# CONTOUR EXTRACTION FOR CORNEAL ENDOTHELIUM IMAGES*

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**Abstract** The crucial procedure of contour extraction for corneal endothelium image is to segment cell regions from background. The single threshold algorithm is not effective because the image differs very much in illumination. In this paper, an adaptive thresholding algorithm with window n * n was introduced. It was then combined with the thinning algorithm to extract the cell contour. The processing results indicate the efficacy of the algorithm.

**Key words** threshold, thin contour extraction, corneal endothelium image.

# 角膜细胞轮廓抽取*

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**摘要** 角膜细胞图像轮廓提取的关键是分隔出细胞区域与背景，生成二值图像．由于角膜细胞图像光照不均匀，采用传统的单一域值法无法兼顾亮区与暗区，不能正确地提取出角膜细胞区域．为此本文提出了一种基于动态域值选择和细化算法的角膜细胞轮廓抽取算法．首先对被处理图像进行灰度平均和中值滤波平滑处理，消除细胞内部的不均匀性并保持细胞之间的边界；然后应用动态域值选择算法分割出细胞和背景；最后采用细化算法得到角膜细胞的粗轮廓，并采用去毛刺算法去除细化结果上的毛刺，抽取到角膜细胞的轮廓．此算法应用于角膜细胞图像，处理结果证明了算法的有效性．

**关键词** 阈值，细化轮廓抽取，角膜细胞



## Introduction

Eye is the window of human spirit. Corneal disease is very common among ophthalmic diseases. Usually, the diagnosis is based on the doctor's clinical investigation, which often results in large deviations. Medical research indicates that the pathological changes of cornea are directly connected with the cell shapes[1]. Therefore, corneal disease can be automatically diagnosed through analysis of the shape characteristics of the cells using image processing and analyzing techniques.

In this paper, the gray characteristics of the image are analyzed, and a contour extraction algorithm based on the fusion of adaptive thresholding and thinning algorithm is presented. The systematic diagram is shown in Fig. 1.

The original image acquired by CCD system is shown in Fig. 2. The gray levels in each cell are inhomogeneous and the contours between the cells are heavily blurred. In order to extract the contour, preprocessing must be applied[2]. In our application, the average gray algorithm is utilized to eliminate the heterogeneity among the cell regions and the median filter algorithm is used to preserve the contour between the cells.

## 1 Adaptive Thresholding Selection Algorithm

### 1.1 Adaptive thresholding algorithm

After smoothing, the extraction of the cell contour demands image segmentation. Segmentation

* The project supported by the National Natural Science Foundation of China
Received 1999-07-19, revised 1999-09-13

* 国家自然科学基金(编号 699310107)资助项目
稿件收到日期 1999-07-19，修改稿收到日期 1999-09-13

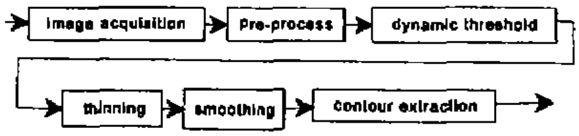



Fig. 1 System diagram
图 1 系统框图

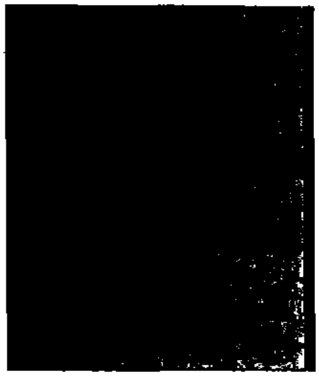


Fig. 2 Corneal endothelium image
图 2 角膜细胞图

plays a crucial role in image processing, which affects the quality of the next processing directly. Up to now, there have developed many segmentation algorithms[3]. Unfortunately, each algorithm has its own suitable field and is not so effective when applied to other situations. Therefore, it is imperative to develop special algorithm with regard to the specific application.

Usually, Maximum-Variance algorthm is adopted in practice. Figure 3(a) shows its processing result for our application. From the figure, it could be seen that the M-V algorithm could not work either for the bright regions or the gray regions. Because the single threshold could not take the bright and gray regions into account, it may be desirable to adaptively determine the correct threshold for each region. Therefore, the adaptive threshold algorithm is developed for the application, in which high threshold could be selected for the bright regions while low threshold for gray regions. The algorithm can be summarized as follows:

(1) Calculate the average gray level $\overline{g}$ for the whole image;

(2) For each pixel, do the following operation

$f(i,j)=|g(i,j)-\overline{g}|$

$i=0,1,\ldots M-1$ ($M$ is the height of the image)

$j=0,1,\ldots N-1$ ($N$ is the width of the image)

(3) For each $n\times n$ window, calculate the average gray level $\overline{f}$ and binarize the image:

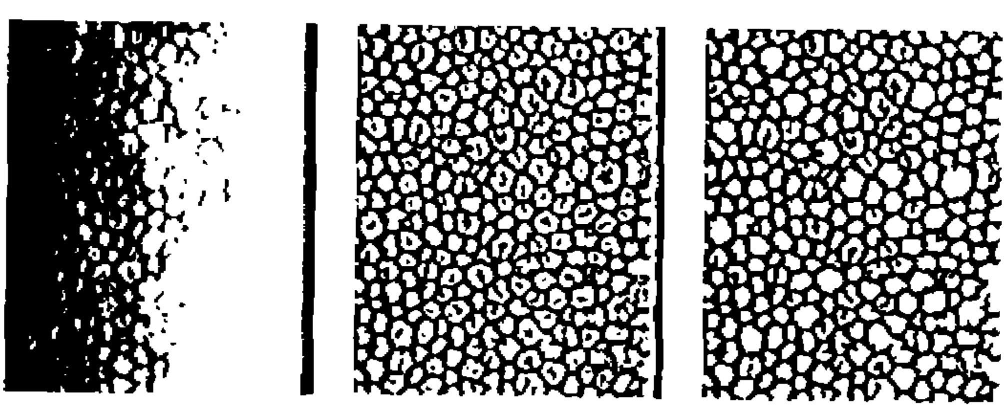
$$g(i,j)=\begin{cases}0 & \text{if } f(i,j)<\overline{f}\\ 255 & \text{otherwise}\end{cases}$$

(4) Repeat step (3) until all the pixels have been scanned.

Figure 3(b) shows the segmentation results. The corneal endothelium regions are separated from the background correctly, although some black holes among the cell regions are generated unpleasantly.

### 1.2 Seed-filling algorithm

In order to eliminate the holes, a seed-filling algorithm is used, which is described as follows:



(a) (b) (c)

Fig. 3 Segmentation result image of corneal endothelium
(a) maximum variance algorithm, (b) adaptive thresholding algorithm, (c) fill-cell algorithm
图 3 角膜细胞分割图 (a) 最大方差法结果图 (b) 动态域值法结果图 (c) 填充结果图

(1) Choose a black pixel in the black field other than the black holes as the seed, then label and put it into the stack.

(2) Get a pixel from the stack

(3) Searching for the black pixels which are unlabelled in its 4-neighborhood, label and put the pixels into the stack.

(4) Repeat step (2) until the stack is empty.

(5) Set the unlabelled black pixel to white.

The above algorithm is used to process the image in Fig. 3 (b), the result is shown in Fig. 3(c).

## 2 Thinning Algorithm for Contour Extraction

Thinning is one of the primary methods for extracting the object shape characteristics. Since the separated regions in our binary image are con—nected, thinning can be used to obtain the contour. In our application, the thinning algorithm is as follows:

(1) Use logic rule P1 to process the pixels among the 3 * 3 neighborhood and label the pixels which should be removed.

(2) Use logic rule P2 to process the pixels among the 3 * 3 neighborhood and label the pixels to be removed. After the whole image is scanned, remove the labeled pixels.

(3) Repeat steps (1)~(2) until the width is one pixel.

The logic rules P1 and P2 are as follows:

P1: $(2 \leqslant N(p_0) \leqslant 6) \&\& (T(p_0)=1) \&\&$
$(p_1 \cdot p_3 \cdot p_5=0) \&\& (p_3 \cdot p_5 \cdot p_7=0)$

P2: $(2 \leqslant N(p_0) \leqslant 6) \&\& (T(p_0)=1) \&\&$
$(p_1 \cdot p_3 \cdot p_7=0) \&\& (p_1 \cdot p_5 \cdot p_7=0)$

where:

$p_i$ is the 8-neighbor of the pixel, $i = 1 \ldots 8$.

$p_i \cdot p_j \cdot p_k$ represents the logical multiplication.

$$N(p_0) = \sum_{i=1}^{8} p_i \quad p_i = 0,1$$

$T(p_0)$ represents the number of flip from 0 to 1 in serial $p1\ p2\ p3\ p4\ p5\ p6\ p7\ p8p1$.

Figure 5(a) shows the thinning result. Since there are many thorns emerging from thinning procedure, it is necessary to smooth the thinning result. There are only two kinds of pixels in Fig. 5(a):

(1) Node pixel: only one direction is connected to the thinning result.

(2) Non-node pixel: at least two directions are connected to the thinning result.

(a)　　(b)　　(c)

Fig. 4 Difference between node and non-node points
(a) non-node pixel (b) node pixel mistaken for non-node pixel (c) node pixel
图 4　端点和非端点的区分
(a) 非端点　(b) 端点易误为非端点　(c) 端点

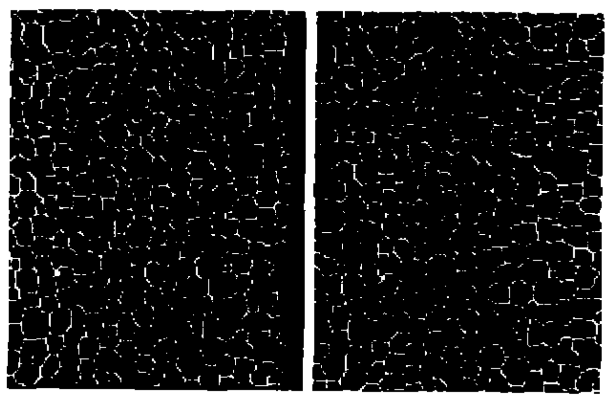
In order to remove the thorns, it is crucial to distinguish the Node and Non-node pixels. If only the number of neighbors is taken into account, it may mistake the Node and Non-node pixels as shown in Fig. 4.

Our Node-determining algorithm is described as follows:

(1) Count the number of white pixel stored in the variable neighbor-num in its 8-neighborhood.

(2) Count the number of white-white pixel pairs in its 8-neighborhood stored in the variable pixels num, and then obtain the real number of white-white pixel pairs neighbors: true-num = neighbor-num-num.

(3) If true-num = 1 OR 0, then the corresponding pixel is the Node pixel.



(a)　　(b)

Fig. 5 Corneal endothelium thinning processing result
(a) thinning processing result, (b) smoothing result
图 5　角膜细胞细化结果图
(a) 细化结果图，(b) 光滑结果图

Otherwise it is Non-Node pixel.

Then the smooth algorithm is used to remove the thorns. It is described as follows:

(1) Find all the Node pixels and put them into the stack.

(2) Get one pixel as the current point from the stack and remove it.

(3) Find the neighbor pixel of the current point. If this pixel is the Node, then remove it and repeat step (3), or else go to step (4)

(4) Repeat steps (2)～(3) until the stack is empty.

## 3 Conclusion

In this paper, one contour extraction algorithm based on adaptive thresholding and thinning algorithm is presented. First, the average-gray and median filter smoothing method is used to eliminate the heterogeneity and preserve the contours between the cells; then the adaptive thresholding is used to segment the cell regions and the background; Finally, the thinning algorithm is adopted to extract the contour. The effectiveness of the proposed method is validated by applying it to 438 images.

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