An Efficient Feature Extraction Method for Iris Recognition Based on Wavelet Transformation

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Abstract— **One of the most reliable biometric is the iris, due to its stability, uniqueness and noninvasive nature. One of the difficult problems in feature based iris recognition is the speed of matching, which is significantly influenced by time required for feature extraction process, size of the template database stored, ...etc. In this paper, a new approach of iris image compression and feature extraction based on discrete wavelet transforma- tion(DWT) is applied. The obtained features dimensionality were further reduced by using principle component analysis(PCA), which drastically reduces the size of the iris database images. In the matching stage, a supervised classifier is introduced, namely, k-nearest neighbor(k-NN). The classification attained was 99.5%. This result shows that the proposed technique is robust and effective compared with other recent works.**

Keywords- Image preprocessing, DWT, PCA, k-NN, Iris recog- nition, classification

I. INTRODUCTION

Automatic reliable personnel identification systems using biometrics have received a great importance in the past few years. Biometrics refers to a science of analyzing human physiological or behavioral characteristics for security pur- poses. The biometric characteristics cannot be faked, forged, guessed and stolen easily. Biometric technologies are being utilized across a variety of applications, e.g., security, fraud prevention, border control, customs immigration, passport, as well as health care identity verification. Iris recognition can easily be considered as the most reliable form of bio- metric technology[17], compared with other biometric tech- nologies, such as face([17], [5], [21], [22], and fingerprint recognition[17], [15]. Iris is believed to allow very high accuracy, and there has been a great interest in iris biometrics in recent years, because it has a good verification rate and resistance to imposter. The iris is a protected internal organ, and externally visible. Texture pattern of an iris is highly stable with age and health condition. one needs not to touch any equipment in order to be identified. Iris recognition system; is similar to other biometric systems, has two stages, enrollment stage and verification/identification(matching stage).

In the enrollment process, extracted feature vector is stored in the database, while in the matching process, the extracted feature is compared with stored features. Both enrollment and matching process include image acquisition, iris localization, iris normalization, and feature extraction. A major approach for iris recognition is to generate feature vectors corresponding to individual iris images and to perform iris matching based on different metrics[23]. One of the difficult problems in feature based iris recognition is that, the speed of matching is significantly influenced by time required for feature ex- traction process, size of the template database stored, format of template database, ... etc. Thus fast, robust, and secured implementation techniques are needed. In order to handle such challenges the wavelet transformation proposed as an option. Wavelet transform is an effective tool for feature extraction, because they allow analysis of images at various levels of resolution. This technique requires large storage and is com- putationally more expensive[18]. Hence an alternative method for dimension reduction scheme is used. In order to reduce the feature vector dimension and increase the discriminative power, the principal component analysis (PCA) has been used. Principal component analysis is appealing since it effectively reduces the dimensionality of the data and therefore reduces the computational cost of analyzing new data. To perform the classification on the reduces iris images data, the k-NN classifier have been used. A schematic diagram of the proposed system is shown in figure (1.1).

The contribution of this paper is the integration of an efficient feature extraction tool and a robust classifier to perform a more robust and accurate automated iris matching system. Also, this paper focuses on a comparison of our results with a similar studies. This paper is organized as follows. In section(II) the iris preprocessing steps that include iris localization, normal- ization and enhancement are described. In section(III) the feature extraction using DWT is introduced. In section(IV) feature reduction using PCA is explained. In section(V) iris matching using k-NN is described. In section(VI) simulation and performance evaluation of the proposed method is shown. And finally, section(VII) is the conclusion.

II. IRIS IMAGE PREPROCESSING

An iris image, contains not only the region of interest; iris, but also eyelid, pupil, ..etc. A change in the camera-to- eye distance may also result in variations in the size of the same iris. Moreover, the brightness is not uniformly distributed due to the non-uniform illumination.

Therefore, before feature extraction, the original image needs to be preprocessed to localize iris, normalize iris, and reduce the influence of the above mentioned factors, as will be explained.

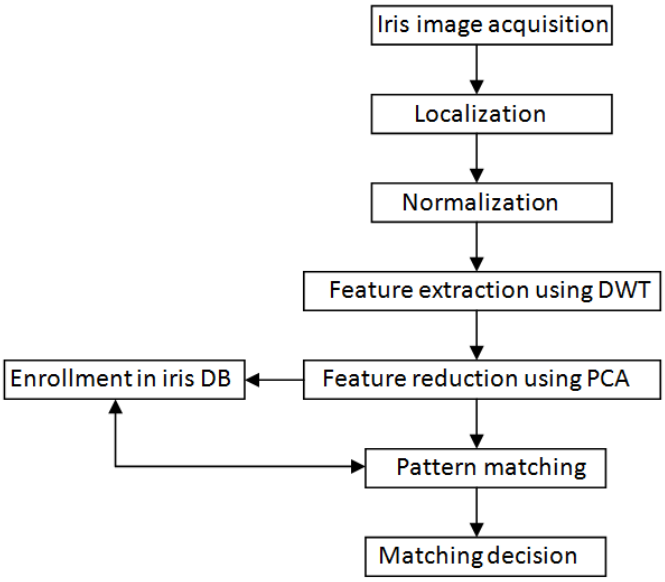


Fig. 1.1: Proposed iris recognition system

A. Iris localization

The iris is an annular part between the pupil and the sclera figure (2.1). The first step in iris localization is to detect pupil, the center of pupil used to detect the outer radius of iris patterns. In order to do that, one need to detect the pupil and to localize the outer iris as discussed below.

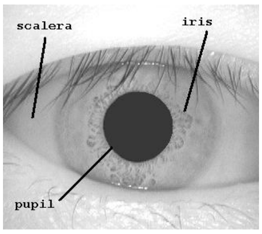


Fig. 2.1: Image of the eye.

1) *Pupil Detection:* To remove the effect of illumination the iris image is converted into grayscale. As pupil is the largest black area in the intensity image, its edges can be detected easily from the binarized image by using suitable threshold on the intensity image. But the problem of binarization arises in case of persons having dark iris. Thus the localization of pupil fails in such cases. In order to overcome these problems Circular Hough Transformation[9] for pupil detection can be used. The basic idea of this technique is to find curves that can overcome artifacts such as shadows and noise. The procedure first finds the intensity image gradient at all the locations in the given image by convolving with the sobel filters. The gradient images $G_{vertical}$ and $G_{H\ orizontal}$ along x and y direction, is obtained by kernels that detect horizontal and vertical changes in the image. The sobel filter kernels are

$$C_{vertical} = \{-1,-2,-1;0,0,0;1,2,1\}$$
$$C_{horizontal} = \{-1,0,1;-2,0,2;-1,0,1\} \quad (1)$$

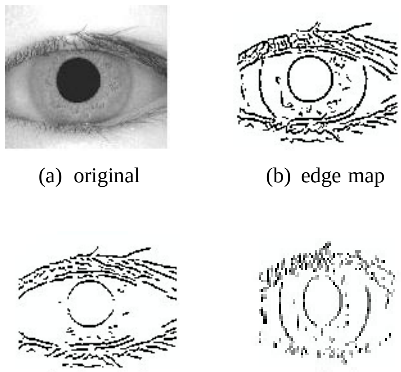
The absolute value of the gradient images along the vertical and horizontal direction is obtained to form an absolute gradient image using the equation

$$G_{abs} = G_{vertical} + G_{horizontal} \quad (2)$$

where Gvertical is the convolution of image with Cvertical and Ghorizontal is the convolution of image with Chorizontal . The absolute gradient image is used to find edges using Canny[2]. The edge image is scanned for pixel (P) having true value and the center is determined with the help of the following equations

$$x_c^2 + y_c^2 - r^2 = 0 \quad (3)$$

here, xc and yc are center coordinates, and r is the radius. The processes of pupil detection are shown in figure (2.2).



(a) original (b) edge map

(c) horizontal edge map (d) vertical edge map

Fig. 2.2: a) an eye image b) corresponding edge map c) edge map with only horizontal gradients d) edge map with only vertical gradients.

B. Iris normalization

Irises from different people may be captured in different size and, even for irises from the same eye, the size may change due to illumination variations and other factors. Such elastic deformation in iris texture will affect the results of iris matching. For the purpose of achieving more accurate recognition results, it is necessary to compensate for the iris deformation. Daugman[4], [7], [12] solved this problem by projecting the original iris in a Cartesian coordinate system into a doubly dimensionless pseudo-polar coordinate system.

To transform the annular region of iris into polar equivalent the following set of equations are used:

$$I(x(\rho,\theta), y(\rho,\theta)) \longrightarrow I(\rho,\theta) \quad (4)$$

here

$$x_p(\rho,\theta) = x_{p0}(\theta) + r_p * \cos(\theta)$$
$$y_p(\rho,\theta) = y_{p0}(\theta) + r_p * \sin(\theta)$$
$$x_i(\rho,\theta) = x_{i0}(\theta) + r_i * \cos(\theta)$$
$$y_i(\rho,\theta) = y_{i0}(\theta) + r_i * \sin(\theta)$$

where r_p and r_i are respectively the radius of pupil and the iris, while $(x_p(\theta), y_p(\theta))$ and $(x_i(\theta), y_i(\theta))$ are the coordinates of the pupillary and limbic boundaries in the direction θ. The value of θ belongs to $[0; 2\pi]$, ρ belongs to [0; 1]. Figure (2.3) shows the process of iris normalization

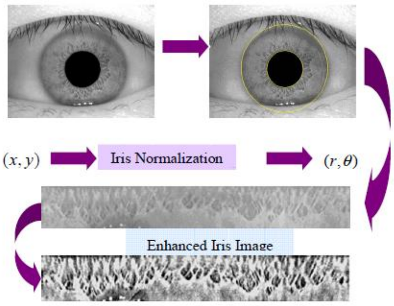


Fig. 2.3: Iris image normalization and enhancement.

III. DWT BASED FEATURE EXTRACTION

In encoding stage, two level Discrete Wavelet Transforma- tion (DWT) is applied on the above segmented and normalized iris region to get approximation. In order to make matter easier, an overview of DWT is given. The proposed system uses DWT coefficients as feature vector. The wavelet is a powerful mathematical tool for feature extraction, and has been used to extract the wavelet coefficient from normalized iris images. Wavelets are localized basis functions, which are scaled and shifted versions of some fixed mother wavelets. The main advantage of wavelets is that they provide localized frequency information about a function of a signal, which is particularly beneficial for classification[14]. A review of basic fundamental of Wavelet Decomposition is introduced as follows: The continuous wavelet transform of a signal X (t), square-integrable function, relative to a real-valued wavelet, Ψ(t) is defined as[16]:

$$W_\Psi(a,b) = \int_{-\infty}^{\infty} f(x) * \Psi_{a,b}(t)dx \quad (5)$$

where

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{|a|}}((t-a)/b)$$

and the wavelet $\Psi_{a,b}$ is computed from the mother wavelet Ψ by translation and dilation, wavelet, a the dilation factor and b the translation parameter (both being real positive numbers).

Under some mild assumptions, the mother wavelet Ψ satisfies the constraint of having zero mean[3], [19]. Equation (5) can be discretized by restraining a and b to a discrete lattice (a = 2b , a ∈ R+ , b ∈ R) to give the DWT. DWT is a linear transformation that operates on a data vector whose length is an integer power of two, transforming it into a numerically different vector of the same length. It is a tool that separates data into different frequency components, and then studies each component with resolution matched to its scale. DWT can be expressed as[3].

$$DWT_{x(n)} = \begin{cases} d_{j,k} = \sum(x(n)h_j * (n-2jk)), \\ a_{j,k} = \sum(x(n)g_j * (n-2jk)). \end{cases} \quad (6)$$

The coefficients dj,k refer to the detail components in sig- nal x(n) and correspond to the wavelet function, whereas aj,k refer to the approximation components in the signal. The functions h(n) and g(n) in the equation represent the coefficients of the high-pass and low-pass filters, respectively, whilst parameters j and k refer to wavelet scale and translation factors. The main feature of DWT is multiscale representation of function. By using the wavelets, given function can be analyzed at various levels of resolution [19]. Figure (III-A) illustrates DWT schematically.

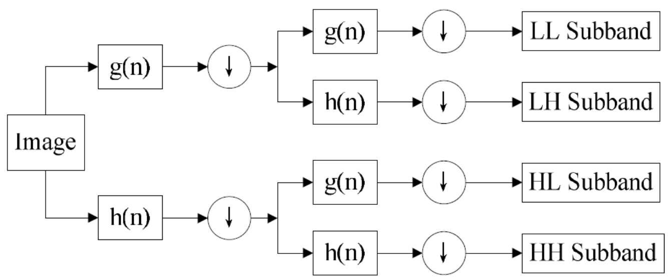


Fig. 3.1: Schematic diagram of 2D DWT.

The original image is process along the x and y direction by h(n) and g(n) filters which, is the row representation of the original image. As a result of this transform there are 4 sub-band (LL, LH, H H, H L) images at each scale. (see Fig.III-A). Sub-band image LL is used only for DWT calculation at the next scale. To compute the wavelet features in the first stage, the wavelet coefficients are calculated for the LL sub-band using Haar wavelet function.

A. Image Compression Eample by DWT

As an example of using DWT to compress an image of the famous Lena image, we apply DWT of level one, level two, and level three on the image as shown in the figures below.

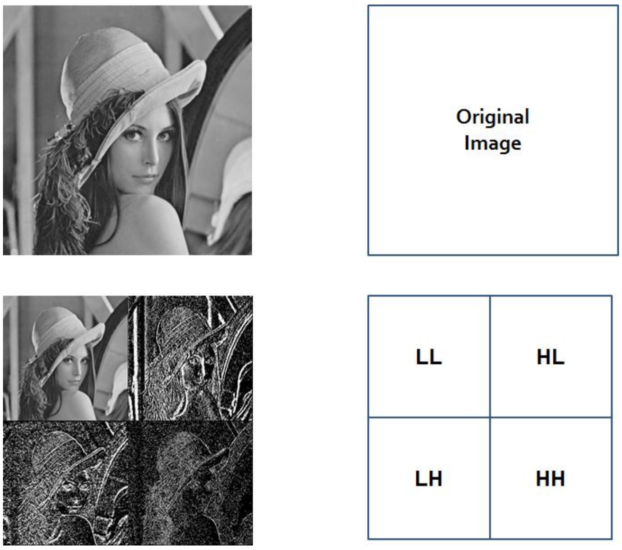


Fig. 3.2: One level DWT

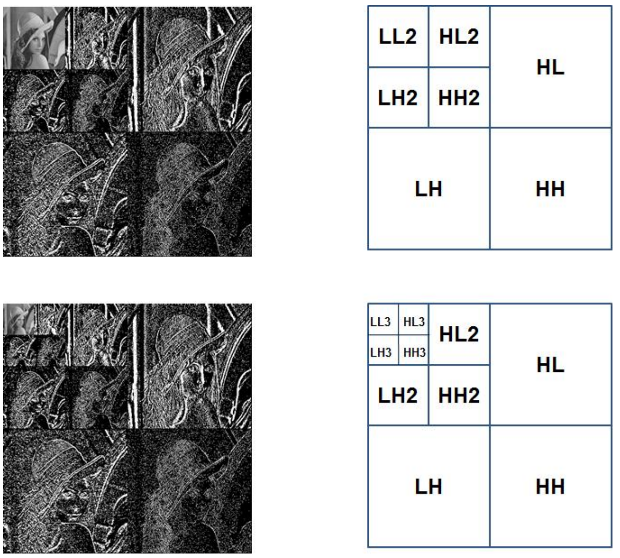


Fig. 3.3: Two and three level DWT

IV. PCA BASED FEATURE REDUCTION

One of the most common forms of dimensionality reduction is principal components analysis. Given a set of data, PCA finds the linear lower-dimensional representation of the data such that the variance of the reconstructed data is preserved [8], [19]. Using a system of feature reduction based on a combined principle component analysis on the feature vectors that calculated from the wavelets limiting the feature vectors to the component selected by the PCA should lead to an efficient classification algorithm utilizing supervised approach. So, the main idea behind using PCA in our approach is to reduce the dimensionality of the wavelet coefficients. This leads to more efficient and accurate classifier. The following algorithm is used to find out the principal components of the input matrix to the neural network. Now the input matrix consists of only these principal components. The size of the input matrix is reduced significantly. Algorithm (4.5) shows the involved steps for extracting principal components of the input vector to the two classifiers. Therefore, the feature extraction process was carried out through two steps: firstly the wavelet coefficients were extracted by the DWT and then the essential coefficients have been selected by the PCA (see Fig.4.4). In figure(4.5) given below an outline of PCA-algorithm.

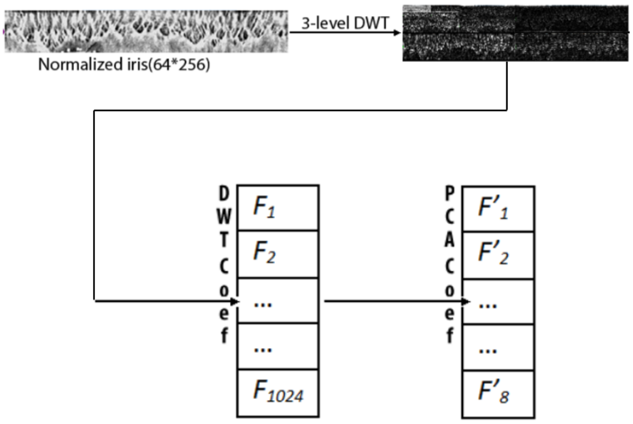


Fig. 4.4: PCA feature reduction of the DWT extracted feature.

Step 1: Calculate the covariance matrix in the new basis $C_y = \frac{1}{n-1} PAP^T$,

$$A = XX^T;\ A \text{ is symmetric.}$$

Step 2: Diagonalize the cov. matrix, i.e., $A = EDE^T$.

Step 3: Find the eigenvalues and eigenvectors from the previous step; $A = EDE^T$, where

D = diagonal matrix contains the eigenvalues of A,

E = matrix contains the eigenvectors of A.

Step 4: Dimension reduction:

- rearrange the eigenvectors and eigenvalues, i.e., sort the columns of the eigenvector matrix E and eigenvalue matrix D in order of decreasing eigenvalue.
- select a subset of the eigenvectors with higher values as basis vectors, project the data onto the new basis; of lower dimensions.

Fig. 4.5: PCA algorithm

V. IRIS MATCHING

After feature extraction, and feature reduction process apllied on the iris image, an iris image is represented as a feature vector of a small length. Therefore, our final task is to classify(match) the image. In pattern recognition, the k-nearest neighbor algorithm k-NN is a method for classifying objects based on closest training examples in the feature space.

k-NN is based on the principle that the instances within a dataset will generally exist in close proximity to other instances that have similar properties [1]. If the instances are tagged with a classification label, then the value of the label of an unclassified instance can be determined by observing the class of its nearest neighbors. The k-NN locates the k nearest instances to the query instance and determines its class by identifying the single most frequent class label. It is usual to use the Euclidean distance, though other distance measures such as the Manhattean distance could in principle be used instead. Figure (5.1) shows a description of the algorithm. The training phase for k-NN consists of simply storing all known instances and their class labels. A tabular representation can be used, or a specialized structure such as a kd-tree. If we want to tune the value of k and/or perform feature selection, n-fold cross-validation can be used on the training dataset. The algorithm on how to compute the K-nearest neighbors is as follows:

1) Determine the parameter K = number of nearest neighbors beforehand. This value is all up to you.
2) Calculate the distance between the query-instance and all the training samples. Any distance algorithm can be used.
3) Sort the distances for all the training samples and deter- mine the nearest neighbor based on the K-th minimum distance.
4) Since this is supervised learning, get all the Categories of your training data for the sorted value which fall under K.
5) Use the majority of nearest neighbors as the prediction value

Fig. 5.1: k-NN algorithm.

VI. SIMULATION

In order to evaluate the proposed iris recognition sys- tem (6.2), [26] image database is used. Figure (6.1) shows an instance of the eye images stored in the database. The data set consists of all gray scale images. This image database contains 2240 eye images from 224 different person. The experiments were performed using Matlab 2010a on Intel Core 2 Duo(2.1 GHz)machine with 3GB Ram. The average time needed for iris recognition was approximately 3 seconds. The searching period depends on the database size. Figure (7.1) shows snapshot of GUI implementation of the proposed technique. In the second stage, the iris image normalized and enhanced DWT was applied on it and dimension reduction was done using PCA.

Method	Accurracy rate
Daugman[7]	100%
Boles[6]	92.64%
Li Ma[13]	94.9%
Avila[11]	97.89%
Abiyev[20]	99.25%
Proposed[11]	99.5%

TABLE I: COMPARISON OF MATCHING PERFORMANCE WITH OTHER METHODS.

As a result of applying the proposed algorithm, a unique feature vector is constructed from it, which is further encrypted using user key and final encrypted vector is stored in the database. This drastically reduces size of total database along with providing higher security against compromise of template database. Finally the supervised classification; k-NN classifier, the attained recognition rate was 99.5%, table (I) shows comparison with other techniques.

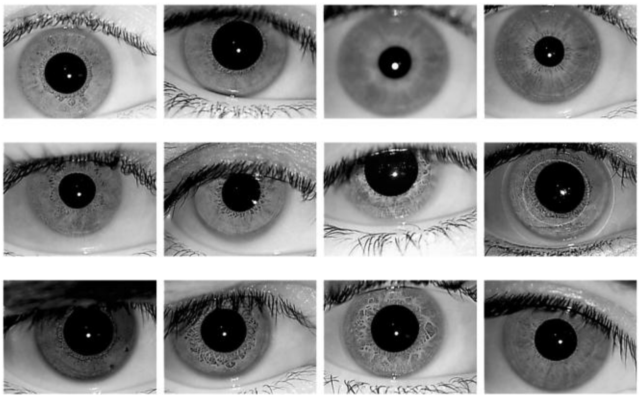


Fig. 6.1: Sample of used eye images DB.

Input: Eye image.
Output: A unique feature vector represent the input eye image.

Step 1: Eye image acquisition.
Step 2: Iris localization.
Step 3: Iris normalization.
Step 4: Feature vectoe extraction using DWT.
Step 5: Feature vectoe reduction using PCA.
Step 6: Apply the pattern matching technique:
    if the pattern exists in the iris DB:
        Output the matching result,
    else
        enroll the feature vector in the iris DB.
    end.

Fig. 6.2: Pseudocode of the proposed technique.

Individ.	FAR(%)	FRR(%)
1-10	0.04	0.03
10-20	0.06	0.05
20-30	0.03	0.04
30-40	0.04	0.04
40-50	0.05	0.07
50-60	0.13	0.06

TABLE II ESTIMATED VALUES OF FAR AND FRR.

A. Performance Evaluation

To evaluate the performance of the proposed system, the following metrics are used [25]:

i. False Acceptance Rate (FAR): is the ratio of the number of false acceptances divided by the total number of identification attempts.
ii. False Rejection Rate (FRR): the percentage of times the system produces a false reject.
iii. Equal Error Rate (EER): The rates at which both accept and reject errors are equal.

To estimate those parameters, a database of 80 persons was divided into two classes, 60 and 20 persons respectively. Every person has a database of 10 images, i.e., 600 database images in total. To calculate FAR, the eleventh image of every individual was compared with 600 database images. Similarly FAR calculated by considering 20 persons as imposters and one was compared with 600 DB images. Table (II) shows the obtained values.

VII. CONCLUSION

In this study, a robust iris matching system was developed. The technique depends mainly on two stages, iris localization and iris recognition. In the recognition stage a robust algorithm have been introduced which reduces the size of the iris image database and correspondingly the computational cost with high accuracy. The located iris's feature extracted using DWT, and then reduced to a compact size. This feature vector of small size were inputted to k-NN classifier for the recognition purpose. The recognition accuracy for pattern classification is 99.5%.

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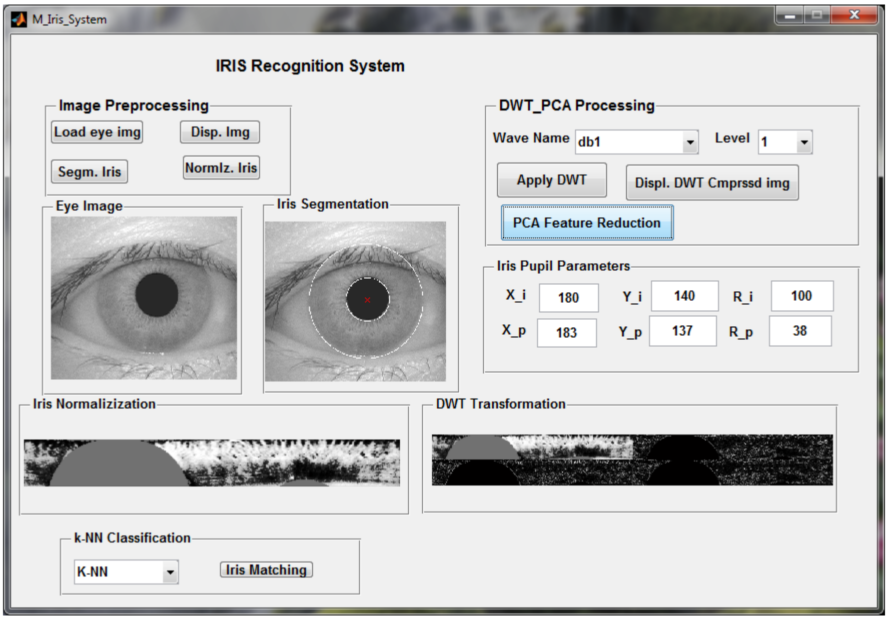

Fig. 7.1: Program demo.