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Iris Segmentation for Non-ideal Images

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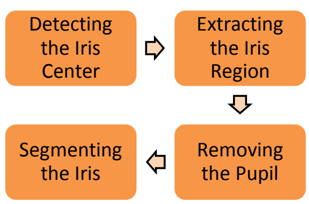
Graphical abstract



Abstract

Iris recognition has been regarded as one of the most reliable biometric systems over the past years. Previous studies have shown that the performance of iris recognition systems highly dependent on the performance of their segmentation algorithms. Iris segmentation is the process to isolate the iris region from the surrounded structures of the eye image. However, several iris segmentation algorithms have been developed in the literature, but their segmentation and recognition accuracies drastically degrade with non-ideal iris images acquired in less constrained conditions. Thus, it is crucial to develop a new iris segmentation method to improve iris recognition using non-ideal images. Hence, the objective of this paper is an iris segmentation method on the basis of optimization to isolate the iris region from non-ideal iris images such those affected by reflections, blurred boundaries, eyelids occlusion, and gaze-deviation. Experimental results on the off axis/angle West Virginia University (WVU) iris database demonstrated the superiority of the developed method over state-of-the-art iris segmentation methods considered in this paper. The performance of an iris recognition algorithm based on the developed iris segmentation method was observed to be improved.

Keywords: Biometrics; iris recognition; non-ideal iris segmentation; optimization

Abstrak

Pengecaman iris telah dianggap sebagai salah satu sistem biometrik yang paling dipercayai sejak beberapa tahun lalu. Kajian terdahulu telah menunjukkan bahawa prestasi sistem pengecaman iris sangat bergantung kepada prestasi algoritma segmentasi mereka. Segmentasi iris adalah proses untuk mengasingkan kawasan iris daripada struktur dikeliling imej mata. Walau bagaimanapun, beberapa algoritma segmentasi iris telah dibangunkan dalam kajian kepustakaan, tetapi ketepatan segmentasi dan pengecaman mereka menurun dengan imej iris bukan ideal telah diperolehi dalam keadaan kurang kekangan. Oleh itu, adalah penting untuk membangunkan satu kaedah segmentasi iris baru untuk meningkatkan pengecaman iris menggunakan imej yang tidak sesuai. Oleh itu, objektif kajian ini adalah pengoptimumankaedah segmentasi iris untuk mengasingkan kawasan iris dari imej iris tidak sesuai, sempadan kabur, kelopak mata dan lain-lain. Hasil ujikaji ke atas pangkalan data iris paksi kira / sudut West Virginia University (WVU) menunjukkan keunggulan kaedah yang dibangunkan untuk segmentasi iris dianggap terkinidalam kertas kerja ini. Pelaksanaan suatu pengecaman algoritma iris berdasarkan kaedah segmentasi iris diperhatikan dan dipertingkatkan.

Kata kunci: Biometrik; pengecaman iris; segmentasi iris tidak ideal; pengoptimuman

1.0 INTRODUCTION

Automatic recognition of individuals has long been a distant dream. In this context, biometric techniques have been emerged as a solution to the problem of recognizing the individuals based on their physiological or behavioral characteristics. Iris recognition is regarded as one of the best biometric techniques, because the iris features are highly unique and stable throughout the human life.[1, 2] The typical iris recognition systems involve four steps, iris segmentation, normalization, feature extraction and matching. However, iris segmentation is the most important step in iris recognition systems, because any error in this step may result to a decrease in recognition performance since the iris features will be improperly encoded. The typical iris segmentation process includes the following steps, detecting the pupil boundary, detecting the outer iris boundary at sclera (the limbic boundary), detecting iris boundaries at lower and upper eyelids, and removing reflections from the iris region. In the literature, numerous iris segmentation methods have been proposed. The majority of these methods utilize the gradient information in detecting the pupil, limbic, and eyelids boundaries.[3,4,5,6,7,8,9&10]

Therefore, they often fail in segmenting the non-ideal iris images due to lighting and specular reflections that deform the gradient information map. Moreover, these gradient-based iris segmentation methods presume that the iris and eyelid boundaries are circular or elliptical in shape; however non-ideal iris images may not maintain particular shapes for the iris and eyelids owing to uncontrolled imaging settings that acquired in.

In the last few years, new schemes on the basis of active contour models have been designed to segment iris images acquired in non-ideal conditions.[11,12,13&14] These schemes enable flexible shapes for iris boundaries, and also allow detecting the limbic and eyelid boundaries simultaneously. In fact, the performance of such schemes is significantly affected by blurred boundaries and reflections noise of non-ideal iris images. In addition, several parameters have to be tuned in order to obtain better convergence to the iris boundaries using active contour techniques.[15] The processing time of active contour techniques relies on adjusting the values of such parameters.[16] Furthermore, active contour-based techniques are iterative techniques (techniques repeat the fundamental procedure to obtain the optimal solution based on a termination criteria), and therefore time consuming. Hence, there is a pressing need to develop a robust iris segmentation method for iris images captured in non-ideal settings.

In this paper, a new iris segmentation method for non-ideal iris images is developed. The developed method involves three major steps. First, the approximate location of the iris center is detected. Second, the iris region is extracted using optimization. Finally, the pupil and reflections are removed from the iris region. The significance of this method is its robustness to realistic noises caused by non-ideal imaging settings such as reflections, blurred boundaries, gaze-deviation, and eyelids occlusion. Furthermore, the iris region is extracted regardless its shape.

■2.0 IRIS SEGMENTATION

2.1 Detecting the Iris Center

To detect the iris center, the pupil region was first isolated. Then, the center of the pupil region was calculated and considered as the desired iris center. A simple thresholding technique was applied to isolate the pupil region from the iris images, with the assumption that the pupil is the biggest and darkest circular region in the iris image.

In this technique, the reflections which may distort the pupil boundary were first eliminated from the iris image using morphological operations (fill image regions and holes). The image pixels with gray level intensities greater than 230 were regarded as reflections and filled up by the surrounding image intensities. Next, an adaptive threshold based on the histogram of the iris image after eliminating the reflections was calculated to isolate the pupil region. This threshold was calculated on the assumption that the pupil region is the darkest region in the iris image. As a result, all pixels fall under this threshold were isolated as pupil pixels. Therefore, an opening morphological operation was applied to remove the small regions composed of such pixels which cannot be a pupil region. Finally, the pupil area was recognized as the biggest circular region of the remaining regions, and the center of the pupil region was obtained as the desired iris center. Figure 1 illustrates example of iris center localization using the proposed technique.

2.2 Extracting the Iris Region

As mentioned above, the iris region of images acquired in non-ideal conditions may not maintain particular shapes. The outer iris boundaries may also partly occlude by reflections or eyelids. To overcome these issues, a new method for extracting the iris region from such images was proposed in this section. The proposed method was based on a simple assumption: the neighboring pixels that have same gray level intensities should belong to the same region. This assumption was formulated as an optimization problem, where the purpose is to aggregate the pixels of iris image in two regions one indicates the iris area and the other indicates non-iris areas. For this purpose, small regions (initial regions) of the iris and non-iris regions were first labeled. Next, the non-initial pixels (the pixels outside initial regions) were appended into initial regions in accordance with the above assumption.

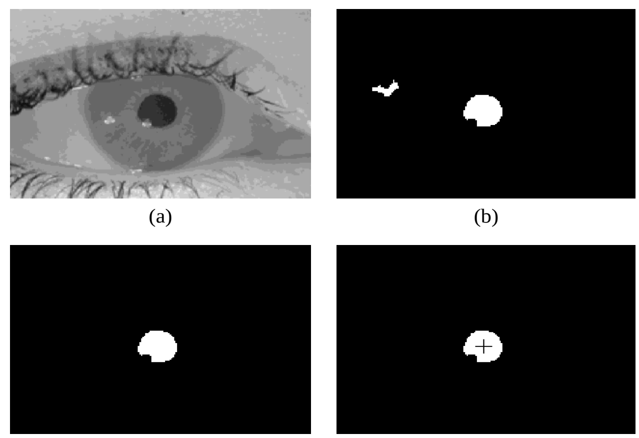
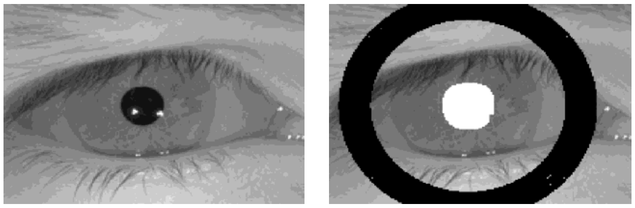

(a) (b) (c) (d)

Figure 1 Example of iris center localization, (a) eliminating the reflections (b) isolating the pupil region (c) removing the small regions which cannot be a pupil region (d) localizing the pupil region and its center, the '+' denotes the localized iris center

The initial regions of the iris and non-iris regions were labeled based on the iris center obtained in the previous section. A small region centered at the iris center was set as an initial region for the iris region, while an annular region around the iris center which is somehow located beyond the limbic boundary was set as an initial region for non-iris regions. On account of this, the localized pupil region in the previous section was dilated a bit and set as an initial region for the iris region, whereas a range of circles centered at the localized iris center were set as an initial region for non-iris regions. Figure 2 shows sample of labeling the initial regions of iris and non-iris regions, where the white pixels denote the iris region and the black pixels denote non-iris regions.
After labeling the initial regions of iris and non-iris regions with '255' (white) and '0' (black) gray level intensities respectively, the iris region was extracted according to impose the following condition: the two neighboring pixels (e.g. p and q) should have similar labels if they have same gray level intensities. This was achieved by minimizing the difference between the label $L(p)$ at pixel p and the weighted average of the labels at neighboring pixels (q) as in the following equation:



(a) (b)

Figure 2 Sample of labeling the initial regions (a) the original iris image (b) the iris image shows the initial regions of iris (white pixels) and non-iris regions (black pixels)

minimize
$$J(L)=\sum_{p}\left(L(p)-\sum_{q\in N(p)}w_{pq}L(q)\right)^{2} \quad (1)$$

where w_{pq} is a weighting function that sums to one, and $q\in N(p)$ indicates that p and q are neighboring pixels. Similar to our work [17], the popular Gaussian weighting function was used:

$$w_{pq}=e^{(-\gamma(I(p)-I(q))^{2})} \quad (2)$$

where γ is a free parameter in this function, and I denotes the gray level intensity; however if the gray level intensities at p and q are similar the wpq is large and vice versa. The $J(L)$ was minimized subject to the following constraint:

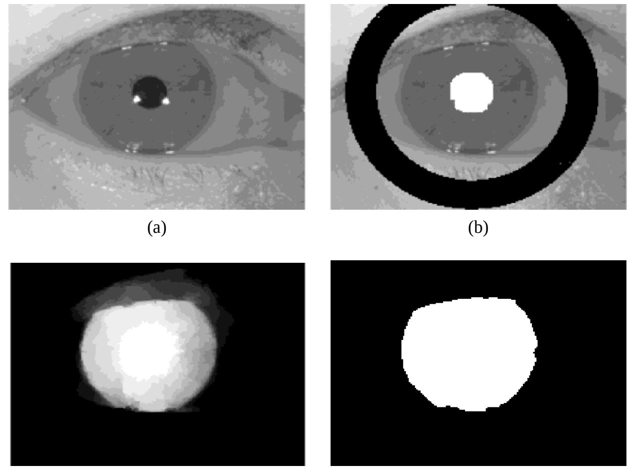
$$l(p_j)=b_j \quad p_j\in \text{initial regions} \quad (3)$$

where l is the label given to pixel p_j, b_j (j = 1, 2, 3, …, m) is the gray level intensity assigned to the initial region that contains p_j, and m is the number of pixels in the image. Since the objective function (Equation 1) is quadratic and the constraint (Equation 3) is linear, this optimization problem was presented as a sparse system of m linear equations and solved using the built in least squares solver for sparse linear systems of Matlab. As a result, a new image displays the pixels outside the initial regions with gray level intensities similar to those of initial regions was produced.

After that, a threshold was applied on this image to generate a binary image shows only two regions, one indicates the iris region and the other one indicates the non-iris regions. According to the gray level intensities assigned to initial regions (Figure 2), the region with '255' (white) gray level intensities of this binary image represents the extracted iris area. Figure 3 presents an example of extracting the iris region using optimization.

2.3 Removing the Pupil

The pupil and reflections are non-iris regions, and hence they must be removed from the iris region in order to complete the iris segmentation process. The pupil region was removed using the thresholding technique described in Section 2. After removing the pupil region, the pixels with gray level intensities greater than $2\times I_M$ were isolated as reflections, where I_M is the mean gray intensity of the iris region after removing the pupil region.



(a) (b) (c) (d)

Figure 3 Extracting the iris region using optimization (a) the original iris image (b) the iris image shows the initial regions (c) iris and non-iris regions obtained by optimization based on the initial regions (d) the iris mask produced by applying a threshold on the image in 'c'

3.0 RESULTS AND DISCUSSION

The performance of the proposed iris segmentation method was evaluated using the WVU iris image database. The WVU database was developed in West Virginia University, the first release of this database was called off axis/angle iris database.[18] Two cameras were used to collect the iris images of this release, a Sony Cyber Shot DSC F717 and a monochrome camera. The Sony camera was used to collect iris images in NIR illuminations, whereas the monochrome camera was used to capture images under visible wavelength illuminations. Only the images collected by means of the monochrome camera would be considered in this paper, because acquiring iris images under the visible wavelength illumination causes reflections on the iris. In the remainder of this paper, the abbreviation WVU indicates to the images collected using the monochrome camera. However, the WVU database contains 584 images collected from 73 subjects. Eight images from each subject, four images from the left eye and the other four from the right eye. These four images were taken in less constrained acquisition settings at 0^o, 15^o, 30^o, and 0^o angles, respectively. The iris segmentation method proposed in this paper was evaluated using the right iris images of the WVU database.

Extensive experiments on right iris images of the WVU database are conducted to evaluate the performance of the proposed iris segmentation method. First, the robustness of the proposed iris segmentation method to different noises is validated. Second, the segmentation performance of the proposed method is qualitatively compared with the performance of Geodesic active contours (GAC) method.[13] Finally, the proposed method is further evaluated through comparing the recognition performance obtained by the proposed method with the recognition performance obtained by the GAC method.

Figure 4 illustrates samples of good iris segmentation results achieved by the proposed iris segmentation method despite of reflections on the iris boundaries, reflections on the iris region, eyelids occlusion, and gaze-deviation.

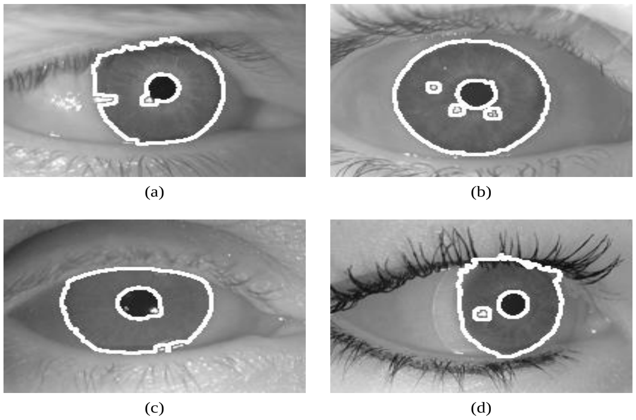


Figure 4 Samples of good iris segmentation results achieved by the proposed method despite of (a) reflections on the iris boundaries (b) reflections on the iris region (c) eyelids occlusion and (d) gaze-deviation

Figure 5 shows segmentation results obtained by the proposed and GAC segmentation methods; the results demonstrated that the proposed method achieved better than GAC method on images with blurred boundaries between the iris and sclera regions. From Figure 5(b), it is clear that the GAC failed to detect iris boundaries due to blurred boundaries between the iris and sclera regions.

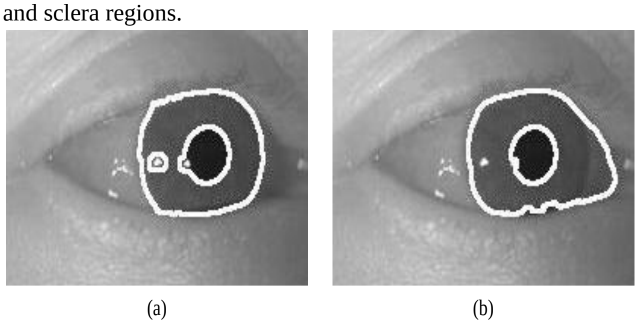


Figure 5 Iris segmentation results obtained by (a) the proposed iris segmentation method (b) the GAC method[13]

In order to validate the effectiveness of the proposed iris segmentation method in improving the recognition performance, an iris recognition system based on the proposed iris segmentation method was first implemented. In this iris recognition system, the segmented iris images were normalized into 64×256 pixels template before applying the Log-Gabor filter[19] to extract the iris features for recognition. After that, the recognition performance of the proposed iris segmentation method was compared with the recognition performance of the GAC iris segmentation method under the same recognition conditions. The equal error rates (EER) were used to show the recognition performances of these methods.

Table 1 Recognition performances based on the proposed and GAC methods using the right iris images of the WVU database

Method	EER (%)
GAC	7.88
Proposed	6.68

From Table 1, it is clear that the proposed iris segmentation method outperformed the GAC method in terms of recognition performance. The proposed method achieved EER up to 17.96% less than that achieved by the GAC method.

■4.0 SUMMARY AND CONCLUSIONS

This paper has presented the development of a new iris segmentation method for non-ideal iris images. The iris was segmented using optimization through labeling small regions from the iris and non-iris regions. Experimental results using iris images of the WVU database demonstrated that the proposed method performed well with different noise factors such as reflections, eyelids occlusion, gaze-deviation, and blurred boundaries. Furthermore, the proposed iris segmentation method showed an improvement in recognition performance compared the GAC method.

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