TEXTURE REMOVAL FOR ADAPTIVE LEVEL SET BASED IRIS SEGMENTATION

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ABSTRACT

Level set based active contour method has been proposed for iris segmentation in recent years, but it can not converge to iris contours in real applications because of its sensitivity to local gradient extremes due to the complex iris texture. In this paper, a novel scheme is proposed to remove local gradient extremes before using level set directly. Firstly, we use two orthogonal ordinal filters to obtain robust gradient map. Then we localize the iris region on the gradient map by an improved Hough transform. After that, a Semantic Iris Contour Map is generated by combining the spatial information of coarse iris location and the gradient map as the edge indicator for level set segmentation. For robust and accurate segmentation, we propose a convergence criterion and a means of updating the parameters for level set. Finally, the accurate segmentation is obtained by the robust adaptive level set method. Encouraging results on ICE 2005 database and CASIA v3 database show the efficiency and effectiveness of our method.

Index Terms— Iris segmentation, level set, semantic iris contour map, convergence criterion

1. INTRODUCTION

Iris segmentation [1] is an important and difficult problem in iris recognition. Traditional methods [2, 3] consider iris contours as circles, while recently active contour has been utilized to improve the performance, which takes iris contours as deformable boundaries. Two main categories of active contour, level set [4] and snake [5] both result in encouraging performance in literature. However, in practical applications, there exist two key problems in active contour. One is how to choose the convergence criterion [6], and the other is how to converge to the global optimal solution.

Iris is an annular region with high distinctive textures between pupil and sclera. That means it is heterogeneous in term of intensity level. Therefore the region based segmentation methods [7] can not tackle this problem properly. Recently, the edge based active contour method have been proposed as an alternative. However, it is difficult to perform it due to its sensitivity to local gradient extremes in iris texture region. Although the texture based level set method [8] has been proposed recently, the iris textures are significantly different from eye to eye.

In this paper, we propose a preprocessing stage to remove the gradient local extremes before applying level set based active contour. Firstly, we detect iris region based on an improved Hough transform; Secondly, Semantic Iris Contour Map (SICM) is generated based on the spatial information of the coarse location of iris region and the original gradient map, which efficiently excludes local extremes in iris region. Finally, level set is adopted for iris segmentation. And a new convergency criterion and an adaptive parameter are proposed for improving the performance the traditional level set method.

The remainder of this paper is organized as follows. Section 2 gives the motivation of this paper. Section 3 describes the technical details of the proposed method. Experimental results and discussions are provided in Section 4, while conclusions are given in Section 5.

2. MOTIVATION

Level set based active contour is used for segmentation via minimizing an energy function to obtain the deformable contour. Although there are many different parameters in different level set methods, but they all have a common form of the object function defined as follows:

$$\varepsilon(\phi) = \mu\varepsilon_{int}(\phi) + \varepsilon_{ext}(\phi) \quad (1)$$

where $\varepsilon_{int}(\phi)$ is defined as the internal energy, while $\varepsilon_{ext}(\phi)$ is the external energy that drives the zero level set towards the contour as external energy.

As mentioned above, iris region contains complex textures, therefore the the region based method level set method is not suitable to this problem due to serious intensity changes in iris region. In this work, we use the edge based level set method proposed by Li et al. [9] for iris segmentation, because it solves the initialization problem which is time con-

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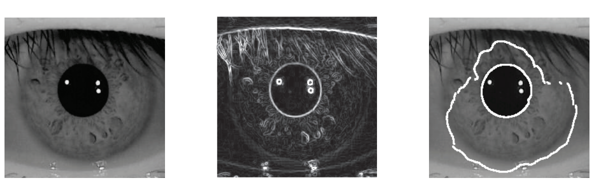
suming in traditional level set methods. In [9] $\varepsilon_{int}(\phi)$ is defined as the penalized term for initialization, and $\varepsilon_{ext}(\phi)$ is calculated as follows:

$$\varepsilon_{ext}(\phi) = \lambda \mathcal{L}_g(\phi) + v\mathcal{A}_g(\phi) \tag{2}$$

where $\mathcal{L}_g(\phi)$ is the geometric energy and $\mathcal{A}_g(\phi)$ is defined as the weighted area to speed up the evolution, v, λ are constant coefficients. The term g is defined as edge indicator function, which is calculated as the gradient map. Please refer to [9] for more details of these terms.

In edge based segmentation, the edge indicator function g is the key part which significantly influences the performance of the algorithm. In iris recognition, the boundary between iris and sclera is low contrast, whose gradient sometimes is even lower than iris textures(see Fig. 1(b)). We choose ordinal filters proposed by Sun et al. [10] to obtain robust gradient image. The main advantage of ordinal filter is its robustness to noises and its adaptiveness to scales. We use horizontal and orthogonal ordinal filters to obtain a robust gradient map. Besides, there are usually lots of local extremes in iris region, such as eyelids, iris textures, eyelashes. These noisy region affects curve evolution. Fig. 1 shows one complex iris texture region and the segmentation result by level set directly. We can see there are many gradient local extremes in iris region, and the segmentation result is dissatisfactory. That is because the curve evolution stops at local extremes rather than iris contours. Therefore we should eliminate these regions in the original g. The low level image processing method can not deal with this properly, and we propose Semantic Iris Contour Map (SICM) as the indicator function rather than the original gradient map.

Regarding to level set, the critical issue is related to its stability and convergence criterion. It is difficult to choose proper parameters and number of iteration to control the convergence, which significantly affects the performance. Therefore, the level set method is usually not robust to noises in complex situations. Most of papers just use a fixed number of iteration and parameters which is time consuming. We propose an adaptive scheme to update these parameters in terms of the spatial information.



(a) (b) (c)

Fig. 1. One failure of iris segmentation by level set. (a) The original iris region; (b) The gradient map by Sobel filtering; (c) The failure of level set.

3. IMPLEMENTATION DETAILS

3.1. Iris Detection

We perform an improved Hough transform which is operated directly on gradient image without edge detection considering the iris contours as circles. Since the outer contour is low contrast, two orthogonal ordinal filters with two Gaussian poles with large scale are used to generate the gradient image. After that, Hough transform is performed to obtain the location of iris, which is represented by center and radius of the circle. A Gaussian filter is used in the voting space to make the result robust to noises. Fig. 2(b) shows an example of the ordinal filter, and Fig. 2(c) illustrates the gradient image obtained by ordinal filters.

3.2. Semantic Iris Contour Map

As mentioned above, iris region is not homogeneous due to the complex textures which usually make curve evolution stop at local extremes. Therefore it is desirable to remove these points for better segmentation. We use a Distance Map generated by sigmoid function and the original gradient image to obtain a Semantic Iris Contour Map, in which there are few local extremes in iris region, instead of the original gradient map g as the edge indicator.

The Distance Map is generated based on the iris location assuming the iris texture is more complex near the pupil than far away from the pupil. It is defined as follows:

$$DM(p) = \frac{1}{1 - exp\{-\frac{d(p,c)-t}{s}\}}. \tag{3}$$

where $d(x, y)$ is Euclidean distance of x and y, c is the center of iris region derived from iris detection. s and t control the smoothness of the sigmoid curve and the step threshold of the curve respectively.

Semantic Iris Contour Map(SICM) is generated based on the original gradient map g and Distance Map(DM) described above, which is calculated as follows:

$$SICM(p) = g(p) \times DM(p). \tag{4}$$

Figure 2(d) shows the corresponding Distance Map of the region of interest in Fig. 2(a).

In most cases, iris region is occluded by eyelashes, eyelids and shadow, if we directly use SICM as the indicator function, then these regions will be included as iris region via curve evolution. So we should hold these regions in SICM, this is why it is called 'semantic'. The eyelids and shadow region are usually along horizontal direction, while the eyelashes region are along vertical. We modify the original SICM into a new one by considering the eyelids, shadow and eyelashes, which is calculated as follows:

$$SICM' = SICM + g_h + g_v. \tag{5}$$

where g_h and g_v are the gradient map in horizontal and in vertical respectively.

Figure 2(e) shows the Semantic Iris Contour Map of iris image in Fig. 2(a). From this figure, we can see that the SICM not only keeps the contour of iris regions but also removes most noises in iris texture region.

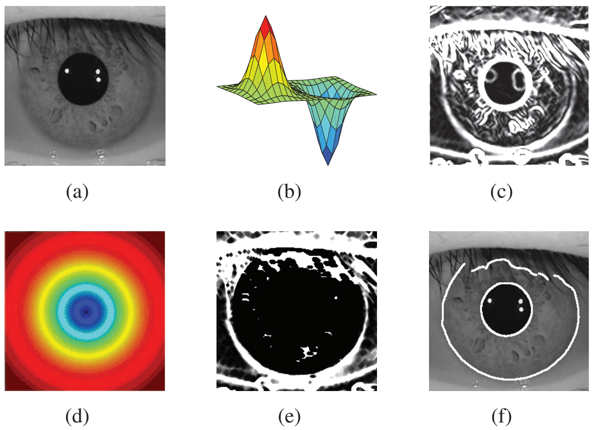


Fig. 2. (a) The region of interest; (b) A simple ordinal filter; (c) The gradient map by two orthogonal ordinal filters; (d) The Distance Map Generated by sigmoid function, the values in the central region are lower than the outer; (e) Semantic Iris Contour Map generated by Distance Map; (f) Localization result of level set based on Semantic Iris Contour Map.

3.3. Self-Adaptive Parameters and Convergence Criteria For Level Set

A key problem in level set is its stability and convergence ability. Among the parameters shown in Eq. 1, the coefficient of the weighted area term v is more important than others, that is because the weighted area term controls the increasing or decreasing area in each iter stage [9]. If it is not properl chosen, the convergence will not be stability. We propose an adaptive method to update it according to the coarse radiu of iris. Since the iris contours are circle-like, and we hav already obtained the coarse center and radius of the circle: we update the coefficient of the weighted area term v afte iteration t as follows:

$$v_{t+1} = k(IrisArea - CurArea_t). \tag{6}$$

where $IrisArea$ is the coarse area of iris region derived from the coarse stage, and $CurArea_t$ is the area of the region which the current curve includes. k is a constance chosen according to the applications.

After the local gradient extremes removal, we can directly use the traditional level set based on a fixed large iteration count, which is time consuming. But an adaptive iteration count will accelerate the convergence. We propose a convergence criteria based on the change of mean and standard variation of points on the contour. Little change of mean indicates there are no translation in curve evolution, and the standard variation indicates the speed of evolution.

4. EXPERIMENTAL RESULTS AND DISCUSSIONS

4.1. Databases

ICE 2005 database and the Lamp subset of CASIA v3 iris database are tested in our experiment. ICE 2005 database includes 1527 images from 120 classes in left eye subset, and 1426 images from 124 classes in right eye subset. CASIA v3 Lamp subset database includes more than 16 thousands images from 882 eyes of 441 persons. The irises in this database have severe deformation. Irises from both of these two databases has obvious complex textures, which is difficult for edge points detection.

4.2. Experimental Results

We use the number of iteration to evaluate the efficiency of our method. To show the effectiveness of proposed method, firstly we unwrap the iris region into a rectangle(see Fig. 3) by Daugman's method [5] after interpolating iris contours with spline curves, then we encode iris using ordinal filters proposed by Sun et al. [10], at last the Hamming Distance is used to evaluate the dissimilarity of different Iriscodes. The traditional level set method (Level Set) and the Daugman's integral-differential operator based method (Intg-Diff) are implemented as comparisons.

Table 1 gives the iteration count and consuming time of the traditional level set method and our method. From Tab. 1 we can see, the iteration count of proposed method is about 60, while in the traditional level set method without the Semantic Iris Contour Map, it is about 300 for each image, which shows the efficiency of our method.

Fig. 3. Normalization image of iris region. Black parts indicate the noisy region.

The effectiveness of our method can also be illustrated by the Receiver Operating Characteristic (ROC) curves in Fig. 4 and Fig. 5. From these two figures, we can see, the traditional level set method gives poorest results on the two databases. This is because most of the curves stopped at local gradient extremes, which give bad segmentation results. While our method achieves the best performance on CASIA v3 Lamp subset, that is because the irises in this database are severely deformable due to the lamp. While on ICE 2005 database, the

Table 1. Experimental results of Time Consuming for ICE 2005 and CASIA v3 Lamp. The iteration counts and consuming-time are used to evaluate the efficiency of level set method and the proposed method.

Methods	Database	Pupil(c)	Iris(c)	Time(s)
Lamp	Level set	200	300	0.856
	Proposed	40	60	0.155
ICE 2005	Level set	250	350	0.915
	Proposed	45	65	0.173

integral-differential operator based methods makes a comparable result, that is because the irises in ICE 2005 database are more circular than the ones in CASIA v3 Lamp subset.

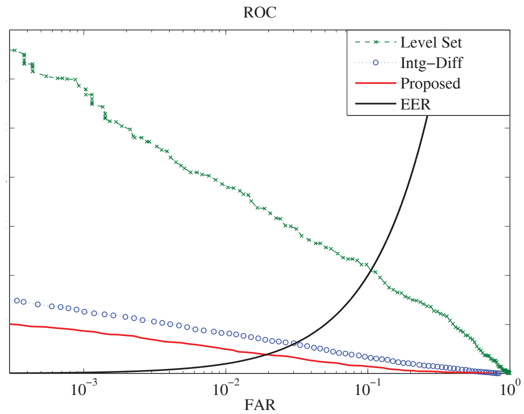


Fig. 4. ROC Curves on Lamp database.

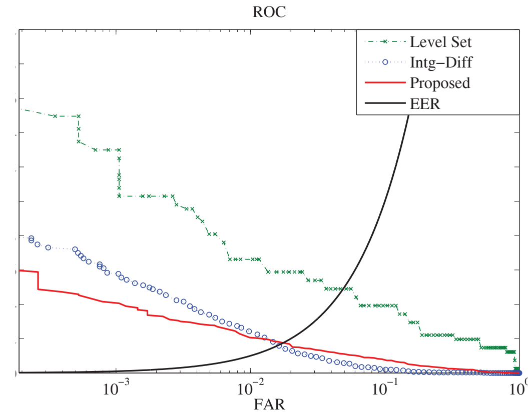


Fig. 5. ROC Curves on ICE 2005 database.

5. CONCLUSIONS

In this paper, we propose a novel scheme to eliminate the local gradient extremes of iris region for accurate segmentation by level set. Firstly, the gradient image is generated by two orthogonal ordinal filters, and the coarse location of iris is obtained by a Gaussian filtered Hough transform. Then a Distance Map is generated by the spatial information derived from the coarse iris localization. After that, the perfect Semantic Iris Contour Map with less local extremes in iris region is obtained by the original gradient image and the Distance Map. Finally, an adaptive level set method is performed for accurate segmentation. The experimental results have shown that our method is efficient and effective on the public databases.

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