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Performance Analysis of Feature Extraction and its Fusion Techniques for Iris Recognition System

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ABSTRACT

The extraction of feature shows a significant part of iris recognition system. The robustness of recognition accuracy mostly depends on efficient extraction of feature. In the development of an effective recognition system, it is required that the best discriminating feature available in an iris pattern to be properly extracted. This paper applied some selected feature extraction techniques: 1D Log-Gabor Filter (1D LGF), 2-D Gabor-Filter (2D GF), Discrete Cosine Tansform (DCT) and Scale Invariant Feature Transform (SIFT) for extraction of iris features and fusion technique. The CASIA iris image dataset was used to evaluate with evaluation parameters: False Acceptance Rate (FAR), False Rejection Rate (FRR), Error Rate (RA) and Recognition Accuracy (RA). The combined 1D Log-Gabor and 2D Gabor filter approach outperformed other techniques with 92.22% of recognition accuracy, FRR of 0.0186, FAR of 0.1052 and ER of 2.87%.

Keywords: Feature Extraction, Iris Recognition, 1-D Log Gabor Filter, 2-D Gabor Wavelet Transform, Scale Invariant Feature Transform

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Introduction

The biometric system involves the verification of people based on the feature vectors obtained from biological or physiological traits [1] [2]. Biometric technologies include identification based on fingerprint, facial, iris, geometry of hand, palm print, keystroke, gait, hand vein, retina, voice and signature. For the effective and accurate security systems, automatic recognition of persons through biometrics is becoming increasingly important. In recent times, the iris of human has gained the interest of biometric recognition research [3].

The extraction of feature signifies greatly relevant aspect of iris recognition because of its impact on recognition rate [4]. A feature can be considered as a function of one or more measurements properties of the object, which is computed in a way of qualifying important characteristics of object [5]. Only significant and distinguished features of iris texture need be obtained and coded so that the template matching can be made expediently and appropriately.

Many methods of feature extraction such as DCT, SIFT, Gabor filter and its variant have been widely applied in image processing applications [6]. Researchers have introduced these techniques to extract iris texture. The extraction of feature using Gabor filters have been extensively used in biometrics [7]. A wavelet of Gabor is filter banks with different scales and orientations [8], it is normally used to obtain textures densities for production of feature coding for iris image[9]. The DCT reveals an image as an addition of sinusoids of varying magnitudes and frequencies [10].

A SIFT is used for defining local properties of an image. In SIFT technique, some main portions are non-sensitive to lighting, rotation and scale changes [11]. This is helpful in finding the salient and steady of an image feature points. The main problem of recognition of iris system comes from the fact that it is really hard to discover suitable features in the iris images and to keep their distinctiveness in an efficient way [12]. This paper conducted an analysis on performance of commonly used techniques of feature extraction in iris authentication system: DCT, 1D Log-Gabor filter, 2-D Gabor filter and SIFT were considered to extract features from iris image. The extracted features when passed to classifier showed which of the extraction methods performed most effectively in the experimental analysis.

Related Work

[13]conducted an analysis comparatively on extraction of features techniques for iris recognition system. The study addressed the problem on efficiency of some methods of extraction of features. Gabor Wavelet Transform (GWT), SIFT and Haar Wavelet Transform were applied to extract iris features. The feature extraction techniques when tested using CASIA iris dataset produced results for individual approach. Finally, the GWT outperformed the other two approaches based on rate of recognition, time of training and testing.

[14] came up with system based on compound local binary pattern technique. The abundant with the distinctive features obtained using Compound Local Binary Pattern (CLBP). Operators were fed to the Neural Network for classification. The system was evaluated using fifty images of eye taken from CASIA database. The proposed system using Neural Network produced an improved accuracy of 96% when compared with the existing feature extraction methods.

[15] employed technique of extraction based on statistical approach using correlation between adjacent pixels. The recognition was achieved by the application of hamming distance. The evaluation of the system was based on FAR and FRR using diverse thresholds in the distance metrics. Experimental outputs with set of statistical iris image features gave better enhancement in ERR when the number of parameters for statistics were increased.

[16] described a distinct method for recognition using iris in which a scheme that applies the

canny edge detection and a circular hough transform were used to find the boundaries of iris in the eye. Discrete wavelet transform of two levels was used to obtain the patterns in an individual's eye in a feature vector method. Recognition was achieved by distance measure classifier. The system gave a better total successive rate (TSR) with reduction in FAR, FRR and ERR.

[17] proposed methods of feature extraction for iris by normalization of image of an iris image using dimensions in statistical approach. The first approach employed first order statistics and the second order statistics. The system aimed at extracting feature correctly at the region of original iris and isolates the eyelid and eyelash which have covered parts of iris region. The proposed methods used weights within pattern matching measures depending on iris region. The methods were tested by using (CASIA v4.0-interval), and (CASIA v1.0-interval) iris image databases. Experimental results showed that the first proposed method produced 99.4% of accuracy rate with (CASIA v4.0-interval) and 98.5% of accuracy with (CASIA v1.0-interval), the second proposed method produced 86.67% of accuracy with (CASIA v4.0- interval).

Methodology

The developed system involved some steps. The approach started with acquisition of images from CASIA iris image database. Images were processed using localization and normalization processes. The preprocessed images were unwrapped into four-sided blocks of permanent dimensions using Daugman Rubber Sheet. The four feature extraction methods; DCT, 1D LGF, 2D GF and SIFT for iris images were applied to extract features. Finally, matching was achieved using Hamming distance.

The samples of iris image from publicly available database are shown in Figure 1.

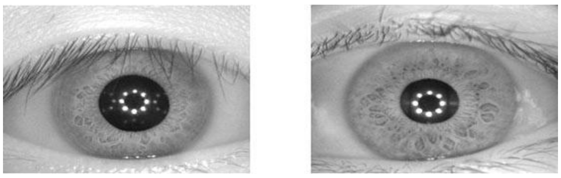

Figure 1: Images of Iris

To pre-process the image of iris, the ROI was demarcated completely. Two image processing techniques: iris segmentation, iris normalization were used.

Iris Localization / Segmentation.

In this stage a proper search was used to obtain the fairly accurate pupil image. The upper and lower parts of the pupil image were considered to circumvent the effects of lashes and lids of the eye. Integro-differential Operator by Daugman was employed for localization of the iris portion. The boundary of iris was described based on three parameters: the radius and the coordinate of the circle x_c and y_c.

$$(r, x_c, y_c) = M_a x_{r,}\, x_0 y_0 [G_\delta(r) * \frac{\partial}{\partial r} \emptyset\, rx0y0 \frac{I(x,y)}{2\pi}\, ds] \quad (1)$$

Where the pixel intensity is denoted by I(x,y) at x, y coordinates in the image of an iris, r shows the radius of various circular regions with the centre coordinates at (x_o, y_0), δ is the standard deviation of Gaussian distribution, $G_\delta(r)$ represents a Gaussian filter of scale sigma, (x_0,y_0) is the assumed center coordinates of the axis the circle

Iris Normalization.

Normalization of the iris annular region to a rectangular region was achieved by rubber sheet mode. A Cartesian was introduced for polar transformation that remapped each pixel of an iris image into a polar coordinate (r,θ) where satisfactory condition is as follows: 0 < r < 1 and 0 < r < 2π as shown in equation (2).

$I(x(r,\theta), y(r,\theta) \rightarrow I(r,\theta)$ (2)

$x(r,\theta) = (1-r)x_p(\theta) + rx_1(\theta)$ (3)

$y(r,\theta) = (1-r)y_p(\theta) + ry_1(\theta)$ (4)

Where the iris region image is *I(x,y)*, The original Cartesian coordinates are *(x,y)*, *(r,θ)* are the corresponding normalized polar coordinates, x_p, y_p and x_1, y_1 are the pupil coordinates and boundaries of iris along the *θ* direction as shown in equation (3) and (4). The rubber sheet model considers the pupil dilation and size inconsistencies in order to produce a normalized representation with constant dimensions.

Iris features were extracted using SIFT, 1D LGF, 2D GF and DCT. The SIFT techniques is represented with block diagram in Figure 2 is as follows:

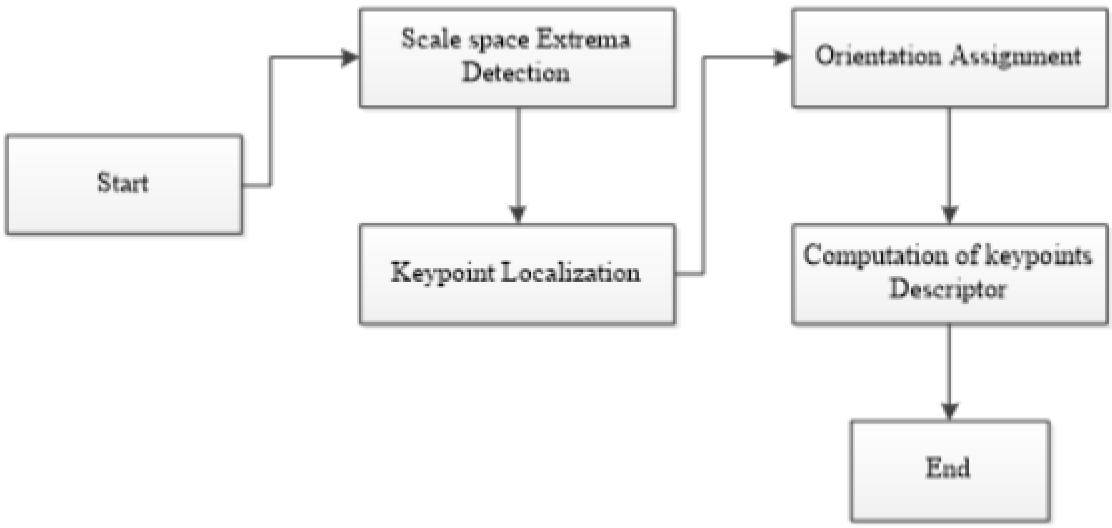

Figure 2: Block Diagram for SIFT

Technique of 1D Log-Gabor filter

The feature extraction of 1D Log- Gabor filter is described as follows:

Step 1: Compute Gabor filter (x, y) = S (x. y) Wr(x, y)

Step 2: Calculate S(x, y) = $e^{i(2\pi(\mu_0 x + v_0 y)+P)}$

Step 3: Convolute the designed filter with iris image

Step 3: Extract the imaginary and real part and of iris image

Re(S(x, y)) = $\cos(2\pi(\mu_0 x + v_0 y) + P$ (5)

Im(S(x, y)) = $\sin(2\pi(\mu_0 x + v_0 y) + P$ (6)

where:

μ_0 = Horizontal sinusoidal frequency

v_0 = Vertical sinusoidal frequency

P = Arbitrary phase shift

Step 4 : Construct envelope with Gaussian profile

$$G(x, y) = Ke^{-\pi}((x^2 - x_0)^2 r + \quad b^{2(y-y_0)^2} r) \quad (7)$$

where:

$$x - x_0 = (x - x_0)\cos(\theta) + (y - y_0)\sin(\theta) \quad (8)$$

$$y - y_0 = (x - x_0)\sin(\theta) + (y - y_0)\cos(\theta) \quad (9)$$

Step 5: Compute the magnitude part to iris features

$$J(\rho, \phi) = I_E\ (x_0 + r\cos\theta, y_0 + r\sin\theta) \quad (10)$$

Where

$$r = r_i + (\rho - 1)\Delta_{r,} \forall\rho \in N: \rho \leq \frac{r_e - r_i}{\Delta_r} \quad (11)$$

$$v = \begin{cases} \frac{-\pi}{4} + (\Phi - 1) \times \Delta_\theta & if\ \phi \leq \frac{\pi}{2\Delta_0} \\ \frac{3\pi}{4} + (\phi - 1) \times \Delta_\theta & if\ \phi > \frac{\pi}{2\Delta_0} \end{cases} \quad (12)$$

where

I_E denotes the iris image gray level 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 is convoluted with filter

J is weighted with imaginary part of Gabor filter with orientations $(0, \frac{\pi}{4}, \frac{\pi}{2} and \frac{3\pi}{4})$. The image of iris is divided in squared section as follows:

$$C(i\quad j) = \sum_{x=1}^{N}\sum_{y=1}^{M} j\left(i + x - \frac{N}{2}, j + y - \frac{M}{2}\right) \times g(x, y, \varphi_k, \lambda) \quad (13)$$

Where;

$$g(x, y, \varphi_k, \lambda) = exp\left\{\exp -(\frac{x\cos\psi_k + y\sin\psi_k}{{\sigma_x}^2})^2 + (-(\frac{-x\sin x_\varphi}{{\sigma_y}^2})^2)\right\} \times sin\left\{\frac{2\pi(x cos\varphi_k + y\ sin\varphi_k)}{\lambda}\right\} \quad (14)$$

Filter measurement is N × M, (i, j) is the centre of each section and $x,\ \lambda, \sigma_{x,}\ \sigma_y$ are factors of filter, referring to orientation, scale and derivatives.

Step 5: End

Technique of 2-D Gabor filter

The feature extraction of 2-D GF is described as follow:

Step 1: Transformation of Iris image

Elimination of the superior and inferior cones of iris is achieved as shown in following equations f:

Technique of Discrete Cosine Transform (DCT)

Step 1: Start

Step 1: Input iris image

Step 2: Obtain the Red, Green and Blue component of that image

Step 3: Compute DCT on each component and append in a new column the result for each Red, Green and Blue in matrix form

Step 4: Reiterate step 1 through 3 for every database image.

Step 5: Read the Query image.

Step 6: Reiterate step 2 and 3 for the query image so as to obtain its feature vector.

Step 7: For every Database image 'i' and a query image, calculate the Mean Squared Error

Step 8: Compute iris codes

Step 9: End

Results and Discussion

The results for the developed iris recognition system are as follows:

The loading of the iris image unto the platform is shown in Figure 2.

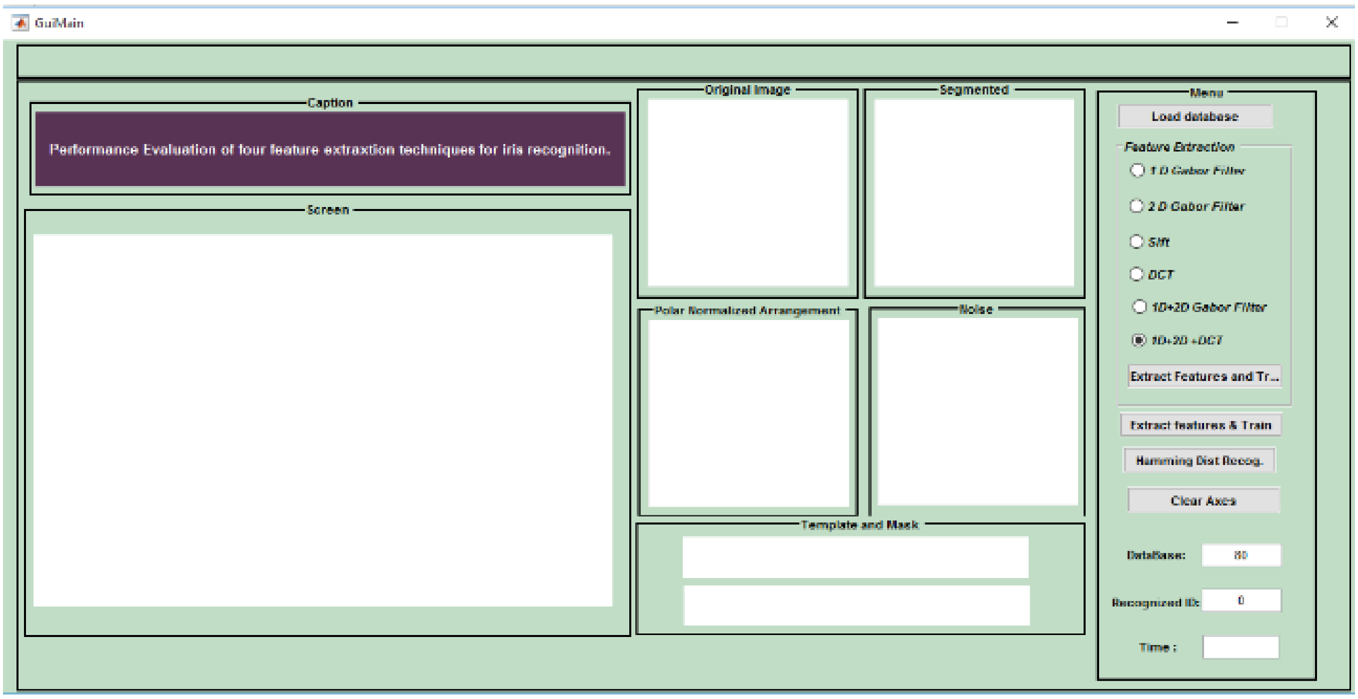

Figure 2: Loading of iris images

Result of Image Segmentation

The section shows the output of segmented region using differential operator..

Result of Image Normalization

The normalization acts on the segmented iris by obtaining the normalized pattern and the noise pattern from the segmented iris image. Figure 4 shows the normalized pattern and the noise pattern, the essence of the normalization is to pass them to the feature encoding stage

Figure 3: Image segmentation

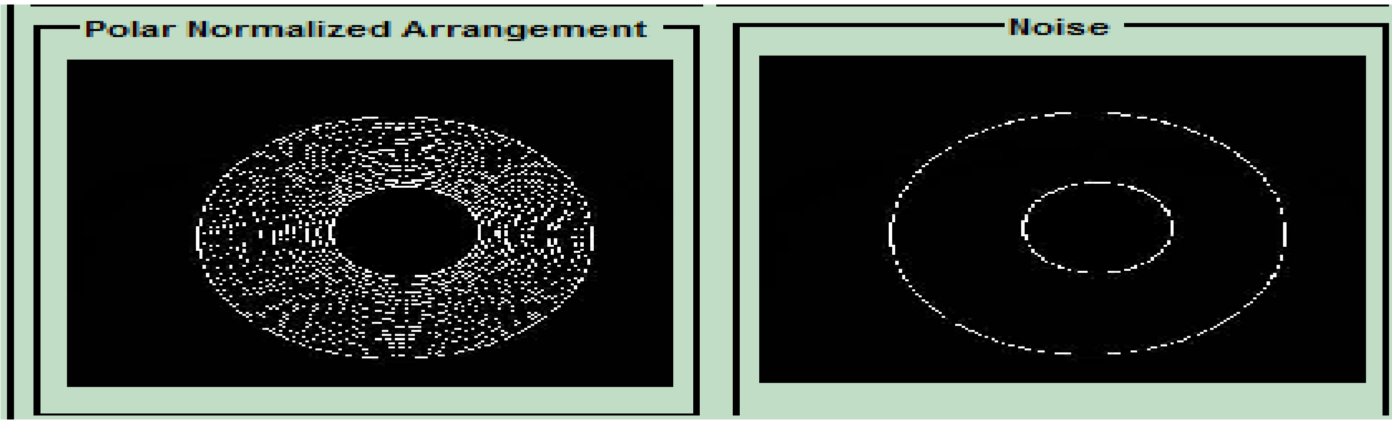

Figure 4: Normalized and Noise Patterns.

Results of Feature Extraction (Encoding)

The feature encoding takes the normalized iris and passed it to the four major feature extraction techniques namely 1D Log- Gabor filter, 2D Gabor Filter, SIFT and Discrete Cosine Transform Algorithm (DCT).

(i) 1D Log-Gabor Filter

The feature encoding generates two patterns namely the template and the mask of size 20 X 240. The sample of generated feature is shown in Figure 5.

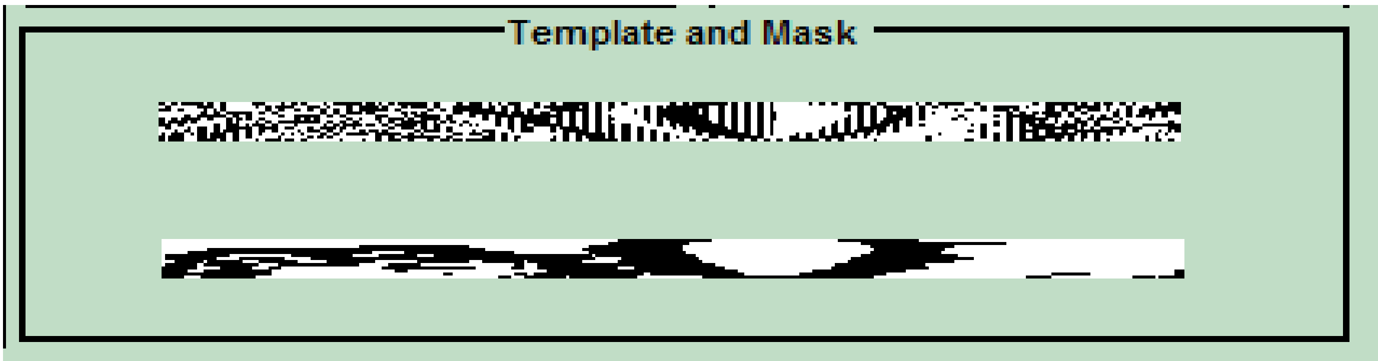

Figure 5: Sample of 1D Log- Gabor features

(ii) 2D Gabor Filter

The feature encoding generates two patterns namely the template and the mask of size 20 X 240 as shown in Figure 6.

Discrete Cosine Transform (DCT)

The feature encoding generates two patterns namely the template and the mask of size 20 X 240. The sample of generated two patterns is shown in Figure 7.

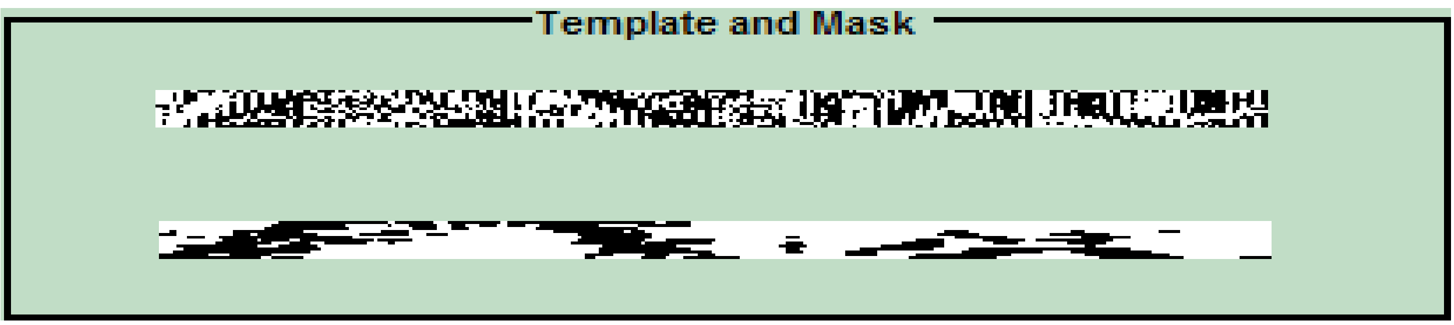

Figure 6: Sample of 2D Gabor features

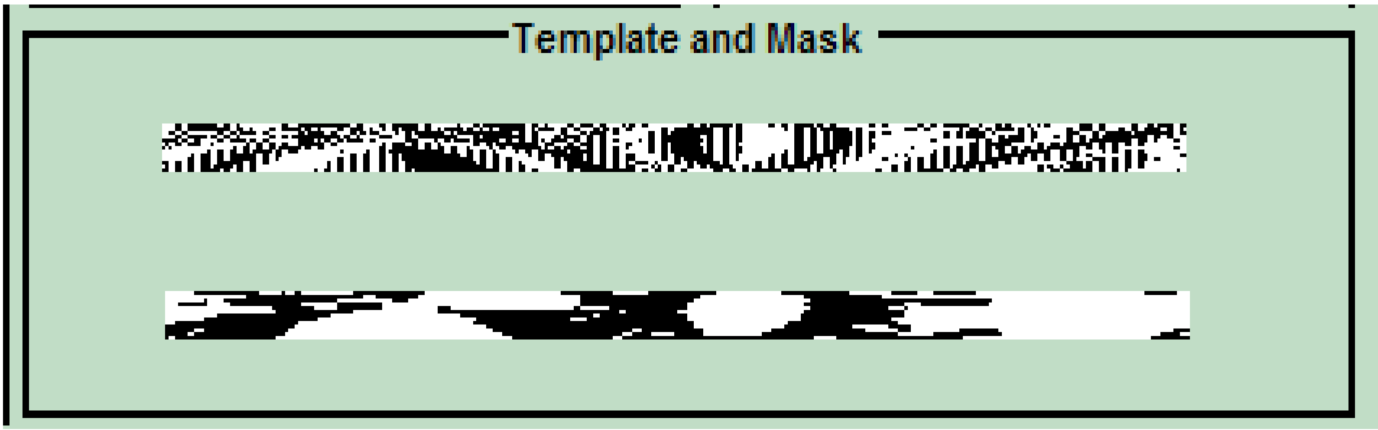

Figure 7: Sample of DCT Features

Scale Invariance Feature Transform (SIFT)

The feature encoding generates two patterns namely the template and the mask of size 256 X 256 as shown in Figure 8 (a) and 8 (b)

Figure 8 (a): Sift mask

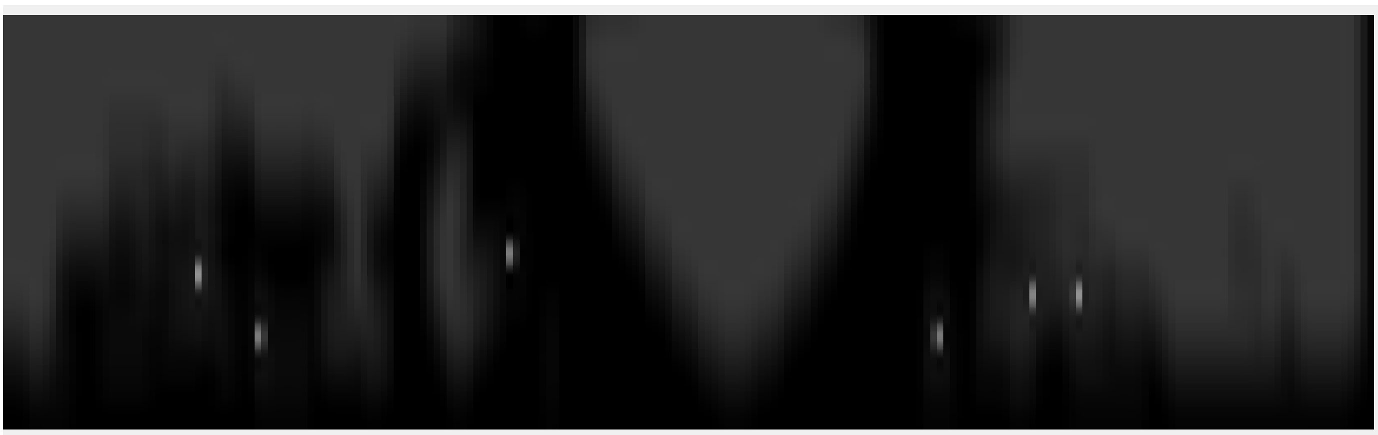

Figure 8 (b): Sift template

Result of Computational Time for Developed System

The computational time of the developed system, which is measured in terms of training time and testing time for the selected feature extraction techniques is as shown in Table 1.

Table 1: Computational Time for Developed System

Algorithm	Training Time (Secs)	Average Testing Time (Secs)
1 D Log-Gabor Filter	24.2939	5.654284561
2 D-Gabor filter	40.3631	5.654284561
SIFT	58.5787	13.92275281
DCT	47.4492	9.788518684
1D Log-Gabor + 2D Gabor filter	59.2213	12.7182
1D Log-Gabor + 2D Gabor filter + DCT	70.5295	15.21885

Result of FAR, FRR, ACCURACY and ER for Developed System

The FAR, FRR, RA and ER of developed system are shown Table 2.

Analysis of Training Time and Testing Time

Different measures taken into consideration are the training time, average testing time, FAR, FRR, RA and ER

Figure 9 shows that the 1D Log-Gabor filter was more efficient when it comes to the computational time as it has the lowest executing time of 24.2939 secs. The combined 1D Log-Gabor + 2D Gabor filter and DCT recorded the prolonged training time of 70.5295 secs.

Table 2: Evaluation Parameters

Technique	FAR	FRR	RA (%)	ER (%)
ID Log-Gabor Filter	0.31215	0.0313	94.44	5.56
2D Gabor Filter	0.1579	0.0248	96.11	3.89
SIFT	0.3915	0.0382	91.67	8.33
DCT	0.3000	0.0375	93.33	6.67
1D Log-Gabor + 2D Gabor filter	0.1052	0.0186	97.22	2.78
1D Log-Gabor + 2D Gabor filter + DCT	0.3750	0.0443	91.11	8.89

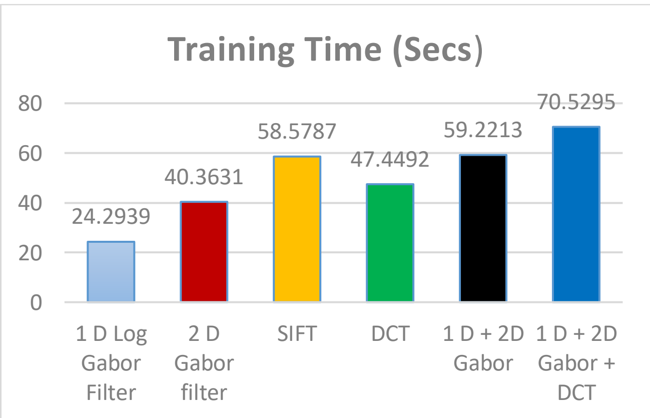

Figure 9: Training Time

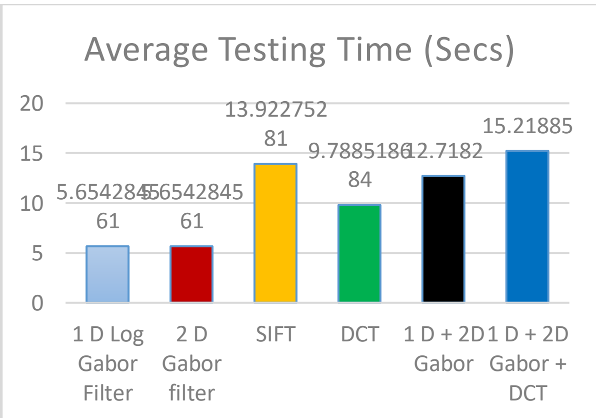

Figure 10: Average Testing Time

In Figure 10, the best average testing time of 5.6454284561 secs was obtained in 1D Log Gabor and 2D Gabor filters. The highest average testing time of 15.21885 was obtained in 1D Log-Gabor + 2D Gabor + DCT.

Analysis of Classification Accuracy

The classification accuracy shows the correct classification rate attained by hamming distance. Figure 11 shows that the 2D Gabor filter has the best classification accuracy of 97.22%, while the lowest accuracy of 91.11% was obtained in 1D Log-Gabor filter + DCT.

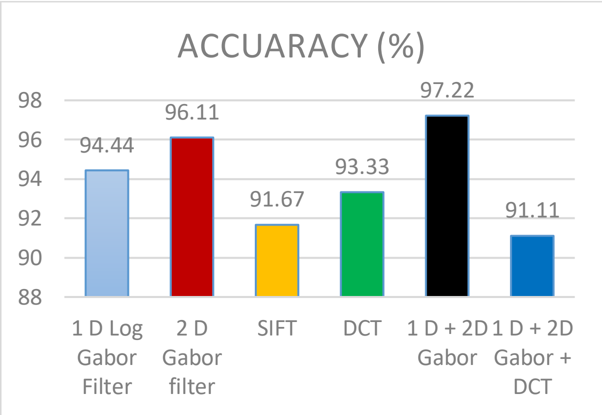

Figure 11: Accuracy

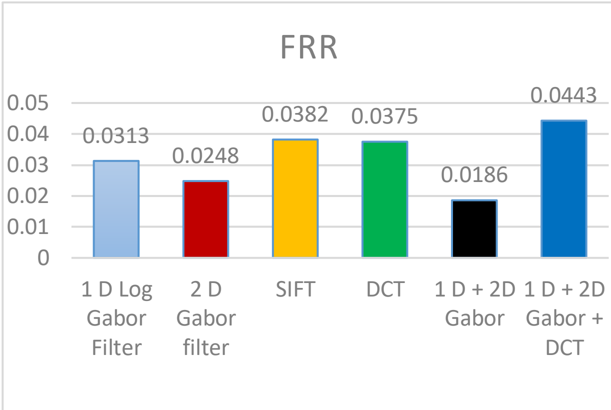

Figure 12: False Acceptance Rate

Analysis for False Acceptance Rate

In Figure 12, the lowest FAR of 0.1579 was obtained in 2D Gabor filter technique, the highest FAR of 0.3915 was obtained in SIFT technique. The iris recognition using SIFT technique for feature extraction may not be the best and effective method for verification system of iris biometric.

Analysis for False Rejection Rate

The false rejection rate is shown in Figure 13. The lowest rate of 0.0248 was obtained in 2D Gabor filter technique, the highest FRR of 0.0443 was obtained in combined technique of 1D Log-Gabor filter + 2D Gabor filter + DCT. Thus, the combined approaches have been identified to be better feature extraction techniques for iris verification system.

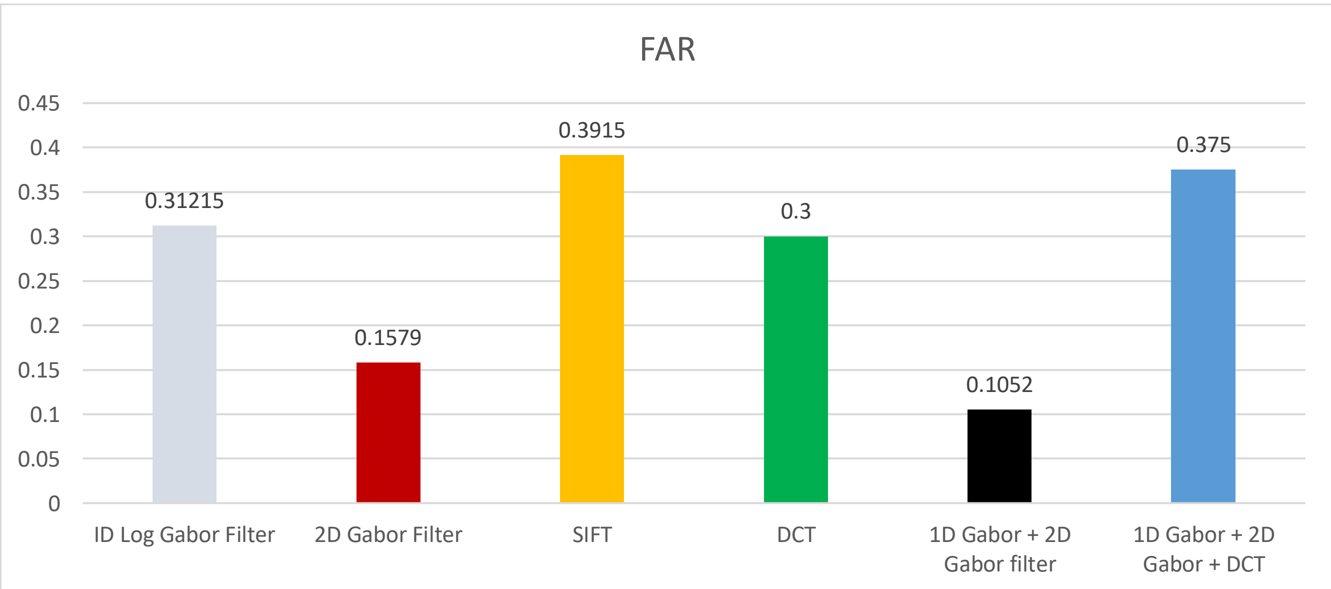

Figure 13: False Rejection Rate

Analysis for Error rate

Figure 14 shows that 1D Log-Gabor + 2 D Gabor filter algorithm had the lowest error rate of 2.78%, which is a valid justification as the most efficient feature extraction technique for classification.

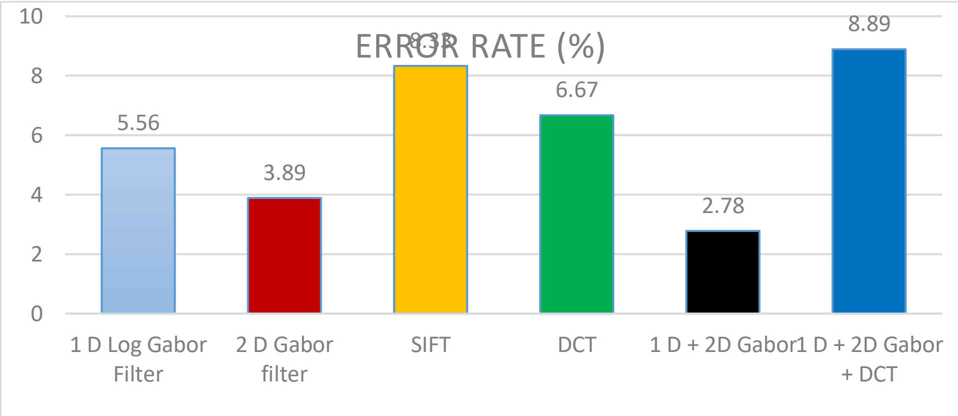

Figure 14: Error Rate

Conclusion

A number of techniques of feature extraction have been employed by researchers in iris biometrics for the feature representation. The paper used four commonly used feature extraction methods: 1D Log-Gabor filter, 2D GWT, DCT and SIFT with its feature level fusion. A performance analysis was conducted of these extraction methods based on different evaluation metrics. The developed system was tested with CASIA Database. The experimental results showed the performance analysis of each feature extraction technique.

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