Iris Recognition Technique*

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Abstract The demand on security is increasing greatly in these years and biometric recognition gradually becomes a hot field of research. Iris recognition is a new branch of biometric recognition, which is regarded as the most stable, safe and accurate biometric recognition method. In these years, much progress in this field has been made by scholars and experts of different countries. In this paper, some successful iris recognition methods are listed and their performance are compared. Furthermore, the existing problems and challenges are discussed.

Key words biometric recognition; iris localization; normalization; feature vector extraction and match

1 Introduction

We are living in the age, in which the demand on security is increasing greatly. Consequently, biometric recognition, which is a safe, reliable and convenient technology for personal recognition, appears. This technology makes use of physiological or behavioural characteristics to identify individuals[1]. A biometric system is a pattern recognition system including acquiring the biometric feature from individual, extracting the feature vector from the raw data and comparing this feature vector to another person’s feature vector. Fingerprint, palm-prints, face, iris, gait, speech and signature are widely used biometric features. Biometric recognition can be used in computer network login, internet access, ATM, credit card, national ID card, driver’s license and so on[2]. Nowadays, fingerprint recognition is used widely and successfully. Face recognition is studied by many scholars and experts. Iris recognition is a relatively new branch of biometric recognition.

The human iris is the annular part between pupil and sclera. It has distinct feature such as freckles, coronas, stripes, furrows and so on[3]. An example of iris image is shown in Fig.1. Compared to other biometric technique, iris recognition has many merits:

1) Uniqueness: Dissector F. H. Adler suggested the uniqueness of iris originally in 1965. The visible features in an iris include the trabecular meshwork of connective tissue, collagenous stromal fibres, ciliary processes, contraction, and frekles[3-5]. These textures ensure that different persons have distinct iris. The probability of two persons’ irises being the same is lower than 10^{-35}. Even though they are twins, their irises are quite different. This fact is the reason why we use iris to recognize personal identity.

2) Reliability: iris is an inner organ in our eyes and protected by eyelid, lash and cornea. Unlike finger and palm, it is seldom hurt and the error of recognition caused by scar will never happen. In this sense, iris recognition is much better than fingerprint and palm-print recognition. Furthermore, our irises matured when we were one year old and would not change in our life.

3) Against artifice: a living eye’s pupillary diameter relative to iris diameter in a normal eye is constantly changing, even under steady illumination. The pupilomotor response could provide a test against artifice.

![Fig.1 The iris image](image-url)
As early as 1885, Alphonse Bertillon first identified persons by iris in jail of Paris. At that time, it depends on observing. In 1993, John Daugman proposed an efficient and stable iris recognition method, which is now used widely. Then, Wildes and Boles proposed another two successful methods. In recent years, the Institute of Automation, Chinese Academy of Sciences has also proposed a few of iris recognition methods which perform perfectly[6-10].

A typical iris recognition system includes four parts: iris image quality estimation, iris localization, normalization, feature vector extraction and match. This is shown in Fig.2. In the following, we will illustrate every part in detail.

2 State of Iris Recognition Research

A great deal of study on iris recognition has been done. It is helpful for us to analyze the existing methods and help us to do our future research. In the following pages, we will list the main points of the existing methods and compare their performance.

2.1 Iris Image Quality Evaluation

Iris image quality evaluation is an especially important step in the automatic iris recognition system, for it avoids the false match and the false non-match caused by bad image quality. The common quality problems for iris image are the eyelid and lash occlusion, the blur of image caused by motion and defocus.

Daugman computed the total high frequency power in the Fourier spectrum of an iris image to measure the quality. The higher the high frequency power is, the clearer the image will be[11]. Based on this theory, Li Ma et al.[10] proposed an iris image quality algorithm according to the power of low, middle and high frequency components. It estimates the iris image quality from two aspects. The first aspect is the total spectrum power of an iris region which can effectively discriminate clear iris images from eyelid and lash occluded iris images. The second aspect is the portion of the middle frequency power to the sum of the high and low frequency power. As we know, the texture of iris is always characterized in the middle component, therefore the ratio is larger. From this value, we can distinguish the clear image from the defocused and motion blurred image. This estimation model is a valid model for it gives attention to the primary quality problems.

Chen Ji et al.[12] proposed an algorithm based on wavelet packet decomposition. Through computing the energy of the characteristic sub-band, the definition of an iris image can be evaluated. This method only gives attention to the definition of the iris image. Xing Lei et al.[13] gave a method to estimate the iris image quality from image definition, inside and outside eccentricity and iris visibility. This model focuses on almost all the problems that will take place in image acquisition operation; however, it is sensitive to the illumination environment.

It should be explained that the iris image quality evaluation has a close relation to iris image acquisition, feature vector extraction and match. If the algorithm for feature vector extraction and match can efficiently process iris image of low quality, requirements for image quality evaluation and acquisition will be reduced. In contrast, if the algorithm for feature vector extraction and match doesn’t perform stably, more requirements for image quality evaluation and acquisition will need. In a word, we should improve the algorithm of recognition part, so that the users of this system don’t bother that they have to try many times until their iris image is eligible.

2.2 Iris Localization

Iris localization is an especially important step in the whole iris recognition system. Only when we segment iris correctly from the original iris image, we can obtain an accurate matching result. Iris localization, by definition, means to detect the location of iris’ inner and outer boundaries. An example of iris image from CASIA database is shown in Fig.3. We can find that an eye is composed of three main parts: sclera, iris and
pupil. Sclera is white and out of the iris, and pupil is always black and in the centre of the eye. Furthermore, the inner and outer boundaries of iris are almost circular counter.

Generally speaking, the aim of iris localization is to locate iris accurately and fast. In practice, if an algorithm performs accurately, it always needs a long time to locate iris. Daugman[4] proposed a coarse to fine localization method. First, it finds out the coarse centre and radius of pupil and iris; then searches some possible area of the image domain for the maximum in the blurred partial derivative, which respect to increasing radius and the normalized contour integral of intensity values along a circle arc. It searches iteratively for a maximum contour integral derivative with increasing radius at successively finer scales of analysis through the three parameter space of centre coordinates and radius which define the path of contour integration.

Daugman didn’t introduce how to find the coarse centre and radius of pupil and iris. Afterwards, there are many algorithms having been proposed to improve Daugman’s localization algorithm. These algorithms almost improve the coarse localization method and adopt the same method that was proposed by Daugman in fine localization part. He Jiafeng et al.[14] detected the edge points of pupil and iris according to the sum of the values of several adjacent points on the intensity derivative curve and obtained the iris coarse location through curve-fitting. Wang Chengru et al.[15] used the improved Sobel detector to extract iris edge. Geometric features of circle and voting scheme are used to search the iris circle centre. Finally, the coarse iris inner and outer boundaries are detected by using radius histogram of Hough transform.

Another classic iris localization method was proposed by Wildes[16]. Wildes’ system performed its contour fitting in two steps. First, transform the original iris image to a binary edge-map, which is recovered via gradient-based edge detection. Second, use the Hough transform to detect the circular curve through the edge points.

The algorithms proposed by Wildes and Daugman can localize iris correctly. However, the two methods cost a long time. Cui et al.[6] proposed a robust and fast iris localization method based on texture segmentation. First, find the edge points of iris from the low frequency component of the original iris image through Haar wavelet transform, for it can avoid the influence of eyelash. Second, set a circle to the edge points on the inner boundary. After these two operations, the location of pupil can be found out. Finally, detect the outer boundary of iris with an integral differential operator. This algorithm is efficient and accurate for it filters the noise such as eyelash to do localization.

An example of localization is shown in Fig.4. Actually, the algorithm for iris localization is always not stable when dealing with low quality iris image. Therefore, we should improve our iris localization method to reduce the requirements for image quality evaluation and image acquisition.

2.3 Iris Normalization

The purpose of iris normalization is to get the same region of iris to do matching regardless pupil dilation and the different iris size caused by the different distance between the eye and video zoom factor. Moreover, the shift, accounting for the offsets of the eye in the plane parallel to the camera’s sensor,
should also be eliminated.

Wildes\cite{16} used an image-registration technique to eliminate dilation, scaling and rotation. This approach wraps a new iris image into alignment with a normal image according to a mapping function so that the difference between the two iris images is minimal. Daugman \cite{3-5} map image coordinates to polar image coordinates. The angular coordinate ranges between $0\sim 2\pi$ and the radial coordinate ranges from the iris inner boundary to its outer boundary as a unit interval. This is called the homogeneous rubber sheet model. Actually, there are some other problems we should think about in the normalization part such as the non-uniform brightness problem. Both Wildes and Daugman did not explain how to deal with these problems.

Li Ma et al.\cite{7} gave a method to eliminate other problems in normalization part to improve the performance of match. Enhancement is adopted to eliminate the non-uniform brightness problem and the low intensity contrast problem. There are two steps in this part. One is the background illumination estimation and the other is histogram equalization. This progress is shown in Fig.5.

![Normalized Image](a)

![Illumination Estimation](b)

![Enhanced Image](c)

**Fig.5** Normalization, illumination estimation and enhancing

The normalization algorithm always depends on the algorithm of feature vector extraction and match. Moreover, we should make the texture on iris become clearer and eliminate the factors that will lead to error of match in iris normalization operation.

### 2.4 Feature Vector Extraction and Match

Feature selection and extraction is to find out the important features to do matching. As we know, the visible features of an iris are ciliary processes, contraction furrows, crypts, rings, corona, freckles and so on. How to set a model to extract the feature of different irises and match them is especially important for it determines the results of the whole system directly. Actually, there are many models; in the following we will introduce some perfect models.

Daugman\cite{3-5} used the 2-D Gabor transform of the normalization iris image to extract the feature. The 2-D Gabor filter is helpful for us to analyze the information of an image because it is orientation-selective and spatial-frequency-selective. When projecting the normalization iris image onto quadrature 2-D Gabor wavelets, it generates a series of complex-valued coefficients whose real and imaginary parts specify the coordinates. Then, the 256 byte iris code will be produced. Different persons have different iris texture; therefore their iris codes are quite different. Daugman used the hamming distance to indicate the degree of iris code. The higher the hamming distance is, the more distinct the two irises are. That is if the two iris codes are produced from the same iris image, the hamming distance will be zero. This algorithm is always thought to be the best iris feature extraction and match method because it only needs a little space of memory to store the information of iris.

Wildes\cite{16} represented the iris texture with a Laplacian pyramid constructed with four different resolution levels and the correlation over small blocks of pixels (8×8) to determine whether two irises are belong to one person. The Fisher’s linear discrimination is adopted for match.

Li Ma et al.\cite{7} proposed a simple and efficient method by characterizing key local variations. First, they constructed a set of one dimensional intensity signal to extract the most impotent information of the originals iris normalization image, then, did wavelets transform and recorded a position sequence of local sharp variation points as the feature vector. Finally, the result was obtained through exclusive OR operation. Compared with the above methods, this method is especially simple and cost a short time.

Dorairaj et al.\cite{17} adopted Principle Component Analysis (PCA) and Independent Component Analysis (ICA). PCA has been used as a preprocessing step that reduces dimensions for obtaining ICA components for iris. Here, we only introduce a few of algorithms for
feature extraction and match. In practice, there are many successful algorithms.

3 Future Work

In iris recognition field, there are many problems have been solved; however, there are also many problems need us to solve. A prominent difficulty is the design of iris image acquisition system. At present, there are a few companies having this technology; moreover, the equipment is especially expensive. One of the reasons is the illumination. Usually, the texture of iris can not be seen under visible light. The rich and complex feature can only been seen under the near infrared. The other reason is the difficulty how to ensure every image is focused and has few quality problems as possible. In practice, there are many uncertain factors to cause iris image quality problems. We can not avoid all of them, but we should avoid them as possible as we can.

How to construct an unusual iris image quality evaluation system is also a difficult task for us. Now, many scholars have proposed many algorithms to construct an iris image quality evaluation model. Actually, these algorithms only give attention to some of the problems such as eyelid and lash occlusion and defocus. In practice, there are more problems we should think of. Constructing an efficient, simple and universal iris image quality evaluation model is important.

The algorithms of iris localization are various. They have improved the speed and accuracy of localization; however, they don’t perform well when locating the outer boundary of iris. As we know, the outer boundary region of iris always has eyelash occlusion problem. To design an iris localization algorithm which will not be influenced by some eyelash collsion is a challenge for us.

The other parts such as normalization, feature vector extraction and match also need to be improved to reduce the FMR and FNMR of the whole system. In a word, there are many challenges for us in the future.

4 Conclusions

Iris recognition has a long and colourful history. In these years, it becomes a hot field of research. Now, there are many iris recognition algorithms having been proposed. In this paper, we list some successful algorithms and compare their performance. Furthermore, we introduce some existing problems and challenges for the researcher in this field. We hope this paper will be helpful for the new comers of this field.

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References


Brief Introduction to Author(s)

XIE Mei (解梅) graduated from Department of Electronic Engineering of Chengdu Institute of Radio Engineering (currently Institute of Electronic Engineering, University of Electronic Science and Technology of China), Chengdu, China, February 1982. Before 1985 she worked as a Research Assistant at the China Southwest Institute of Electronics Technology. In 1985, she joined with Electrical Engineering Department, University of Electronic Science and Technology of China (UESTC). She received the M.S. and Ph.D. degrees all in Institute of Electronic Engineering, from UESTC, in 1991 and 1996, respectively.

From Sept. 1997 to Sept. 1998, she was with the Digital Signal Processing Lab of the Department of Electrical and Electronic Engineering, University of Hong Kong, as a Postdoctoral Fellow, where she worked on the wavelets applications in image processing and digital communications. During the academic years 1998-1999, she was on leave from Hong Kong University as a Postdoctoral Fellow of Electrical Engineering at the University of Texas, San Antonio, US, and switched research interest to focus on algorithms and software for the detection and segmentation of the mammograms.

She is currently a professor at the Institute of Electronic Engineering of UESTC. Her major research interests include digital signal processing, image processing, and computer networks. Her current technical interests include video compression, biology recognition, and wavelet analysis. She is now in charge of several projects, which founded separately by Ministry of Information Industry, National Defense Foundation of China, etc.

She has published over 40 academic papers, and accomplished over 5 research projects. Professor Xie has received a number of awards and honors, including: 2nd Class Award of Ministry of Electronic Industry for Science and Technology Progress, UESTC Award for Distinguished Young Faculty, Honor of Excellent Teacher. Prof. Xie is a member of Expert Group of Ministry of Information Industry of China and a member of Expert Group of Natural Science Foundation of China.