New Corneal Reflection Removal Method Used In Iris Recognition System

Walid Aydi, Nouri Masmoudi, Lotfi Kamoun

Abstract—Images of human iris contain specular highlights due to the reflective properties of the cornea. This corneal reflection causes many errors not only in iris and pupil center estimation but also to locate iris and pupil boundaries especially for methods that use active contour. Each iris recognition system has four steps: Segmentation, Normalization, Encoding and Matching. In order to address the corneal reflection, a novel reflection removal method is proposed in this paper. Comparative experiments of two existing methods for reflection removal method are evaluated on CASIA iris image databases V3. The experimental results reveal that the proposed algorithm provides higher performance in reflection removal.

Keywords—iris, pupil, specular highlights, reflection removal

I. Introduction

IRIS recognition is one of the most important and reliable technique aging invariant, compared with other biometric features like face, voice...etc. From his beginning [1] till now [2]-[7] have been proposed for automatic personal identification.

Due to the acquisition technique and the reflective properties of the cornea, images of human iris contain specular reflection as shown in Fig. 1. The cornea is the transparent and very smooth, front part of the eye that covers the iris, pupil, and anterior chamber. It's considered as a convex mirror giving rise to the corneal image or corneal reflection.

The corneal reflection is the fact that the light produces on the eye. This is considered as noisy points in iris image that causes severe errors during iris segmentation method. Many specular reflection removal methods have been proposed yet. In this paper we will, just focus on two recently methods.

In 2009 bilinear interpolation method [8] uses an edge map to interpolate reflection points in original image. The second method in 2010 [9] uses connectivity of four pixels after evaluating image complement in order to interpolate corneal reflection. There are also many other methods that use morphological operator to remove specular reflection [6]. In this work we start in section II by giving explanation of two corneal reflection methods using bilinear and four pixels connectivity interpolation. In section III we propose a new

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method aiming at accurate and fast interpolation of corneal reflection. This algorithm consists of four modules, namely, Top-hat, image thresholding, image dilation and corneal reflection Interpolation.

The remainder parts of this paper are subdivided in two sections. In section IV, comparative experiments of two existing methods for reflection removal method are evaluated on CASIA iris image databases V3.0. In section V we present the conclusion and a description of our future work.

II. Previous Work

A. First Method: bilinear interpolation

In [8], Zhaofeng begin by evaluating a binary reflection map using adaptive thresholding value (top 5 % brightest intensity in the iris image) as shown in Fig. 1. Then he fills reflections points, in the original image, using bilinear interpolation method.

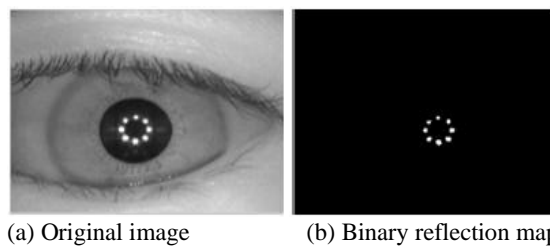(a) Original image   (b) Binary reflection map

Fig. 1 Binary reflection map generation

To evaluate a reflection point $P(x_{ref}, y_{ref})$ the method uses four envelop points: $P_{right}(x_{right}, y_{ref})$, $P_{left}(x_{left}, y_{ref})$, $P_{top}(x_{ref}, y_{top})$ and $P_{down}(x_{ref}, y_{down})$ as illustrated in Fig.2.
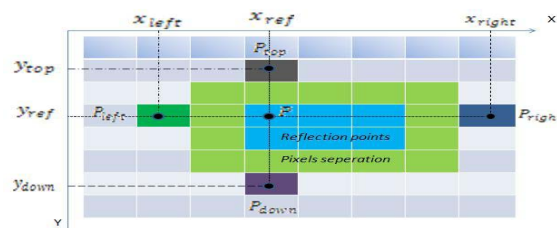

Fig. 2 Reflection points interpolation

In order to clarify how this technique works, we begin by interpolating the first point P. We try first to find the coordinates of 4 nearest points $P_{right}, P_{left}, P_{top}$ and P_{down} who don't belong to the reflection map and far from it by one pixel (pixels separation) using (1) to (4):

$$x_{left} = max\left\{x : \sum_{0}^{L-1} R_{(x+i,y_{ref})} = 0, R_{(x+L,y_{ref})} = 1, x < x_{ref}\right\} (1)$$

$$x_{right} = min\left\{x : \sum_{0}^{L-1} R_{(x-i,y_{ref})} = 0, R_{(x-L,y_{ref})} = 1, x > x_{ref}\right\} (2)$$

$$y_{top} = max\left\{y : \sum_{0}^{L-1} R_{(x_{ref},y+i)} = 0, R_{(x_{ref},y+L)} = 1, y < y_{ref}\right\} (3)$$

$$y_{down} = min\left\{y : \sum_{0}^{L-1} R_{(x_{ref},y-i)} = 0, R_{(x_{ref},y-L)} = 1, y > y_{ref}\right\} (4)$$

Here L=1 controls the seperation between refelection points and the envelop points. It's clear that all points in the same line (column) have the same P_{left} (P_{top}) and P_{right} (P_{down}) respectively. Using the coordinates of reflection points and the four envelop points, we can interpolate the reflection pixels in the original image using (5). The result of this method using MMU iris database is illustrated in Fig. 3.

$$I(P) = \frac{I(P_{left})(x_{right} - x_{ref}) + I(P_{right})(x_{ref} - x_{left})}{2(x_{right} - x_{left})}$$
$$+ \frac{I(P_{top})(y_{down} - y_{ref}) + I(P_{down})(y_{ref} - y_{top})}{2(y_{downt} - y_{top})} \quad (5)$$
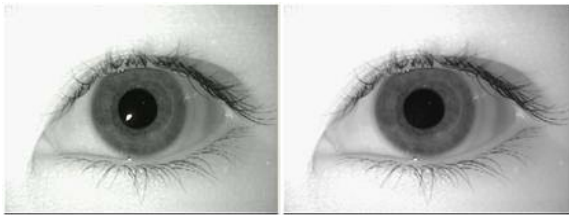
(a) Original image   (b) Result of reflection removal
contaminated by reflections

Fig. 3 Specular reflection removal for MMU iris database

This method gives good result with MMU iris database but it wouldn't with Casia iris database V3.0. Fig. 4 shows the resulted image of Casia iris database V3.0 after corneal reflection removal.
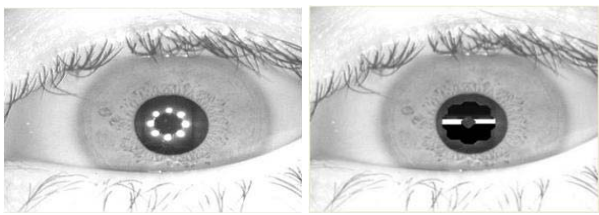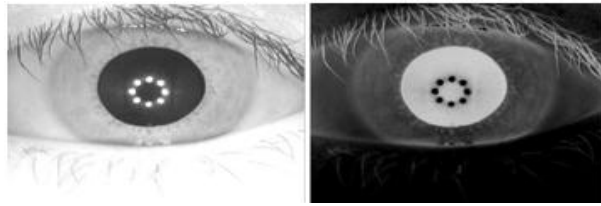

(a) Original image   (b) Result of reflection removal

Fig. 4 Specular reflection removal for casia iris database V3.0

B. Second Method: Connectivity of four pixels

Because the reflection points are white, takingimagecomplement, can transform white points to dark. To compute image complement we subtract each pixel value
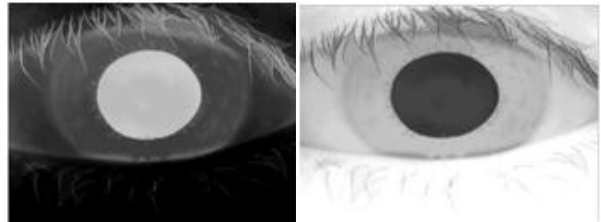
from the maximum value of pixel (here we took it 255) as shown in Fig. 5.

(a) Original image   (b) Image complement

Fig. 5 Image complement

In order to interpolate reflection points, this method fills the dark points or holes in image complement based on connectivity of four pixels. After that, the image complement is evaluated again. Fig. 6 shows the result of this method.

(a) Image complement after   (b) Result of reflection removal
filling dark points.

Fig. 6 Interpolation of reflection points

Although this method gives a good result for MMU iris data base and casia iris image database V3.0 iris strcture was totally modified which is making it unsuitable to generate the template. We can deduce that from the SSIM value gived in the table II. Also this technique sweep all image in order to fill all dark points without focus on the area of interest. So a waste of time for nothing.The SSIM criterion is a method for measuring the similarity between two images which are: original image and the resulted of corneal reflection removal.

III. PROPOSED METHOD: LINEAR INTERPOLATION EXTENSION

In our method we begin by evaluating a reflection map using a Top-hat, morphological operator and a suitable threshold. In Fig. 7 we show the steps of our method.
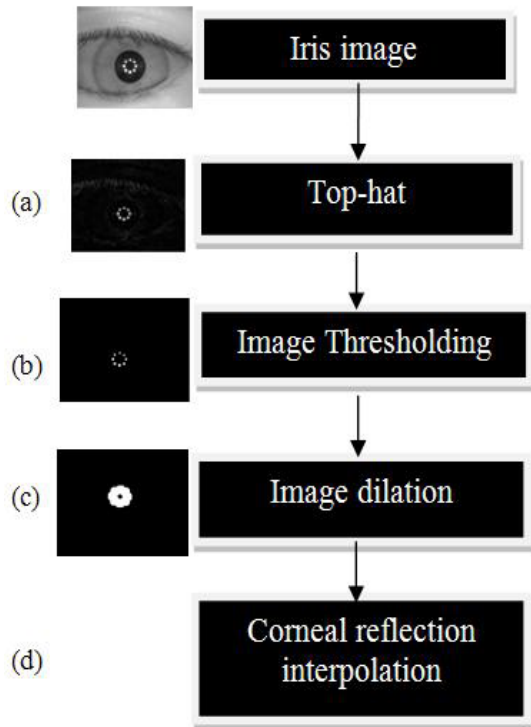
Fig. 7 The flowchart of the reflection map interpolation: a) Top-hat. b) Image thresholding. c) Image dilatation. d) Corneal reflection interpolation

Usually, specular reflections appear as the brightest points in the iris image, this is more specific for CASIA database V3.0.So a white top-hat which is defined as the difference between the input image and its opening by some structuring element. After that a suitable threshold is used to isolate this kind of points.

In thresholding step, we adopt an average threshold based on the histogram of all images database V3.0. After that it follows an image dilate stage in order to cover the most part of these spots and their neighbors. Dilation adds pixels to the boundaries of objects. The number of pixels added to the objects in an image depends on the size and shape of the structuring element used to process the image.

Our method is based on linear interpolation. The idea is to perform first a linear interpolation in x direction and then in the y direction[1]. For example we want to compute the value of unknown function f of pixel located at the point $P(x, y)$ (Fig. 8). We suppose that we know the value of f in the four pixels Q_{dl}, Q_{dr}, Q_{tl} and Q_{tr}. First, we begin by doing linear interpolation in the x direction using two points P_1 and P_2. As shown in (6) and (7):

$$f(P_1) = \frac{x_2 - x}{x_2 - x_1} f(Q_{dl}) + \frac{x - x_1}{x_2 - x_1} f(Q_{dr}) \qquad (6)$$

[1] It's the same if we first performed the linear interpolation in the y-direction and then in the x-direction.

$$f(P_2) = \frac{x_2 - x}{x_2 - x_1} f(Q_{tl}) + \frac{x - x_1}{x_2 - x_1} f(Q_{tr}) \qquad (7)$$

Then in the y direction we deduce the result from (6) and (7).

$$f(P) = \frac{y_2 - y}{y_2 - y_1} f(P_1) + \frac{y - y_1}{y_2 - y_1} f(P_2) \qquad (8)$$
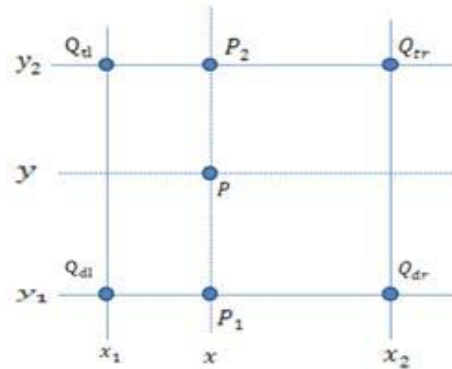

Fig. 8 Reflection point interpolation Scheme

The result of corneal reflection removal of our method applied on MMU iris database and Casia iris databaseV3.0 is shown in Fig. 9 and Fig.10. It gives a good result without detruction of iris structure.

(a) Original image   (b) Reflection removal result

Fig. 9 Result of reflection removal for MMU database

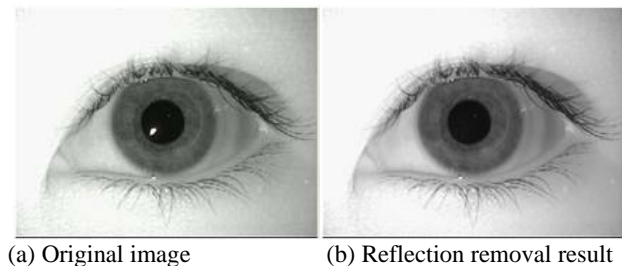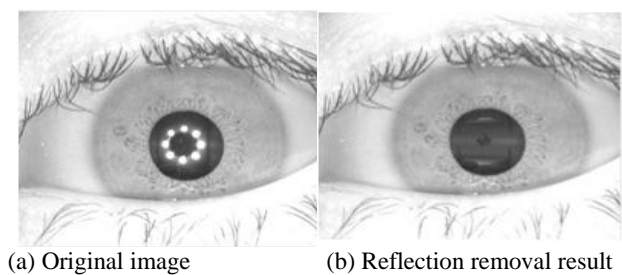(a) Original image   (b) Reflection removal result

Fig. 10 Specular reflection removal for casia iris database

IV. COMPARISON

In the experiment, we used Matlab 7.9.0. With computer Duo CPU 2 GHz and 2.99Go of RAM and CASIA iris image

databases V3.0. In this section we compare between three methods illustrated above. We take in consideration three important metrics: time computing, reserved memory allocated by this algorithm and the structural similarity index SSIM to mesure image quality. For our method and the first one we take the same binary reflection map to interpolate the reflection points in the original image. Our method gives better matches in terms of image quality, time computing and memory occupation. As illustrated in Fig. 11, table I, table II and table III.Note that, the resulted image of our method is useful for segmentation and encoding stages because a little harm is made to the iris structure, but for the second method image structure was modified making it useless to encode data. We notice this from the SSIM value shown in table II. Moreover and during encoding stage if the reflection points are located in iris region the second method is not the good one.
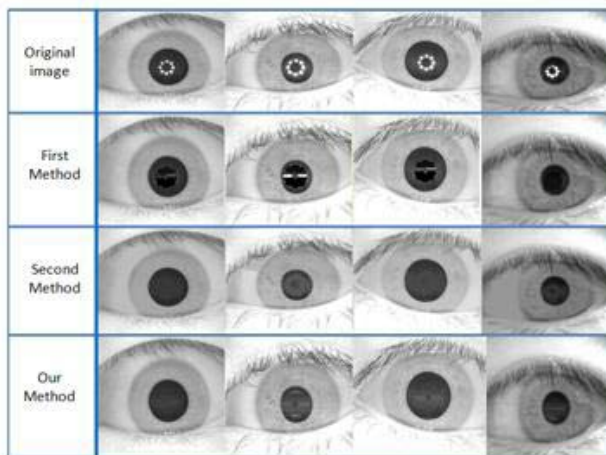

Fig. 11 Result of reflection removal for the three methods from iris Image Database V3.0

TABLE I
THE TIME VALUE WITH DIFFERENT METHOD OF CORNEAL REFLECTION REMOVAL

Image	First Method	Second Method	Our Method
Image1	2.326(s)	0.255(s)	0.184(s)
Image2	2.689(s)	0.262(s)	0.193(s)
Image3	2.516 (s)	0.253(s)	0.180(s)
Image4	2.060 (s)	0.253(s)	0.182(s)
Mean time	2.397(s)	0,255(s)	0.184(s)

s = second.

TABLE II
THE SSIM VALUE WITH DIFFERENT METHOD OF CORNEAL REFLECTION REMOVAL

Image	First Method	Second Method	Our Method
Image1	0.967	0.924	0.980
Image2	0.959	0.915	0.969
Image3	0.961	0.913	0.975
Image4	0.977	0.935	0.981
Mean SSIM	0.966	0.921	0.976

SSIM = Structural SIMilarity

TABLE III
MEMORY OCCUPATION WITH THE THREE METHOD OF CORNEAL REFLECTION REMOVAL

Image	First Method	Second Method	Our Method
Memory occupation(Kbyte)	671.42	794.885	642.0683

Kbyte = Kilobyte.

V. CONCLUSIONS

In this study we compared between three methods that are used for corneal reflection removal. This step is useful to avoid errors in segmentation stage. Especially for methods which use active contour and for others which can easily estimate the center of iris and pupil. We prove that our method is the fast one and made the least harm to iris structure, who make it the suitable one to remove corneal reflection. Also in terms of memory reservation for our algorithm we prove that we had reserved less memory than other .Moreover we can use our method for the most iris database. As the demand for information security increases more and more ,our future work will focus on the implementation of a robust iris recognition system using field-programmable gate arrays (FPGAs).

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