Neural Network Based Biometric Personal Identification

Rahib H.Abiyev, Koray Altunkaya
Near East University, Department of Computer Engineering, Lefkosa, North Cyprus
{rahib,kaltunkaya}@neu.edu.tr

Abstract

This paper presents biometric personal identification based on iris recognition using neural networks. Personal identification system consists of localization of the iris region and generation of data set of iris images and then iris pattern recognition. In this paper, fast algorithm is proposed for the localization of the inner and outer boundaries of the iris region. Located iris is extracted from an eye image, and, after normalization and enhancement it is represented by a data set. Using this data set a neural network is applied for the classification of iris patterns. Results of simulations illustrate the effectiveness of the neural system in personal identification.

1. Introduction

Personal identification based on biometrics has been receiving extensive attention in public security and information security domains. The biometrics identification uses physiological characteristics of humans and distinguishes one from another. These characteristics are face, facial thermogram, fingerprint, iris, retina, hand geometry etc. [1]. During using these characteristics the critical attributes are the variations of selected characteristic across the human population, uniqueness of these characteristics for each individual, its immutability over time and reliably recognizing pattern. Iris has all of these mentioned features. Iris recognition is one of the most reliable biometrics that uses iris characteristics of human eyes and plays an important role in accurate identification of each individual. Iris region is the part between the pupil and the white sclera. This field is sometimes called iris texture. The iris texture provides many minute characteristics such as freckles, coronas, stripes, furrows, crypts, etc [2-6]. These visible characteristics are unique for each subject. Such unique feature in the anatomical structure of the iris facilitates the differentiation among individuals. The human iris is not changeable and is stable. From one year of age until death, the patterns of the iris are relatively constant over a person’s lifetime [1,3]. Because of uniqueness and stability, iris recognition is a reliable human identification.

Iris recognition consists of the iris capturing, preprocessing and recognition of the iris region in a digital eye image. Iris image pre-processing includes iris localization, normalization, and enhancement. Each of these steps uses different algorithms. In iris localization step, the determination of the inner and outer circles of the iris and the determination of the upper and lower bound of the eyelids are performed. The inner circle is located between the iris and pupil boundary, the outer circle is located between the sclera and iris boundary. A variety of techniques have been developed for iris localization. In [3-6], the system with circular edge detector, in [7] a gradient based Hough transform are used for the localization of the iris. Also circular Hough transform [8], random Hough transform are applied to find the iris circles and complete the iris localization. In [10] Canny operator is used to locate the pupil boundary. These methods need a long time to locate iris. In this paper a fast iris localization algorithm is proposed.

Various algorithms have been applied for feature extraction and pattern matching processes. These methods use local and global features of the iris. Using phase based approach [3-6], wavelet transform zero crossing approach [8,15], Gabor filtering [10], texture analysis based methods [8,10,11,12] the solving of the iris recognition problem is considered. In [13,14] independent component analysis is proposed for iris recognition.

Daugman [3-6] used multiscale quadrature wavelets to extract texture phase structure information of the iris to generate a 2,048-bit iris code and compared the difference between a pair of iris representations by computing their Hamming distance. Boles and Boashash [9] calculated a zero-crossing representation of 1D wavelet transform at various resolution levels of a concentric circle on an iris image to characterize the texture of the iris. Iris matching was based on two dissimilarity functions. Sanchez-Avila and Sanchez-
Reillo [15] further developed the method of Boles and Boashash by using different distance measures (such as Euclidean distance and Hamming distance) for matching. Wildes et al. [8] represented the iris texture with a Laplacian pyramid constructed with four different resolution levels and used the normalized correlation to determine whether the input image and the model image are from the same class.

Today with the development of Artificial Intelligence (AI) algorithms, iris recognition systems may gain speed, hardware simplicity, accuracy and learning ability. In this paper a fast iris segmentation algorithm and also an iris recognition system based on neural networks are proposed.

This paper is organized as follows. In section 2 the iris preprocessing steps that include iris localization, normalization and enhancement are described. In section 3 the neural network which is used for iris pattern recognition is described. Section 4 presents experimental results. Section 4 includes the conclusion of the paper.

2. Iris recognition

2.1. Structure of Iris Recognition System

The architecture of the iris recognition system is given in Fig.1. The image recognition system includes iris image acquisition and iris recognition. The iris image acquisition includes the lighting system, the positioning system, and the physical capture system [8]. The iris recognition includes pre-processing and neural networks blocks. During iris acquisition, the iris image in the input sequence must be clear and sharp. Clarity of the iris’s minute characteristics and sharpness of the boundary between the pupil and the iris, and the boundary between the iris and the sclera affects the quality of iris image. A high quality image must be selected for iris recognition. In iris pre-processing, the iris is detected and extracted from an eye image and normalized. Normalized image after enhancement is represented by the matrix that describes greyscale values of the iris image. This matrix becomes the training data set for the neural network. The iris recognition system includes two operation modes: training mode and on-line mode. At fist stage using greyscale values of iris images the training of recognition system is carried out. Neural network is trained for all iris images. After training, in on-line mode using input digital images of iris, neural network performs classification and recognizes the patterns that belong to a certain person’s iris.

2.2. Iris localization

An eye image contains not only iris region but also some unuseful parts, such as the pupil, eyelids, sclera, and so on. For this reason, at first step, the segmentation will be done to localize and extract the iris region from the eye image. Iris localization is to detect the iris area between pupil and sclera. So we need to detect the upper and lower boundaries of the iris and determine its inner and outer circles (Fig.2). A number of algorithms has been developed for iris localization. One of them is based on the Hough transform. An iris segmentation algorithm based on the circular Hough transform is applied in [7,8]. In this paper the rectangular area is applied in order to localize pupil and detect inner circle of iris.

To detect iris we need to detect the pupil. The pupil is a dark circular area in an eye image. Besides the pupil the eyelash region and eyelids are also characterized with black colour. In most eye images the pupil is not located in the middle. In the paper accurately to detect the pupil and localize it we use rectangular area. In this method, we are looking for the black rectangular region in an iris image (Fig. 3). Searching starts from the vertical middle point of the iris image and continues to the right side of the image. A threshold value is used to detect the black rectangular area. Starting from the middle vertical point of iris image, the greyscale value of each point is compared with a threshold value. As it is proven by many experiments the greyscale values within the pupil are very small. So a threshold value can be easily chosen. If greyscale values in each point of the iris image are less than threshold value, then the rectangular area will be found. If this condition is not satisfied for the selected position, then the search

![Figure 1. Steps of iris recognition](image)
is continued from the next position. This process starts from the left side of the iris, and it continues to the end of the right side of the iris. In case the black rectangular area is not detected, the new position in the upper side of the vertical middle point of the image is selected and the search for the black rectangular area is resumed. If the black rectangular area is not found in the upper side of the eye image, then the search is continued in the down side of image. In Fig. 3(a), the search points are shown by the lines. In Fig. 3(a,b), the black rectangular area is shown in white colour. Choosing the size of the black rectangular area is important and it affects the accurate determination of the pupil’s position. If we choose small size, then this area can be found in the eyelash region that leads to inaccurate detection of pupil. In this paper a (10, 10) rectangular area is taken to accurately detect the location of the pupil. After finding the black rectangular area, we start to detect the boundary of the pupil and iris. At first step, the points located in the boundary of pupil and iris, in horizontal direction, then the points in the vertical direction are detected (Fig. 4). The border of the pupil and the iris has much a larger greyscale change value. Using a threshold value on the iris image, the algorithm detects the coordinates of the horizontal boundary points of \((x_1, y_1)\) and \((x_2, y_2)\), as shown in Fig. 4. The same procedure is applied to find the coordinates of the vertical boundary points \((x_3, y_3)\) and \((x_4, y_4)\). After finding the horizontal and vertical boundary points between the pupil and the iris, the following formula is used to find the centre coordinates \((x_p, y_p)\) of the pupil.

\[
x_p = \frac{x_3 + x_4}{2}, \quad y_p = \frac{y_3 + y_4}{2}
\]

(1)

The same procedure is applied for two different rectangular areas. In case of small differences between coordinates, the same procedure is applied for four and more different rectangular areas in order to detect accurate position of pupil’s centre. After finding centre points, the radius of the pupil is determined.

\[
r_p = \sqrt{(x_c - x_1)^2 + (y_c - y_1)^2},
\]

or

\[
r_p = \sqrt{(x_c - x_3)^2 + (y_c - y_3)^2}
\]

(2)

Because of the change of greyscale values in the outer boundaries of iris is very soft, the current edge detection methods are difficult to implement for detection the outer boundaries. In this paper, another algorithm is applied in order to detect the outer boundaries of the iris. We start from the outer boundaries of the pupil and determine the difference of sum of greyscale values between the first ten elements and second ten elements in horizontal direction. This process is continued in the left and right sectors of the iris. The difference corresponding to the maximum value is selected as boundary point. This procedure is implemented by the following formula.
Here $DL$ and $DR$ are the differences determined in the left and right sectors of the iris, correspondingly. $x_p$ and $y_p$ are centre coordinates of the pupil, $r_p$ is radius of the pupil, $right$ is the right most $y$ coordinate of the iris image. In each point, $S$ is calculated as

$$S_j = \sum_{k=j}^{k+10} I(i,k)$$

where $i=x_p$, for the left sector of iris $j=10,...,y_p-(r_p+10)$, and for the right sector of iris $j=y_p+(r_p+10)$. $I(i,k)$ are greyscale values.

The centre of the iris is determined using

$$y_i = (L + R) / 2, \quad r_i = (R - L) / 2$$

$L=i$, where $i$ correspond to the value $\text{max}(|DL|)$, $R=j$, where $j$ correspond to the value $\text{max}(|DR|)$.

### 2.3 Iris normalization

The irises captured from the different people have different sizes. The size of the irises from the same eye may change due to illumination variations, distance from the camera, or other factors. At the same time, the iris and the pupil are non concentric. These factors may affect the result of iris matching. In order to avoid these factors and achieve more accurate recognition, the normalization of iris images is implemented. In normalization, the iris circular region is transformed to a rectangular region with a fixed size. With the boundaries detected, the iris region is normalized from Cartesian coordinates to polar representation. This operation is done using the following operation (Fig.5).

$$\theta \in [0,2\pi], \quad r \in [R_p, R_L(\theta)]$$

$$x_i = x_p + r\cos(\theta), \quad y_i = y_p + r\sin(\theta)$$

Here $(x_i, y_i)$ is the point located between the coordinates of the papillary and limbic boundaries in the direction $\theta$. $(x_p, y_p)$ is the centre coordinate of the pupil, $R_p$ is the radius of the pupil, and $R_L(\theta)$ is the distance between centre of the pupil and the point of limbic boundary.
enhancement, background illumination (Fig. 6(c)) is subtracted from the normalized image to compensate for a variety of lighting conditions. Then the lighting corrected image (Fig. 6(d)) is enhanced by histogram equalization. Fig. 6(e) demonstrates the preprocessing results of iris image. The texture characteristics of iris image are shown more clearly. Such preprocessing compensates for the nonuniform illumination and improves the contrast of the image.

Normalized iris provides important texture information. This spatial pattern of the iris is characterized by the frequency and orientation information that contains freckles, coronas, strips, furrows, crypts, and so on.

3. Neural network based iris pattern recognition

In this paper, a Neural Network (NN) is used to recognise the iris patterns. In this approach, the normalized and enhanced iris image is represented by a two-dimensional array. This array contains the greyscale values of the texture of the iris pattern. These values are input signals for the neural network. Neural network structure is given in Fig. 7. Two hidden layers are used in the NN. In this structure, \(x_1, x_2, \ldots, x_m\) are greyscale values of input array that characterizes the iris texture information, \(P_1, P_2, \ldots, P_n\) are output patterns that characterize the irises.

![Figure 7. Neural Network Architecture](image)

The \(k\)-th output of neural network is determined by the formula

\[
P_k = f\left(\sum_{j=1}^{h_2} v_{j k} \cdot f\left(\sum_{i=1}^{h_1} u_{ij} \cdot f\left(\sum_{l=1}^{m} w_{il} x_i\right)\right)\right)
\]  

(7)

where \(v_{jk}\) are weights between the output and second hidden layers of network, \(u_{ij}\) are weights between the hidden layers, \(w_{il}\) are weights between the input and first hidden layers, \(f\) is the activation function that is used in neurons. \(m\) is the number of input signals, \(h1\) and \(h2\) are the number of neurons in hidden layers, \(n\) is the number of output neurons \((k=1, \ldots, n)\).

After activation of neural network, the backpropagation learning algorithm is applied for training. The trained network is then used for the iris recognition in online regime.

4 Experimental results

In order to evaluate the iris recognition algorithms, the CASIA iris image database is used. Currently this is largest iris database available in the public domain. This image database contains 756 eye images from 108 different persons. Experiments are performed in two stages: iris segmentation and iris recognition. At first stage the above described rectangular area algorithm is applied for the localization of irises. The experiments were performed by using Matlab on Pentium IV PC. The average time for the detection of inner and outer circles of the iris images was 0.14s. The accuracy rate was 98.62%. Also using the same conditions, the computer modelling of the iris localization is carried out by means of Hough transform and Canny edge detection realized by Masek [7] and integrodifferential operator realized by Daugman [3-6]. The average time for iris localization using Hough transform is obtained 85 sec, and 90 sec using integrodifferential operator.

Table 1 demonstrates the comparative results of different techniques used for iris localization. The results of Daugman method are difficult for comparison. If we use the algorithm which is given in [16] then the segmentation represents 57.7% of precision. If we take into account the improvements that were done by author then Daugman method presents 100% of precision. The experimental results have shown that the proposed iris localization rectangular area algorithm has better performance. In second stage the iris pattern classification using NN is performed. 50 person’s irises are selected from iris database for classification. The detected irises after normalization and enhancement are scaled by using averaging. This help to reduce the size of neural network. Then the images are represented by matrices. These matrices are the input signal for the neural network. The outputs of the neural network are classes of iris patterns. Two hidden layers are used in neural network. The numbers of neurons in first and second hidden layers are 120 and 81, correspondingly. Each class characterizes the certain person’s iris. Neural learning algorithm is applied in order to solve iris classification. From each set of iris images, two patterns are used for training and two patterns for testing. After training the remaining images are used for testing. The recognition rate of NN system was
The obtained recognition result is compared with the recognition results of other methods that utilize the same iris database. The results of this comparison are given in table 2. As shown in the table, the identification result obtained using the neural network approach illustrates the success of its efficient use in iris recognition.

5. Conclusion

Personal identification based on iris recognition using neural networks is presented in this paper. A fast iris localization method is proposed. Using this method, iris segmentation is performed in short time. Average time for iris segmentation is obtained to be 0.14 sec on Pentium IV PC using Matlab. Accuracy rate of iris segmentation 98.62% is achieved. The located iris after pre-processing is represented by a data set. Using this data set as input signal the neural network is used to recognize the iris patterns. The recognition accuracy for trained patterns was 99.25%.

6. References


Table 1. Accuracy rate for iris segmentation

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Accuracy rate</th>
<th>Average time</th>
</tr>
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<tbody>
<tr>
<td>Daugman [17]</td>
<td>57.7%</td>
<td>90 s</td>
</tr>
<tr>
<td>Wildes [8]</td>
<td>86.49%</td>
<td>110 s</td>
</tr>
<tr>
<td>Masek [7]</td>
<td>83.92%</td>
<td>85 s</td>
</tr>
<tr>
<td>Proposed</td>
<td>98.62%</td>
<td>0.14 s</td>
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Table 2. The recognition performance of comparing with existing method

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Accuracy rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daugman [4]</td>
<td>100%</td>
</tr>
<tr>
<td>Boles [9]</td>
<td>92.64%</td>
</tr>
<tr>
<td>Li Ma [10]</td>
<td>94.9%</td>
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<tr>
<td>Avila [15]</td>
<td>97.89%</td>
</tr>
<tr>
<td>Neural Network</td>
<td>99.25%</td>
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