.3453	Matched
18	9	2	0.2435	6.7675	Matched
19	10	2	0.2345	4.7688	Matched
20	1	2	0.2790	3.6756	Matched

Table 5: Result of extracted features using SIFT (impostor)

S/N	Class	Index of image recognized	Hamming distance	Testing time (secs)
21	No Class	No Image	No Value	7.6556
24	No Class	No Image	No Value	6.5654
22	3	0.1347	0.1347	6.4532
23	2	0.298	0.298	7.6763

Table 6: Result of extracted features using Haar wavelet transform

S/N	Class	Index of image recognized	Hamming distance	Testing time (secs)	Matched
1	1	1	0.3356	5.6764	Matched
2	1	3	0.3646	6.7856	Matched
3	2	2	0.2567	4.6543	Matched
4	2	2	0.3525	3.4576	Matched
5	3	1	0.3673	5.6564	Matched
6	3	3	0.4895	5.6564	Mismatched
7	4	2	0.3452	7.6784	Matched
8	4	2	0.3425	3.3333	Matched
9	5	2	0.2963	2.3243	Matched
10	5	1	0.4523	6.7543	Mismatched
11	6	1	0.3563	5.6754	Matched
12	6	1	0.5145	6.4564	Mismatched
13	7	3	0.3563	3.5456	Matched
14	7	2	0.2856	7.6751	Matched
15	8	2	0.3808	4.4343	Mismatched
16	8	1	0.2967	6.7716	Matched
17	10	3	0.3673	3.4542	Matched
18	9	2	0.3701	2.4351	Matched
19	10	2	0.2891	5.6765	Matched
20	1	2`	0.3452	8.6561	Matched

Table 7: Result of extracted features using Haar wavelet transform (impostor)

S/N	Class	Index of image recognized	Hamming distance	Testing time (secs)
21	No Class	No Image	No Value	7.6556
24	No Class	No Image	No Value	6.5654
22	4	0.3546	0.5362	6.4532
23	No Class	No Image	No Value	7.6763

Result for comparative performance analysis of feature extraction methods
The feature extraction methods was analyzed by comparatively comparing the results of performance metric measurements as shown in section 3.6, training time and testing time obtained from each iris feature extraction technique used in this study as discussed in Table 8.

Table 8: Comparative performance analysis of the proposed system

Feature Extraction Techniques	Precision	Sensitivity	Accuracy	Specificity
Gabor Wavelet Transform	0.9500	0.9500	0.9200	0.7500
Haar Wavelet Transform	0.8000	0.8000	0.7916	0.7500
SIFT	0.9000	0.9000	0.8333	0.500

Conclusion

The iris feature extraction is the most important and significant aspect of iris recognition system. Several feature extraction techniques have been proposed by researchers in iris biometrics for the extraction of iris features template from iris images. This study employed selected iris feature methods: Haar Wavelet Transform, Gabor Wavelet Transform and Scale Invariant Transform in which a comparative performance analysis was conducted of these extraction methods. The proposed comparative analysis of selected iris feature extraction was evaluated with CASIA Database. The experimental results showed that out of three extraction techniques used in this work, Gabor wavelet Transform performs better than the other two feature extraction methods based on precision, sensitivity and accuracy.

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