A HUMAN IRIS RECOGNITION TECHNIQUES TO ENHANCE E-SECURITY ENVIRONMENT USING WAVELET TRANSFORM

Jafar M. H. Ali and Aboul Ella Hassanien
Kuwait University, Faculty of Business Administration,
Quantitative Methods and Information Systems Department
P.O. Box 5969 Safat, code no. 13060 Kuwait

ABSTRACT
In this paper, efficient biometric security techniques for iris recognition system with high performance and high confidence are described. The system is based on an empirical analysis of the iris image and it is split in several steps using local image properties. The system steps are capturing iris patterns; determine the location of the iris boundaries; converting the iris boundary to the stretched polar coordinate system; extracting the iris code based on texture analysis using wavelet transforms; and classification of the iris code. The proposed system use the wavelet transforms for texture analysis, and it depends heavily on knowledge of the general structure of a human iris. The system was implemented and tested using a dataset of 240 samples of iris data with different contrast quality. The classification rate compared with the well known methods is discussed.

KEYWORDS

1. INTRODUCTION
Today’s e-security are in critical need of finding accurate, secure and cost-effective alternatives to passwords and personal identification numbers (PIN) as financial losses increase dramatically year over year from computer-based fraud such as computer hacking and identity theft [15]. Biometric solutions address these fundamental problems, because an individual’s biometric data is unique and cannot be transferred. Biometrics is automated methods of identifying a person or verifying the identity of a person based on a physiological or behavioral characteristic. Examples of physiological characteristics include hand or finger images, facial characteristics, and iris recognition. Behavioral characteristics are traits that are learned or acquired. Dynamic signature verification, speaker verification, and keystroke dynamics are examples of behavioral characteristics [2,3].

Biometric system uses hardware to capture the biometric information, and software to maintain and manage the system. In general, the system translates these measurements into a mathematical, computer-readable format. When a user first creates a biometric profile, known as a template, that template is stored in a database. The biometrics system then compares this template to the new image created every time a user accesses the system. For an enterprise, biometrics provides value in two ways. First, a biometric device automates entry into secure locations, relieving or at least reducing the need for full-time monitoring by personnel. Second, when rolled into an authentication scheme, biometrics adds a strong layer of verification for user names and passwords. Biometrics adds a unique identifier to network authentication, one that is extremely difficult to duplicate. Smart cards and tokens also provide a unique identifier, but biometrics has an advantage over these devices: a user can not lose or forget his or her fingerprint, retina, or voice.

The practical applications for biometrics are diverse and expanding, and range from healthcare to government, financial services, transportation and public safety and justice [2,3]. Such applications are online identification for ECommerce, access control of a certain building or restricted area, off-line personal identification, financial ATM (Automated Teller Machine), on-line tickets purchase and internet kiosk and
military area access control and etc. Using iris recognition in ATM [5,6,7,12,13,14,16], a customer simply walks up to the ATM and looks in a sensor camera to access their accounts. The camera instantly photographs the iris of the customer. If the customers iris data matches the record stored a database access is granted. At the ATM, A positive authentication can be read through glasses, contact lenses and most sunglasses. Iris recognition proves highly accurate, easy to use and virtually fraud proof means to verify the identity of the customer. In this paper we present an iris recognition system using a wavelet theory. The proposed system use the wavelet transforms for texture analysis, and it depends heavily on knowledge of the general structure of a human iris. The paper is organized as follows. Section (2) discusses in details the proposed system. Results will discuss in section (3). Conclusions are shown in section (4).

2. THE PROPOSED SYSTEM

In this section, we will discuss in details the proposed system. Figure (1) shows the overall flow of the system. The system contains four main steps; image acquisition, image analysis and isolating iris boundary, Iris-code construction, and classification evaluation. The following subsections, more details about each step will discuss.

---

Figure 1. The overall system flowchart.

---

2.1 Image Acquisition

One of the major challenges of automated iris recognition system is to capture a high quality image of the iris while remaining noninvasive to the human operator [10]. Given that the iris is a relatively small (1 cm in diameter), dark object and that human operators are very sensitive about their eyes, this matter required careful engineering. The following points should be concern:

- Desirable to acquire images of the iris with sufficient resolution and sharpness to support recognition.
- It is important to have good contrast in the interior iris pattern without resorting to a level of illumination that annoys the operator.
- The images should be well framed (i.e. centered)
- Noises in the acquired images should be eliminated as much as possible.
Figure (2) shows the device configuration for acquiring human eye images.

![Figure 2. Configuration of the proposed image acquisition device](image)

The human eye should be 9 cm far away from the camera as shown above. The halogen lamp is in a fixed position to get the same illumination effect over all the images, thus excluding the illuminated part from the Iris while getting the Iris Code is easier, to acquire a more clear images through a CCD camera and minimize the effect of the reflected lights caused by the surrounding illumination, we arrange two halogen lamps as the surrounding lights and the two halogen lamp should be in front of the eye.

### 2.2 Image localized and Isolating Iris boundary

The proposed algorithm is based on the fact that there is some obvious difference in the intensity around each boundary, and since the value of the pixels in the pupil not always be zero so we need an edge detection algorithm to make all values of the pupil to be zero to easy determination of the pupil center and then get the pupil boundary. We start the algorithm by applying the edge detection method based on discrete approximation [17] to differential operators such as Laplacian of Gaussian (LOG), which denoted by $G(x, y)$ to the image $I(x, y)$ at the position $(x, y)$ to acquire the image information, where $G(x, y)$ is smoothing function of scale $\sigma$ that smoothes the image to select the spatial scale of edges under consideration. The LOG function is defined as:

$$
G(x, y) = \frac{1}{\sqrt{2\pi\delta^2}} \cdot e^{-\frac{(x^2 + y^2)}{2\delta^2}} \cdot (x^2 + y^2 / \delta^4 - 2 / \delta^2)
$$

(1)

Edge detection result should be enhanced using linear method like Median filter to remove the garbage around the pupil to gain clear pupil to determine perfect centre. Get the centre of the pupil by counting the number of black pixels (zero value) of each column and row. Then get each row and column that has the maximum number of these black pixels. Then determine the center by simple calculation according to the image coordinate to set it correct on the image, consequently we can determine the radius of the pupil. Thus we can find the pupillary boundary (inner). A similar procedure is extended by using a coarse scale to locate the outer boundary (limbus) which can be apparent by using the mid-point algorithms of circle and ellipse. Merging the existing edge segments into boundaries by linking these edges, we can precisely isolate the iris boundary from the eye.

The proposed iris boundary isolation algorithm is described as following steps:
• **Step-1: Edge detection:**
  We will localize the pupillary boundary by using a finer scale then apply the Zero-Crossing for each pixel to make a comparison between pixels to make all values of the pupil to be zero to easy determine the boundary.

• **Step-2: Edge Linking:**
  Using coarse-to-fine scale to get boundaries by merging the existing edge segments into boundaries this is done by edge linking.

• **Step-3: Enhancement:**
  The result of step-1 and step-2 should be enhanced by using median filter.

• **Step-4: Pupil/limbus center:**
  Determine the center of the pupil \((x_0, y_0)\) by counting the number of black pixels (zero value) [17] as follows:
  - Count every pixel in each row.
  - Get the row of maximum number of pixels.
  - Get the position of the first and last pixels respectively, \((x_1, y_1)\) and \((x_2, y_2)\) of this row.
  - Then find the center of this row by, \(x_0 = x_1 + x_2 / 2\).
  - Similarly, apply the previous steps for determining the center of the column of maximum number of pixels by \(y_0 = y_1 + y_2 / 2\). We actually can not obtain only one point, so we select the center point as the most frequently crossed point. Consequently, the radius of virtual circle of the pupil can be determined.

• **Step-5: Isolate the iris boundary:**
  Segment the image of the iris from the eye by applying boundary detection technique to localize the pupillary boundary. This technique based on merging the existing edge (the maximum number of point of the edge) segments into boundaries by edge linking [17] as follows:
  - Define the size of neighbourhoods \(5 \times 5\).
  - Link similar points which having closed values, the entire image undergoes this process, while keeping a list of linked points.
  - When the process is complete the boundary is determined by the linked list which can be apparent by using the mid-point algorithms of circle and ellipse.
  - Similar steps can be extended by using a coarse scale to locate the outer boundary (limbus).

2.3 Polar Transformation Algorithm

The localized iris part from the image should be transformed into polar coordinates system. Locating iris in the image delineates the circular iris zone of analysis by its own inner and outer boundaries. The Cartesian to polar reference transform suggested by Daugman [8] authorizes equivalent rectangular representation of the zone of interest as shown figure 5. In this way we compensate the stretching of the iris texture as the pupil changes in size, and we unfold the frequency information contained in the circular texture in order to facilitate next features extraction. Moreover this new representation of the iris breaks the noecentricity of the iris and the pupil. The \(\theta (\theta \in [0; 2\pi])\) parameter and dimensionless \(p (p \in [0; 1])\) parameter describe the polar coordinate system. Thus the following equations implement:

\[
I(x(p, \theta), y(p, \theta) \rightarrow I(p, \theta) \quad (2)
\]

\[
x(p, \theta) = (1 - p) * x_p(\theta) + p * x_i(\theta) \quad (3)
\]

\[
y(p, \theta) = (1 - p) * y_p(\theta) + p * y_i(\theta) \quad (4)
\]

\[
x_p(\theta) = x_{p0}(\theta) + r_p * \cos(\theta) \quad (5)
\]

\[
y_p(\theta) = y_{p0}(\theta) + r_p * \sin(\theta) \quad (6)
\]
\[ x_r(\theta) = x_{i0}(\theta) + r_i \cos(\theta) \]  
\[ y_r(\theta) = y_{i0}(\theta) + r_i \sin(\theta) \]  
Where \( r_p \) and \( r_i \) are respectively the radius of the 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 \( \theta \).

### 2.4 Feature Extraction: Iris Code

This section illustrates the technique of how to get the feature vector (iris code) to be able to compare the similarities of the human eyes and to identify the person. Gabor transform and wavelet transform are typically used for analyzing the human iris patterns and extracting feature points from them [11,18]. In this paper, a wavelet transform is used to extract features from iris images. Among the mother wavelets, we use Haar wavelet. The wavelet transform breaks an image down into four sub-sampled, or images. The results consist of one image that has been high pass in the horizontal and vertical directions, one that has been low pass in the vertical and high pass in the horizontal, and one that has been low pass filtered in both directions. This transform is typically implemented in the spatial domain by using 1-D convolution filters \( g \).

![Haar transform](image)

Figure 3. Harr transform

Figure (3) shows the result of Harr transform. Where, \( H \) and \( L \) mean the high pass and low pass filter, respectively. While \( HH \) means that the high pass filter is applied to signals of both directions. The results of Haar transform in four types of coefficients: (a) coefficients that result from a convolution with \( g \) in both directions \( (HH) \) represent diagonal features of the image. (b) Coefficients that result from a convolution with \( g \) on the columns after a convolution with \( h \) on the rows \( (HL) \) correspond to horizontal structures. (c) Coefficients from high pass filtering on the rows, followed by low pass filtering of the columns \( (LH) \) reflect vertical information. (d) The coefficients from low pass filtering in both directions are further processed in the next step. The following MATLAB code illustrates the Haar decomposition process:

```matlab
function [s,d]=dwhaar(Signal)
N = length(Signal); s = zeros(1, N/2); d = s;
for n=1:N/2
    s(n) = 1/2*(Signal(2*n -1) + Signal(2*n));
    d(n) = Signal(2*n -1) - s(n);
end
```

Wavelet Decomposition Using the Haar Transform

```matlab
function T = wavelet-decomp(Signal)
N = size(Signal,2); J = log2(N);
if rem(J,1) error('Signal must be of length 2^N.');
T = zeros(J, N); T(1,:) = Signal;
for j=1:J
    Length = 2^(J+1-j);
    T(j+1, 1:Length) = dwthhaar( T(j, 1:Length) );
    T(j+1, Length+1:N) = T(j, Length+1:N);
end
```

For the 450x60 iris image in polar coordinates, we apply wavelet transform 4 times in order to get the 28x3 sub-images (i.e. 84 features). By combining these 84 features in the HH sub-image of the high-pass filter of the fourth transform \( (HH4) \) and each average value for the three remaining high-pass filters areas \( (HH1, HH2, HH3) \), the dimension of the resulting feature vector is 87. Each value of 87 dimensions has a real value between -1.0 and 1.0. By quantizing each real value into binary form by convert the positive value into 1 and the negative value into 0. Therefore, we can represent an iris image with only 87 bits.
2.5 Matching process: Hamming Distance Calculation

Comparison of Iris Code records includes calculation of a Hamming Distance (HD) [4], as a measure of variation between the Iris Code recorded from the presented iris and each Iris Code recorded in the databases. Let $A_j$ and $B_j$ be two iris codes to be compared, the Hamming distance function can be calculated as:

$$\text{HD} = \frac{1}{87} \sum_{j=1}^{87} A_j \oplus B_j$$  \hspace{1cm} (9)

where $\oplus$ denotes exclusive-OR operator. (The exclusive-OR is a Boolean operator that equals one if and only if the two bits $A_j$ and $B_j$ are different).

**The Matching Algorithm**

Let $A_j$ and $B_j$ be two iris codes to be compared and to test if $A_j$ is in the database or not. The following steps describe the process:

- For $j = 1$ to $87$ do
  - Comparing bit-by-bit code $A_j$ with the first code $B_j$ in the database.
  - If the result of the XOR is (0), this means the two bits are the same, so count the number of zero’s
  - Else don’t count it and continue to the next bit
  - Next $j$ until reaching the final code in the database.

- Calculating the similarities (matching) ratio by the following formula:

$$MR = \frac{N_z \times 100}{T_n}$$  \hspace{1cm} (10)

Where $N_z$ and $T_n$ are the number of zero’s and total number of bits in each code, respectively. MR is a matching ratio.

3. RESULT AND DISCUSSION

To show the effectiveness of the proposed algorithm, in our implementation we divide the 240 samples of irises data into 20 equal size folders, such that a single folder is used for testing the model that has been developed from the remaining nineteen sets. The images were acquired under different conditions. The original images were collected as grey-level images. Figure (4) shows examples of failures and success cases or iris pattern during the acquisition process. Figure (5) illustrates that the iris has been isolated by localizing the inner and outer boundaries. It is obvious that the process can discriminate the regions with different texture characteristics. For wavelet transform the best results were obtained for the high pass (H) in scales 3 and 4 in vertical direction. Maximal statistical measure value was 2.54 which means that it is quite good and accurate result. Acceptance Rate (FAR) and False Rejection Rate (FRR) are two critical measurements of system effectiveness. This system is scored a perfect 0.001% FAR and 0.55% FRR.

(a) Failure cases
Table 1. Classification rate

<table>
<thead>
<tr>
<th>Method</th>
<th>Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wildes</td>
<td>99.2%</td>
</tr>
<tr>
<td>Daugman’s</td>
<td>100%</td>
</tr>
<tr>
<td>Our system</td>
<td>97.3%</td>
</tr>
</tbody>
</table>

Table (1) shows the classification rate compared with the well known two methods; Wilde's and Daugman’s [9,14]. In two test modes, is a little better than ours. In fact, the dimensionality of the feature vector in both methods is much higher than ours. The feature vector consists of 2048 components in Daugman's method, while only 84 in our method. In addition, they extract features in much smaller local regions. These make their methods a little better than ours. Now, we are working on more precisely representing the variation of texture of the iris in local region and reducing the dimensionality of the feature vector. Thus, we expect to further improve the performance of the current method.

4. CONCLUSION

We describe in this paper efficient techniques for iris recognition system with high performance from the practical point of view. These techniques are:

- A method of evaluating the quality of an image in the image acquisition step and excluding it from the subsequent processing if it is not appropriate.
- A computer graphics algorithm for detecting the centre of the pupil and localizing the iris area from an eye image.
- Transforming the localized iris area into a simple coordination system.
- A compact and efficient feature extraction method which is based on 2D multiresolution wavelet transform.
- Matching process based on Hamming distance function between the input code and the registered iris codes.

The system find out the recognition rate is about 97.3%.
REFERENCES