BIOMETRIC IDENTIFICATION USING FAST LOCALIZATION AND RECOGNITION OF IRIS IMAGES

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ABSTRACT

Iris recognition is one of important biometric recognition approach in a human identification. Iris recognition system consists of localization of the iris region and generation of data set of iris images followed by iris pattern recognition. In this paper, a 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 (NN) is used for the classification of iris patterns. The adaptive learning strategy is applied for training of the NN. The results of simulations illustrate the effectiveness of the neural system in personal identification.

Keywords: Iris recognition, iris localization, neural network, biometric personal identification.

1. INTRODUCTION

Biometrics technology plays important role in public security and information security domains [1]. Iris recognition is one of important biometric recognition approach in a human identification is becoming very active topic in research and practical application. 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. 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 this uniqueness and stability, iris recognition is a reliable human identification technique.

Iris recognition consists of the iris capturing, pre-processing and recognition of the iris region in a digital eye image. Iris image pre-processing includes iris localization, normalization, and enhancement. 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. 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 localizing of the iris. Also circular Hough transform [8,9], random Hough transform are applied to find the iris circles and complete the iris localization. In [7,11] 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 [10,12], Gabor filtering [11], texture analysis based methods [8,10-17] the solving of the iris recognition problem is considered. In [18,19,20] 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 [10] 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 [12] 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.

2. STRUCTURE OF THE IRIS RECOGNITION

The architecture of the iris recognition system is given in Fig.1. The iris image acquisition includes the lighting system, the positioning system, and the physical capture system [8,9]. 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 the 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 online mode. At fist stage, the training of recognition system is carried out using greyscale values of iris images. Neural network is trained with all iris images. After training, in online mode, neural network performs classification and recognizes the patterns that belong to a certain person's iris.

3. IRIS LOCALIZATION

An eye image contains not only the iris region but also some unuseful parts, such as the pupil, eyelids, sclera, and so on. For this reason, at first step, segmentation will be done to localize and extract the iris region from the eye image. Iris localization is the detection of 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. A number of algorithms has been developed for iris localization. Some of them are based on the Hough transform. An iris segmentation algorithm based on the circular Hough transform is applied in [7,8]. In these researches the canny edge detection algorithm with circular Hough transform is applied to detect the inner and outer boundaries of the iris. The circular Hough transform is employed to deduce the radius and centre coordinates of the pupil and iris regions. In this operation, starting from the upper left corner of iris, the circular Hough transform is applied. This algorithm is used for each inner and outer circle separately. The application of the Hough transform requires a long time to locate the boundaries of the iris. In this paper, a fast algorithm for detecting the boundaries between pupil and iris and also sclera and iris has been proposed. To find the boundary between the pupil and iris, we must detect the location (centre coordinates and radius) of the pupil. The rectangular area technique is applied in order to localize pupil and detect the inner circle of iris. The pupil is a dark circular area in an eye image. Besides the pupil, eyelids and eyelashes are also characterized by black colour. In some cases, the pupil is not located in the middle of an eye image, and this causes difficulties in finding the exact location of the pupil using point-by- point comparison on the base of threshold technique.

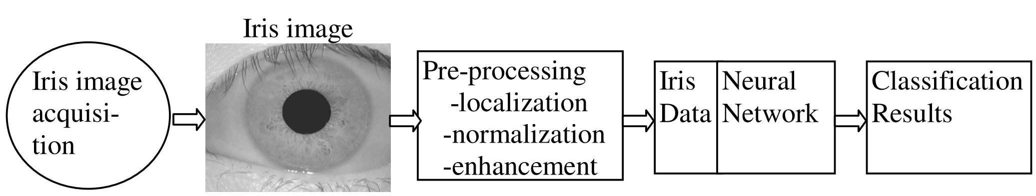


Fig. 1. The architecture of the iris recognition system

In this paper, we are looking for the black rectangular region in an iris image (Fig. 2).

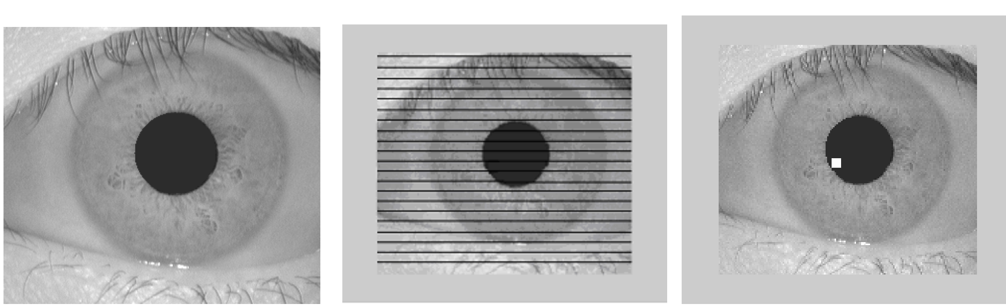
Choosing the size of the black rectangular area is important, and this affects the accurate determination of the pupil's position. If we choose a small size, then this area can be found in the eyelash region. In this paper a (10x10) rectangular area is used to accurately detect the location of the pupil. 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 the 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 the threshold value, then the rectangular area will be found. If this condition is not satisfactory for the selected position, then the search is continued from the next position. This process starts from the left side of the iris, and it continues until 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. Fig 2(a) shows iris image. In Fig. 2(a), the searching points are shown by the lines. In Fig. 2(b), the black rectangular area is shown in white colour. 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. 3). In Fig. 3 the circle represents the pupil, and the rectangle that is inside the circle represents the rectangular black area. The border of the pupil and the iris has a much 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_1,y_2), as shown in Fig. 3. The same procedure is applied to find the coordinates of the vertical boundary points (x_3,y_3) and (x_4,y_3). 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.

$$x_p = (x_3 + x_4)/2, \quad y_p = (y_3 + y_4)/2 \quad (1)$$

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 a more accurate position of the pupil's centre. After determining the centre points, the radius of the pupil is computed using equation (2).

$$r_p = \sqrt{(x_c - x_1)^2 + (y_c - y_1)^2}, \quad \text{or } r_p = \sqrt{(x_c - x_3)^2 + (y_c - y_3)^2} \quad (2)$$

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 of the outer boundaries.



(a) (b) (c)

Fig. 2. Detecting the rectangular area. (a) Iris image, (b) The lines that were drawn to detect rectangular areas, (c) The result of detecting of rectangular area

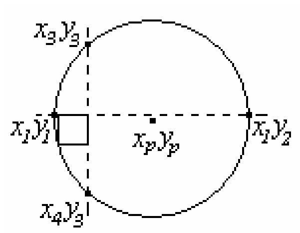


Fig. 3. Finding the centre of the pupil

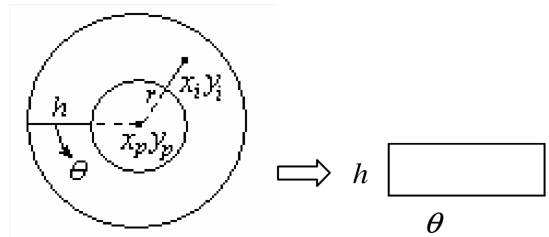


Fig. 4. Normalization of the iris

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.

$$DL_i = \sum_{i=10}^{y_p-(r_p+10)} (S_{i+1} - S_i);\ DR_j = \sum_{j=y_p+(r_p+10)}^{right-10} (S_{j+1} - S_j) \quad (3)$$

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

$$S_j = \sum_{k=j}^{k+10} I(i,k) \quad (4)$$

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

The centre and radius of the iris are determined using

$$y_s = (L+R)/2, \quad r_s = (R-L)/2 \quad (5)$$

$L=i$, where i correspond to the value $max(|DL_i|)$, $R=j$, where j correspond to the value $max(|DR_j|)$.

4. 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.4).

$$\theta \in [0,2\pi],\ r \in [R_p, R_L(\theta)]$$
$$x_i = x_p + r\cdot\cos(\theta); \qquad y_i = y_p + r\cdot\sin(\theta) \quad (6)$$

Here (x_i,y_i) is the point located between the coordinates of the papillary and limbic boundaries in the direction θ. (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.

In the localization step, the eyelid detection is performed. The effect of eyelids is erased from the iris image using the linear Hough transform. After normalization (Fig. 5(a)), the effect of eyelashes is removed from the iris image (Fig. 5(b)). Analysis reveals that eyelashes are quite dark when compared with the rest of the eye image. For isolating eyelashes, a thresholding technique was used. To improve the contrast and brightness of image and obtain a well distributed texture image, an enhancement is applied. Received normalized image using averaging is resized. The mean of each 16x16 small block constitutes a coarse estimate of the background illumination. During enhancement, background

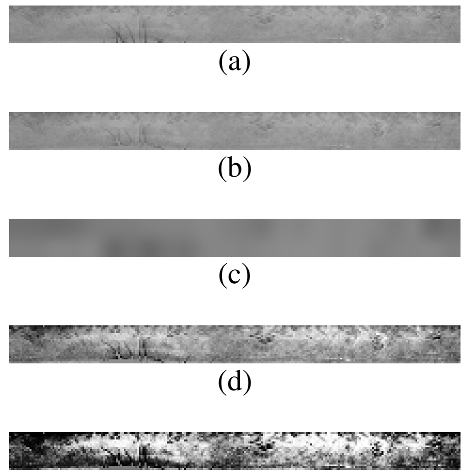


Fig. 5. a) Normalized image, b) Normalized image after removing eyelashes c) Image of nonuniform background illumination, d) Image after subtracting background illumination, d) Enhanced image after histogram equalization

illumination (Fig. 5(c)) is subtracted from the normalized image to compensate for a variety of lighting conditions. Then the lighting corrected image (Fig. 5(d)) is enhanced by histogram equalization. Fig. 5(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.

5. 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. Architecture of NN is given in Fig. 6. 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.

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

$$P_k = f_k(\sum_{j=1}^{h2} v_{jk} \cdot f_j(\sum_{i=1}^{h1} u_{ij} \cdot f_i(\sum_{l=1}^{m} w_{li} x_l))) \quad (7)$$

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, x_l is input signal. Here k=1,..,n, j=1,..,h2, i=1,..,h1, l=1,..,m, m is number of neurons in input layer, n is number of neurons in output layer, h1 and h2 are number of neurons in first and second hidden layers, correspondingly.

In formula (7) P_k output signals of NN are determined as

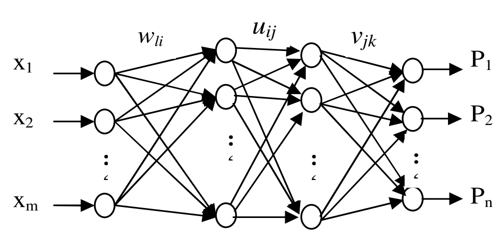


Fig. 6. Neural Network Architecture

$$P_k = \frac{1}{1+e^{-\sum_{j=1}^{h2} v_{jk} y_j}} \quad \text{where,}$$

$$y_j = \frac{1}{1+e^{-\sum_{i=1}^{h1} u_{ij} y_i}}; \quad y_i = \frac{1}{1+e^{-\sum_{l=1}^{m} w_{li} x_l}} \qquad (8)$$

Here y_i and y_j are output signals of first and second hidden layers, respectively.

After activation of neural network, the training of the parameters of NN starts. The trained network is then used for the iris recognition in online regime.

6. 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 99.25%. 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.

7. CONCLUSION

Using neural networks an personal iris recognition system 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

Table 1. Accuracy rate for iris segmentation

Methodology	Accuracy rate	Average time
Daugman [16]	57.7%	90 s
Wildes [8]	86.49%	110 s
Masek [7]	83.92%	85 s
Proposed	98.62%	0.14 s

Table 2. The recognition performance of comparing with existing methods

Methodology	Accuracy rate
Daugman [4]	100%
Boles [10]	92.64%
Li Ma [11]	94.9%
Avila [12]	97.89%
Neural Network	99.25%

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 feature vector. Using this vector as input signal the neural network is used to recognize the iris patterns. The recognition accuracy for trained patterns is 99.25%.

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