An Adaptive Algorithm of Iris Image Key Points Detection

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Abstract

A modification of iris recognition algorithm using Hermite transform to find iris key points has been developed. The iris image mask for the areas free of eyelids, eyelashes and glares is constructed. The key points are found inside the masked iris region. The use of eye rotation compensation based on Polar Hermite Transform before iris parameterization makes the method more effective. The proposed algorithm is tested with CASIA-IrisV3 database. The estimation of optimal number of iris key points is analyzed.

Keywords: biometrics, iris recognition, Hermite transform, iris key points, mask.

1. INTRODUCTION

The extraction of iris feature parameters consists of 2 steps: iris segmentation and iris parametrization. At the segmentation step [1] the iris areas which are free of glares, eyelashes and eyelids are determined (Fig. 1). These areas are called as iris mask. The parameterization step [2, 3] extracts the iris informative parameters from the masked iris area. These parameters are used at the iris comparison and iris identification stage. These techniques are under intensive investigation now. Special contest had been organized by SOCIA Lab for best mask construction for UBIRIS.v2 database [4] of visible wavelength iris images captured at-a-distance and on-the-move [5].

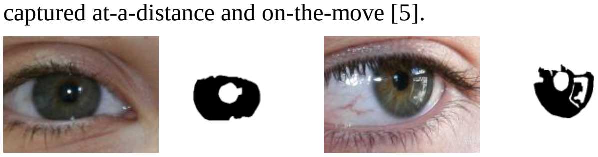


Figure 1: The examples of eye images and their masks.

In our previous work [6] the key points based iris recognition method using Hermite transform [7] was proposed. This method showed good results for CASIA-IrisV3 [8] database, although 0.23% of iris images were recognized incorrectly. CASIA database contains iris images (Fig. 2) with infrared illumination.

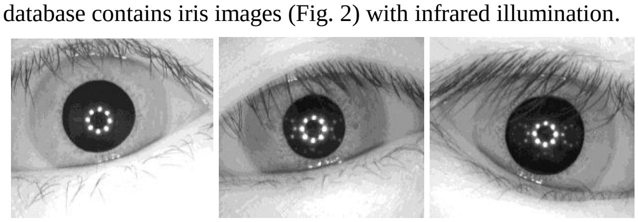


Figure 2: The examples of CASIA iris images.

This work proposes the modification of the previous iris parametrization method. In this work the iris mask which determines the iris areas free of eyelids, eyelashes and glares is built automatically for each eye from the database. The intersection of taken eyes masks forms the common pair mask for each eyes pair. The key points are then selected only inside the common mask region and these key points are unique for the taken pair.

The structure of the article is follows: section 2 describes the algorithm of iris mask construction. Section 3 proposes Polar Hermite Transform algorithm for eye rotation determination. The composition of common images mask is described in section 4. In section 5 we estimate the optimal number of key points for iris parameterization and present the experimental results for CASIA-IrisV3 database.

2. IRIS MASK CONSTRUCTION

The general scheme of iris recognition method described in [6] is the following:

- After iris localization the iris is mapped to a rectangular image [9] (Fig.3).
- Then the iris key points are selected using the Hermite transform method in the parameterization region of the normalized iris image.
- At the identification stage the comparisons between key points matrixes are used [6, 9].

In [6] we used only the top right quarter of normalize iris image as the parametrization region (Fig. 3). In this work we construct the parametrization region (the iris mask) using the whole normalized iris image.

Figure 3: Iris localization and normalization.

To compare iris images correctly the iris mask must exclude the areas occluded by eyelids, eyelashes and glares. Otherwise many key points will correspond to these bad areas (Fig.4). This is caused by the form of Hermite transform function $\varphi_{1,0}$ found optimal for iris convolution analysis in [6] (Fig.5).

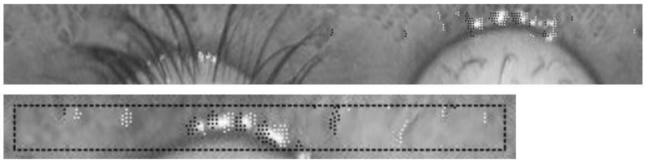


Figure 4: The normalized iris image which parametrization region (inside the dotted line) is occluded by eyelid and eyelashes.

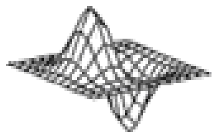


Figure 5: Hermite transform function

$$\varphi_{1,0}(x,y) = -\frac{\sqrt{2}}{\pi} \cdot x \cdot e^{-(x^2+y^2)}.$$

The mask value is equal 1 in the point (i, j) if this point is not occluded by glares, eyelids or eyelashes. Otherwise the mask value is 0. The mask construction consists of two steps. We find:

1. the points occluded by glares and eyelashes,
2. the points occluded by eyelids.

To find glares and eyelashes Canny Edge detector [10] is used (Fig. 6). The Canny algorithm thresholds in this work are TL=0, TH=50. With these values we detect glares and eyelashes edges and suppress the detection of the edges in the iris texture regions.

The eyelid is often less contrast than glares so the eyelid edges are only partially detected by Canny edge detector with the chosen thresholds. To find the whole eyelid in the normalized iris image we use the following formula (the same formula as is used to find the iris boundary at the iris segmentation stage):

$$\max_{r,x_o,y_o} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r,x_o,y_o} \frac{I(x,y)}{2\pi r} ds \right|.$$

The results of iris mask detection are shown in Fig.6.

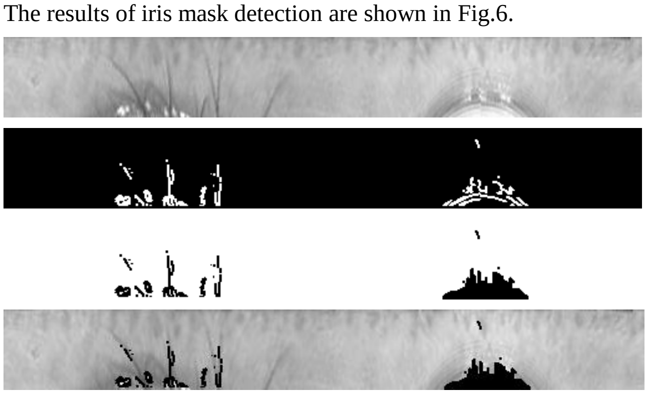


Figure 6: The normalized iris image, its edges by Canny edge detector, obtained iris mask and the result of masking (black areas are excluded by the mask).

3. EYE ROTATION ESTIMATION USING POLAR HERMITE TRANSFORM

If one of the images is rotated throw the angle θ relative to the other one then this angle must be taken into account at the comparison stage. So we have to shift the rotated normalized iris image cyclically before parameterization. This operation is equivalent to the initial image rotation (Fig. 7).

Figure 7: Normalized iris images before rotation.

To determine the rotation angle we use the Polar Hermite Transform. Let $l_{i,j}$ be the cartesian Hermite coefficients [11, 12] of the image, i.e. the coefficients of expansion of iris image intensity information in series of Hermite functions ψ which are eigenfunctions of the Fourier Transform.

$$l_{i,j} = \int_{-\infty}^{\infty} dy \int_{-\infty}^{\infty} I(x,y) \cdot \psi_{i,j}(x, y)\, dx.$$

The polar Hermite coefficients $l^p_{n-k,k}$ are calculated from the cartesian Hermite coefficients $l_{n-m,m}$ using formulae [11, 12]:

$$l^p_{n-k,k} = \sum_{m=0}^{n} G_n^{c\tilde{p}}(m,k) \cdot l_{n-m,m} \quad ,$$

$$G_n^{c\tilde{p}}(m,k) = \frac{1}{2\pi} \int_0^{2\pi} \alpha^c_{n-m,m}(\omega) \cdot \tilde{\alpha}^p_{n-k,k}(\omega) d\omega \quad ,$$

$$\alpha^c_{n-m,m}(\omega) = \sqrt{\frac{n!}{(n-m)!m!}} \cdot \cos^{n-m}\omega \cdot \sin^m \omega \quad , \quad m=0,\dots n,$$

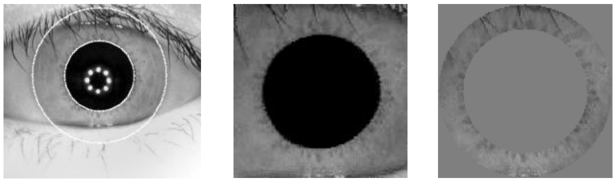
$$\tilde{\alpha}^p_{n-k,k}(\omega) = \sqrt{\frac{2^n (n-k)!k!}{n!}} \cdot \begin{cases} \sqrt{2}\cos(n-2k)\omega, & 0 \le k < \frac{n}{2} \\ 1, & k = n-k \\ \sqrt{2}\sin(n-2k)\omega, & \frac{n}{2} < k \le n \end{cases}$$

The very useful property of polar coefficients is that the polar coefficients of rotated throw the angle θ image are calculated fast:

$$\begin{bmatrix} l^p_{n-m,m}(\theta) \\ l^p_{m,n-m}(\theta) \end{bmatrix} = \begin{bmatrix} \cos(n-2m)\theta & \sin(n-2m)\theta \\ -\sin(n-2m)\theta & \cos(n-2m)\theta \end{bmatrix} \cdot \begin{bmatrix} l^p_{n-m,m} \\ l^p_{m,n-m} \end{bmatrix}.$$

So to calculate the polar coefficients for the image rotated through the angle θ we just multiply the rotation matrix and the polar coefficients of non-rotated image.

To calculate the angle of eye image rotation the images are first transformed to the normalized template ($N \times N$ square). The template has the pupil in the center of the iris and the pupil have the fixed radius ($r' = N/3$). Then the iris is reduced to the fixed width of 64 pixels. The part of image which is inside the $N \times N$ square is used as normalized template image (Fig. 8b) and we use for the rotation estimation only the ring marked in Fig. 8c.



(a) (b) (c)

Figure 8: (a) – the input image, (b), (c) – the normalized template construction.

Then we calculate the polar Hermite coefficients $l_{n-i,i}$ for $n = 0,1,...,31$, $i = 0,1,...,n$ for the inspected normalized eye image and polar coefficients for the same image rotated through the different angles $\varphi = \pm 2^o, \pm 4^o, ..., \pm 20^o$. All these coefficients are compared with polar coefficients of the rotated image. As images comparison metric we use the sum of square differences between the corresponding coefficients of images. The angle with the smallest comparison distance is taken as rotation angle between the images. An example of the proposed algorithm for the images given in Fig. 7 is shown in Fig. 9.

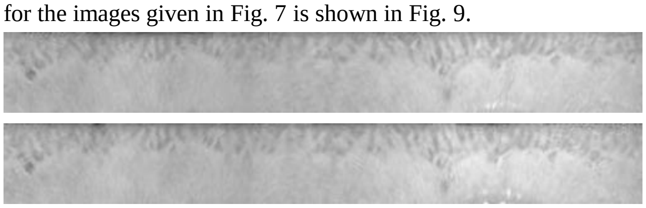


Figure 9: The normalized iris images after rotation.

4. COMMON MASK OF TWO IRISES

After rotation correction the common mask of two images is formed. The common mask is an intersection of the masks of each iris image (Fig. 10). To reduce the influence of glares, eyelashes and eyelids areas at the iris key points extraction stage we narrow the common mask by the fixed number of pixels.

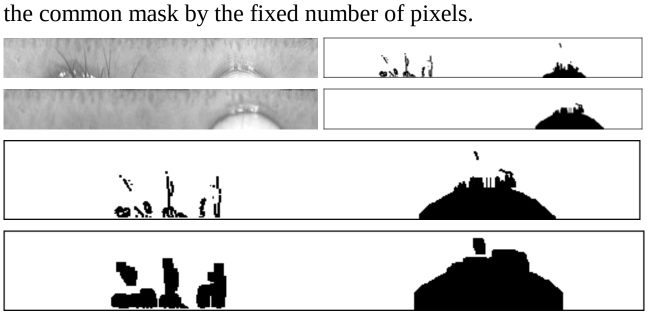


Figure 10: The common mask of two iris images after rotation elimination (the mask is marked by white color) and the narrowed common mask.

5. PRACTICAL APPLICATION OF THE ADAPTIVE ALGORITHM OF IRIS IMAGE KEY POINTS DETECTION

Before the iris key points extraction the histogram of normalized iris image is equalized inside the common mask region (Fig. 11). Key points are found for the histogram equalized iris images. The value $F(x_0, y_0) = \left(I(x,y) * \varphi_{1,0}(x,y)\right)(x_0, y_0)$ is calculated in each point of masked image for key points extraction, where $\varphi_{1,0}$ is the Hermite transform function. As an iris code (iris key points) we take *N* points (*N* = 300, the choose of this *N* value will be argued below), which form two groups: *N*/2 points with the maximal *F* values (black points in Fig. 12) with the condition that the minimal distance between these points is 2 pixels, and similarly *N*/2 points with the minimum of *F* values (white points).

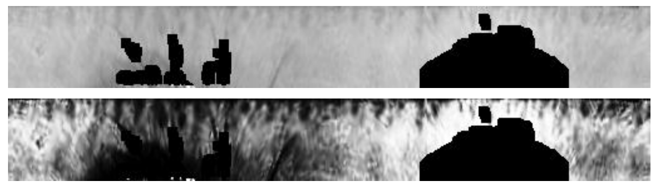


Figure 11: The normalized iris image with the common mask before and after histogram equalization.

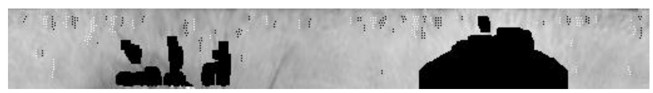


Figure 12: The iris key points.

5.1 Estimation of optimal number of key points

In previous work [6] it was shown that the optimal number of iris key points is close to 150 points for the case of the top right quarter used as the parameterization region (Fig. 13).

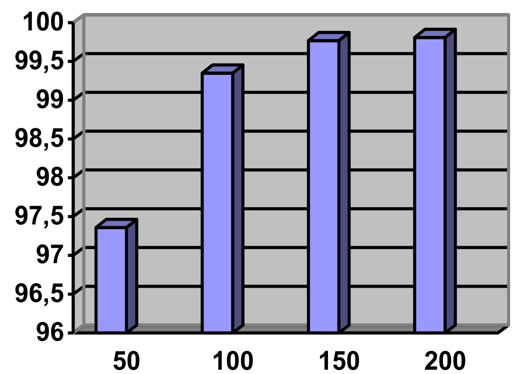


Figure 13: The diagram of correct recognition rate (in %) depending on number of key points.

Using this diagram the optimal number of key points for the masked parameterization region was selected. We realized the next calculations for each of two points group. Let M_i is the maximum of convolution modulus value for the image i for the taken key points group and the convolution value for the last taken key point (150^{th} key point) from this group is $\frac{M_i}{k_i}$. We averaged k_i values throw the whole database and obtained the average value $k_{mean} = 2.08$. Thus for image i we found N_i key points in the common mask region in the range $\left[\frac{M_i}{k_{mean}}, M_i\right]$. Averaging of N_i values for the whole CASIA-IrisV3 database gave us the average value $N \approx 300$.

5.2 Results for CASIA-IrisV3 iris database

To evaluate the effectiveness of the proposed key points method all irises which were falsely recognized in [6] (using the fixed parameterization region) were tested. All these eyes are recognized correctly using the masked parameterization regions approach. So the iris key points recognition algorithm allows us to obtain 100% correct recognition rate with CASIA-IrisV3 database.

6. CONCLUSION

A modification of previously proposed iris recognition algorithm using Hermite transform to find iris key points has been developed. The iris mask which determines the iris areas free of eyelids, eyelashes and glares is constructed automatically for each eye. The key points are found inside the masked iris region. Eye rotation compensation was performed using Polar Hermite Transform. The proposed algorithm is tested with CASIA-IrisV3 database and showed 100% recognition rate. The future work will include speed optimization of the proposed algorithms and their application to visible wavelength iris data.

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