High Efficiency Iris Feature Extraction Based on 1-D Wavelet Transform

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ABSTRACT

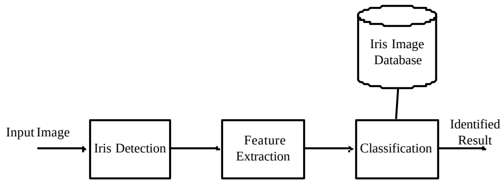
In this paper, a new technique is proposed for high efficiency iris recognition, which adopts 1-D wavelet transform to extract iris texture feature and probabilistic neural network (PNN) to recognize iris pattern. A comparative experiment of existing methods for iris recognition is evaluated on CASIA iris image databases. The results reveal the proposed algorithm possesses a very high efficiency and low dimensionality of feature vectors than existing methods.

Keywords: iris recognition; wavelet transform; probabilistic neural network

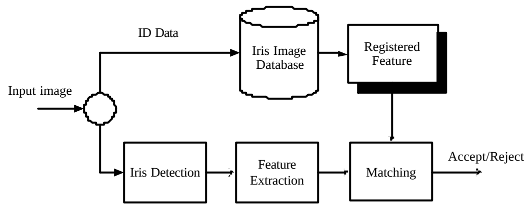
1. INTRODUCTION

Iris recognition [1], [7], [12-14] is the process of automatically differentiating the people on the basis individuality information from their iris images. The technique is used to verify the identity of a person accessing a system. It is favorable for reliable authentication system that the use of automatic identity verification systems based on biometric products.

Two types of iris recognition system are depicted in Fig. 1, which is iris identification and iris verification. Both iris identification and iris verification use a store data set based on reference patterns (templates) for N known iris image. Both involve similar analysis and decision techniques. Verification is simpler because it only requires comparing the test pattern against one reference pattern and it involves an alternative decision: Is there a good enough match against the template of the claimed face images? The error rate of iris identification can be greater because it requires choosing which of the N iris images known to the system best matches the test image or " no match" if the test image differs sufficiently from all the reference templates.



(a)



(b)

Fig 1. Iris recognition scheme (a) Identification; (b) Verification.

The iris recognition system consists of three sub-system: a iris detection system that include detecting, locating iris and extract iris circular ring, feature extraction system that composes of Sobel transform [4] and 1-D wavelet transform [2-3], and a Probabilistic Neural Network (PNN)[5] used as pattern classifier and applied successfully for different applications. However, as the increasing dimensionality could lead to higher computational cost, a dimensionality reduction procedure that eliminates information redundancy and allows for further information transform through limited channels is performed. For the purpose of dimensionality reduction procedure in iris images space is performed by implementing 1-D wavelet transform for iris image features extraction and as the consequences [16].

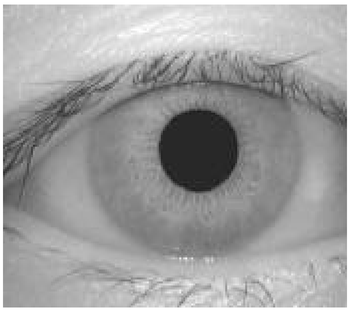
There are many traditional algorithms [7-15] successfully applied to iris recognition, but they are too complex to be applied in fast iris recognition. To address these problems related to computational and memory requirements, we focus our investigation on low complexity and high speed iris recognition system. Firstly, to reduce system complexity, we use 2-D wavelet transform to obtain a low resolution image and Hough transform to localize pupil position. By the center of pupil and the radius of pupil, we can acquire the iris circular ring. The more iris circular ring is acquired, the more information is enough to be utilized. Secondly, we adopt Sobel transform to extract iris texture in iris circular ring as feature vectors and 1-D discrete wavelet transform to reduce the dimensionality of feature vector. In our experiments, the wavelet permits to further reduce the system complexity and obtain discriminant feature vector. PNN is a very simple classifier model that has proved to be effective for iris recognition. Finally, the combination of the new method and PNN is evaluated on the CASIA iris database [6] for iris recognition. The basic conclusion drawn from our experiments is that the proposed method is well suitable for a low complex computation and low power devices.

2. IRIS IMAGE ACQUISITION

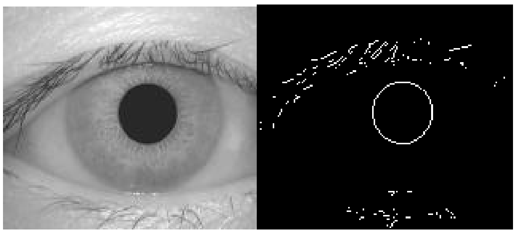
The iris image, as shown in Fig. 2 (a), does not only contain abundant texture information, but also some useless parts, such as eyelid, pupil, and etc. Because the iris is between the pupil (inner boundary) and the sclera (out boundary), the pupil is usually taken as circle. To localize the iris, we propose a simple and efficient method. The procedure is as following:

1. A new image is the representation of the original image by 2-D wavelet, and its size is only quarter of the original image.
2. The edge of pupil in new image is detected by Sobel transform.
3. The center coordinates and the radius of the pupil is determined by Hough transform.
4. The iris circular ring is obtained by the position of pupil.

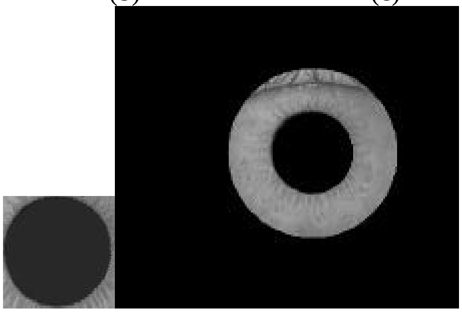
In the above mentioned methods, the first step reduces the dimensionality of image to improve the efficiency of extracting iris image. The second and third steps provide an approach to localize the position of the pupil. But the position of pupil is in the new image, the twice center coordinates and radius of the pupil is the position of pupil in original image. When the center coordinates and the radius of the pupil in original is obtained, the iris circular ring is extracted to as features.



(a)



(b) (c)



(d) (e)

Fig 2. Iris localization. (a) Original iris image (b) New image after wavelet transform (c) New image after Sobel transform (d) Pupil image (e) Iris image

The more iris circular ring is extracted, the more information is used as feature. The recognition performance is much better, but the efficiency is slightly affected. In the next section, the detailed description of the iris feature extraction method is presented.

3. IRIS TEXTURE FEATURE EXTRACTION

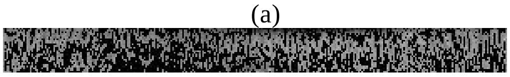
Iris texture has abundant texture information for iris identification or matching. We propose a very efficient algorithm to extract iris feature for iris recognition. The proposed method is based on the iris features existing in high frequency. The proposed method is different from traditional 2-D iris feature extraction method. Firstly, The Sobel transform is used to extract iris texture, the texture information is transformed 1-D energy profile signal, and the 1-D wavelet transform is applied in 1-D profile signal [16]. Finally, the PNN [5] is used as a classifier in iris recognition system.

The purpose of Sobel transform is used to extract the iris texture. The vertical projection is used as preprocessing to make texture image to 1-D energy profile signal. Each iris image is projected onto the 1-D energy profile signal. The signal is more concentrated in the signal so that the wavelet coefficients are more discriminant, and the set of coefficients obtained is as feature vectors. The wavelet transform technique has shown as an effective procedure for the reduction of dimensions and removes high frequency noises. Finally, the probabilistic neural network (PNN) is selected as the pattern recognition classifier because its high performance and high efficiency.

3.1 Sobel transform

The iris image is captured in different size from different people. It is not convenient for iris recognition, and the recognition performance is also affected. In the cause of the convenience of computation and achieving the high recognition performance, each captured iris circular ring number from different iris image is the same and the iris ring is unwrapped to a rectangular block as Fig. 3 (a) with a fixed size.To capture the texture of iris, we adopt the Sobel transform to analyze texture shown as Fig. 3(b).

(a)



(b)

Fig.3 (a) Unwrapped iris image; (b) Unwrapped iris image after Sobel transform

3.2 Vertical projection

To reduce system complexity, we adopt vertical projection to obtain 1-D energy profile signal. The exploit the benefits driving from concentrated energy, every row is accumulated as energy signal. This method is evaluated on the CASIA iris databases, which contains a set of iris images as Fig. 2 (a) from Chinese.

Let X be an iris image of size mxn, m is the number of iris circular ring, and n is pixels of each iris circular ring.

$$X = \begin{bmatrix} x_{1xn} & \cdots & x_{1xn} \\ \vdots & \ddots & \vdots \\ x_{mx1} & \cdots & x_{mxn} \end{bmatrix}$$

After vertical projection, the 1-D energy signal Y is obtained.

$$Y = [y_1 \quad \cdots \quad y_n]$$

The m is very smaller than the n. Thus, the information of iris texture after vertical projection is abundant than the information of iris texture after horizontal projection. So, We adopt the vertical projection to extract the 1-D energy signal.

3.3 Wavelet transform

The wavelets [2-3] to signal and image processing have provided a very flexible tool for engineers to apply in various fields such as speech and image processing. In an iris recognition system, the 2-D wavelet transform is only used for preprocessing. The goal of preprocessing often reduces the dimensions of feature vectors and removes noise. Nevertheless, the computational complexity is comparatively high. Thus, the paper proposes 1-D wavelet transform as filters to extract feature vectors, and it can reduce the computational complexity.

Here, we develop a feature extraction algorithm based on the 1-D wavelet transform. By combining the appropriate wavelet transform coefficients with the PNN gets an excellent result.

The wavelet is constructed from two-channels filter bank as Fig. 4. In wavelet decomposition of 1-D signal, a signal is put through both a low-pass filter L and a high-pass filter H and the results are both low frequency components A [n] and high frequency components D [n]. The signal y [n] is reconstructed by the construction filters $\tilde{H}$ and $\tilde{L}$.

The wavelet filters are used to decompose signal s into high and low frequency by convolution.

$$D[n] = \sum_{k=-\infty}^{\infty} s[k] \cdot H[n-k] \Leftrightarrow D = \langle s, H \rangle$$

$$A[n] = \sum_{k=-\infty}^{\infty} s[k] \cdot L[n-k] \Leftrightarrow A = \langle s, L \rangle$$

In order to construct multi-channel filter, we can cascade channel filter banks. Fig. 5 is a 3-level symmetric octave structure filter bank. This is an important concept from multi-resolution analysis (MRA).

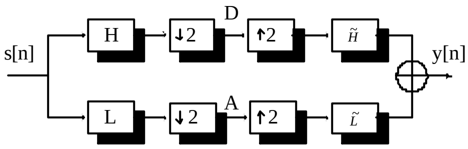


Fig.4. Two-channels filter bank

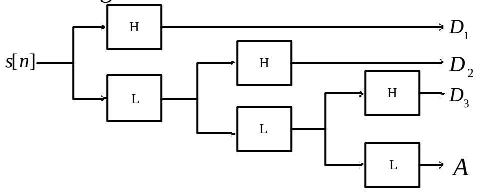


Fig.5. 3-level octave band filter bank

The purpose of the vertical projection approach is to reduce dimensions of iris texture and to become a 1-D energy profile signal. Thus, the efficiency of iris recognition will improve very much. But the 1-D energy signal is still very large. To overcome this problem, we resort to wavelet transform to decompose signal into low frequency as feature vector (Fig. 6).

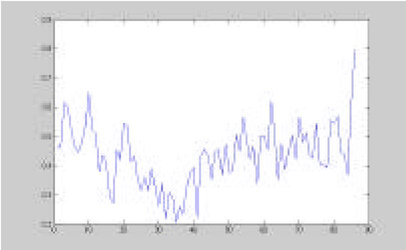


Fig 6. The 2-level wavelet transform of 1-D energy signal

4. PNN CLASSIFIER

In 1988, D.F.specht have designed a very efficiency probabilistic neural network (PNN) that is well adapted to manipulate classification problem. The purpose of this paper is for iris recognition. The experiment reveals it is excellent in efficiency and performance.

The basic concept cited Bayesian classifier to PNN model as Fig. 7. To probability density function, it has three assumptions:

1. The classification of probability density function is the same.
2. Probability density function is Gaussian distribute.
3. The variance matrix of Gaussian distribute probability density function is diagonal matrix.

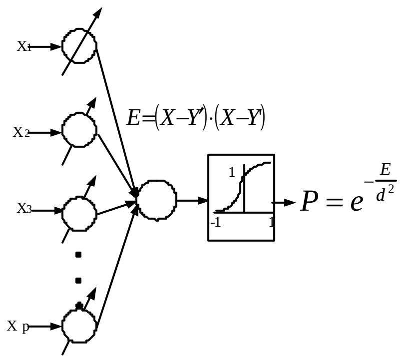


Fig 7. The simplified structure of PNN model

When the external factor is change, the PNN only change the weight of new data. The other neural network needs not to change all network weights.

The PNN model has been used for classification, because of its simplicity, performance and efficiency. Hence, this paper adopt PNN model as classifier.

5. EXPERIMENT PROCEDURE AND ITS RESULTS

In this section, we refer to our method of combining Sobel transform, vertical projection with wavelets as the feature extraction method for iris recognition. The iris database used in the comparison is the CASIA iris database and the classifier used is a probabilistic neural network (PNN). The database contains756 iris images acquired of 108 individuals (7 images per individual).

Experiments are divided into iris identification and iris verification. In the following experiments, a total of 324 iris images (three iris images of each person is extracted) were randomly selected as the train set and another 324 images as the testing set from the remaining images. Such procedure was carried out 10 times. The experimental platform is the AMD K7 Athlon 2.2 GHz processor, 1G SDRAM, Windows XP, and the software is Matlab 6.5.

5.1 Evaluation on Iris Identification under Second Level of 1-D Wavelet Transform Decomposition

For iris identification system, the goal is to determine which one of a group of known iris images best matches the input iris image samples. Firstly, the feature vectors are extracted from all image samples. All feature data is randomly divided into train data X and test data Y. Train data X directly input PNN as weight of hidden layer. To input a test data Y is to obtain a reference output P in PNN model.

$$P = e^{-\frac{E}{d^2}}$$

Where

$$E = (X - Y')\cdot(X - Y')$$

If we have N image samples, then there are N reference output probabilistic values P in PNN model. To determine Y belongs to the image from a variety of images by the maximum probabilistic value P. To select the maximum P determines the class of Y. The iris recognition rate R is defined:

$$\mathbf{R} = \frac{\mathbf{N}_1}{\mathbf{N}_2}\times 100\%$$

Where N_1 denotes the number of correct recognition in face images, N_2 the total number of iris images.

Our experiment results compare with the different levels of 1-D wavelet decomposition. The results show in Table 1. The represent of db is the different length of Daubechies filters.

Table 1. The recognition performance of comparing with different levels of 1-D wavelet decomposition

Methods	Average recognition rates (%)	The best recognition rates (%)
db1-1	88.18	92.9
db1-2	91.08	94.44
db1-3	88.3	91.98
db2-1	89.72	93.52
db2-2	92.28	95.37
db2-3	89.23	91.05
db3-1	89.29	92.28
db3-2	**92.81**	**96.6**
db3-3	87.81	92.9
db4-1	88.02	91.05
db4-2	90.99	95.68
db4-3	88.58	90.43

From these results of Table 1, it shows the superiority of using 1-D wavelet transform. The 1-D wavelet transform can achieve the average recognition rate of 92.81 and the best recognition rate of 96.66 percent using db3-2 wavelet filters. The db3-2 provides the best recognition performance and we select it for subsequent evaluation.

5.2 Evaluation on Iris verification with db3-2 wavelet transform decomposition

Iris verification system refers whether the iris image samples belong to some specific iris image or not. Thus, the result has only two alternatives, accept or reject the identify claim depending on the calculation by a threshold.

The performance of iris verification is estimated with the Equal Error Rate (EER). When FAR is equal to the FRR, the EER is obtained as Fig.8. False acceptance ratio (FAR) is ratio of accepting an unregistered iris image to reject a registered one. False rejection ratio (FRR) is ratio of rejecting a registered iris image to accept an unregistered one. The high performance of iris verification system is in low EER.

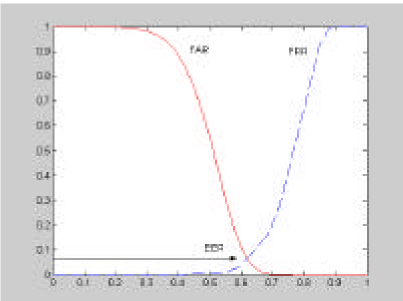


Fig. 8 Equal Error Rate (EER)

In the experiment, we replace the recognition rate with EER.

Table 2. The recognition performance of comparing with db 3-2 wavelet decomposition

Methods	db 3-2
Average EER(%)	5.56
The best EER(%)	4.36

The results show in Table 2. In these experiments, the best EER is 4.36% and the average EER is 5.36%. These results further illustrate the superiority of the proposed method. These observations demonstrate that the iris recognition techniques can be suitable for low power applications showing that the complexity of the proposed method is very low.

5.3 Evaluation on Iris Identification with Existing Methods

The previous methods [7-15] for iris recognition mainly focus on feature extraction and matching. Thus, we only analyze and compare the performance and efficiency of feature representation and matching of these methods. Here, we will present a comparison between the proposed method and their methods described on the CASIA iris databases in Table 3.

Table 3. The recognition performance of comparing with existing methods

Methods	Daugman [10]	Li Ma [11]	Proposed
Average Recognition Rates (%)	100	99.43	92.88
The best Recognition Rates (%)	100	100	96.66
Dimension	2048	200	**74**
Complexity	High	High	Low

Looking at the results shown in Table 3, we can find the proposed method has the best efficiency. The feature vector consists of 2048 components in Daugman's method. Although his method has very good performance, the feature vector is very higher than our method. Owing to high efficiency and simplicity of the proposed method, it is very suitable for low power applications or HW platforms having small portions of memory available (smartcard).

6. CONCLUSIONS

It is well-known that if the dimension of the network input is comparable to the size of the training set, which is the usual case in iris recognition, the system will easily bring about over-fitting and result in poor generalization. In this paper, a general design approach using a PNN classifier for iris recognition to cope with small training sets of high dimensional problems is presented. Firstly, iris images are projected onto 1-D signals by the vertical projection. Then the 1-D signal features are extracted by the 1-D wavelet transform. A novel paradigm, the results of combining the vertical projection, 1-D wavelet transform, and PNN is encountering and has excellent efficiency.

From the simulation results described in experiments, it is clear that the proposed method has excellently high efficiency than the traditional methods. The complexity of feature extraction method for iris recognition is excellently low. The proposed method provides excellently effective, and achieves a considerable computational reduction while keeping good performance. We have proved the proposed method can achieve very fast iris recognition. In future, we will further improve the recognition performance of iris recognition and apply it to embedded system.

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