염색체 영상에서 한 픽셀 두께로 연결된 경계선 추출을 위한 알고리즘

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An Algorithm for Extracting Connected Boundary with One-pixel Thickness from Chromosome Image

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ABSTRACT

In this paper we propose an algorithm to extract connected boundary with one-pixel thickness of chromosome, which has advantages as follows: easy to implement, low computational complexities, and ability to extract the boundary with either 4-pixel connectivity or 8-pixel connectivity.

1. INTRODUCTION

In many fields of image analysis and object recognition, no one will disagree that the most serious preoccupation is the extraction of boundary of object. Object boundaries are defined as linked edges and play an important role both in human and machine vision systems.

There are psychological grounds for considering object boundary in human vision systems. Experiments have shown that humans concentrate most of their attention on the borders between more or less homogeneous regions [1].

In machine vision systems it is often the case that only the shape of object is concerned and the interior of object is ignored. Thus edge and boundary extraction problems have been one of the hottest issues and received very strong spotlights last decades.

In human cytogenetics it is a current trend to automate a sequence of procedures that contains analysis and interpretation of human chromosomes. It is boundary of chromosome which offers much information about the geometrical features of chromosome. Thus the problems of extracting boundary are regarded as one of the most important task in that areas. A large number of schemes to detect edge and boundary have been presented in the literature. That information has been summarized in surveys by Davis [2] and in books by Jain [3] and Pratt [4].

In general there are two requirements to be satisfied for object boundary to have an importance as an information carrier of object. They are as below:

i. Object boundary should be completely connected. This continuity of boundary offers a full description of object.
ii. One-pixel thickness of the boundary of object is recommended. This requirement insures easy boundary chain coding and offers convenient way of extracting important features and measurements from boundary representation.

2. ALGORITHM

The algorithm we propose is split into three consecutive parts: filtering, thresholding and boundary discrimination.

(1). MULTISTAGE MEDIAN FILTERING

We choose a test image that contains single object which is chromosome with homogeneous background. The median filter has nonlinear low-pass characteristics and effectively removes the impulsive noise. In contrast to moving average filter, median filter tends to preserve edge sharpness very well thus suitable for edge filtering.

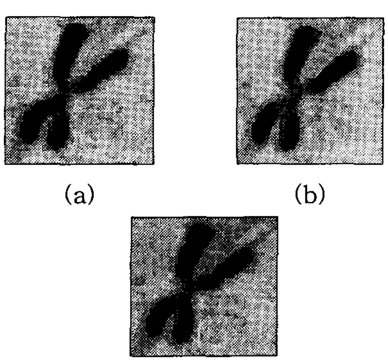
Chromosome has rather complicated boundary like coastline thus we need to preserve edge details in horizontal, vertical and diagonal directions. This can be accomplished by multistage median filter [5] that uses subfilters which are sensitive to these directions, which is described as below:

Among pixels $x_{i+q,j+q}$, $-(n-1)/2 \leq q \leq (n-1)/2$, in n by n window (n; odd integer) the multistage median is defined as

$$y_{ij} = \mathrm{Med}\ (\ \mathrm{Med}(z_1,\ z_2,\ x_{ij}), \mathrm{Med}(z_3,\ z_4,\ x_{ij}), x_{ij}\ )$$

where,
$$z_1 = \mathrm{Med}\ (x_{i,j-q}\ ,\dots,\ x_{ij}\ ,\dots,\ x_{i,j+q})$$
$$z_2 = \mathrm{Med}\ (x_{i-q,j}\ ,\dots,\ x_{ij}\ ,\dots,\ x_{i+q,j})$$
$$z_3 = \mathrm{Med}\ (x_{i+q,j-q}\ ,\dots,\ x_{ij}\ ,\dots,\ x_{i-q,j+q})$$
$$z_4 = \mathrm{Med}\ (x_{i-q,j-q}\ ,\dots,\ x_{ij}\ ,\dots,\ x_{i+q,j+q})$$

We used 3 by 3 window and obtained result that the noises were removed but the edge details were preserved. Fig.1(a) shows the test image and the results of median filtering (b) and multistage median filtering(c). We adopted the result of multistage median filtering.



(a) (b) (c)

Fig.1 Test image and results of median and multistage median filtering.

(2). THRESHOLDING

There are many ways of thresholding techniques [6],[7] but the general method that can be applied to any problem has not found yet. The test image that we chose contains single object which is chromosome with homogeneous background which corresponds to slide glass. Thus the image shows bimodal histogram distribution. This situation is well defined and very limiting case.

One of hills in histogram represents the background and the other the object. We thresholded the image at the valley of the histogram to construct binary image whose black region corresponds to a chromosome and white region to background.

In medical imaging it is often the case where sharp acumen and precise decisions of the expert are required. In this work we chose various thresholds at the valley of the histogram and selected one that is best and then binarized the thresholded image.

Fig.2(a) shows the thresholded image of Fig.1(c) and Fig.2(b) shows the binarized image of Fig.2(a).

(a) (b)

Fig.2 The thresholded image and binarized image of the result of multistage median filtering.

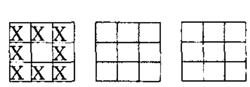
(3). BOUNDARY EXTRACTION CRITERIA

At this stage we have only to decide whether a pixel is on the object boundary or not. In other words we should classify every pixel in the image into three groups: The first group is a set of white pixels outside the object which is classified as background, the second group is a set of black pixels inside the object, and the third group is a set of black pixels on the object boundary, which is what we want.

To accomplish this classification task we pushed every nine neighboring pixels into 3 by 3 window and established a set of criteria to examine whether the centered pixel lies on the object boundary or not. These criteria are based on the local knowledge about eight surrounding pixels and can be described as below:

1. If the centered pixel is white this can not be laid on the object boundary or inside the object. In this case the pixel proves to lie in the background and no action is needed to be taken.
2. If the centered pixel is black and eight surrounding pixels are all black then this centered pixel must be inside the object. In this case we convert the state of that pixel to white so that the pixels both inside and outside the object have the same state, white.
3. Finally if the centered pixel is black and surrounding eight pixels have at least one white pixel then this centered pixel must be located on the boundary. In this case we don't do anything so that the state of that pixel can be preserved as it was, black.

Three cases are illustrated by Fig.3



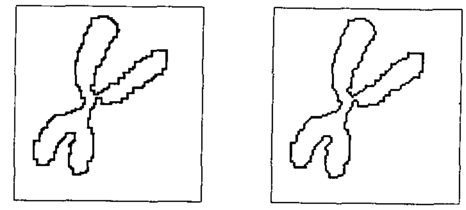
(a) (b) (c)

Fig.3 Three groups of center pixel.
X represents Don't care conditions.

3. RESULTS AND DISCUSSION

With this method we obtained connected boundary representation of chromosome having one-pixel thickness as phrased above. This representation of boundary shows four neighbor pixel connectivity as shown by Fig.4(a).

If we regard the black centered pixel having one white surrounding pixel as being inside the object and thus boundary pixels are confined to



(a) (b)

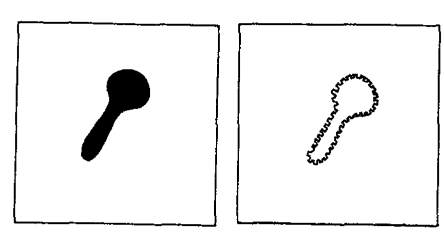
Fig.4 Four-pixel connectivity and eight-pixel connectivity.

having more than two (including two) white surrounding pixels, we'll obtain the boundary representation with eight neighbor pixel connectivity as shown by Fig.4(b).

In either case boundary representation we got has no discontinuity and preserves one-pixel thickness.

There are many existing boundary tracking methods that link neighboring edge elements accoring to whether their magnitude and direction differences are below certain threshold or not [3]. The first problem of this method is that the choice of start pixel on the boundary is not straightforward. The second problem is when the image is noisy the boundary tracking performance is very obscure.

If we apply this method to binary image, one situation can take place where two or more succesor candidates emerge. At this stage we are recommended to choose arbitrary one. This choice can make us being astray inside the object then the boundary tracking algorithm enter a maze.



(a) (b)

Fig.5 Result of turning through 90° left or right according to location of the current pixel.

Another boundary tracking scheme in binary image is presented by Fairhurst [8] and Duda [1]. This scheme starts with arbitrary pixel on the boundary and repeat turning through 90° left or right according to whether the current pixel is inside the object or not. As shown in Fig.5 boundary of saw-toothed shape is obtained.

Fig.6 shows the results of Sobel operator [9] Laplacian operator [3], and Kirsch template matching technique [10] on the same binary chromosome image that we used on our algorithm.

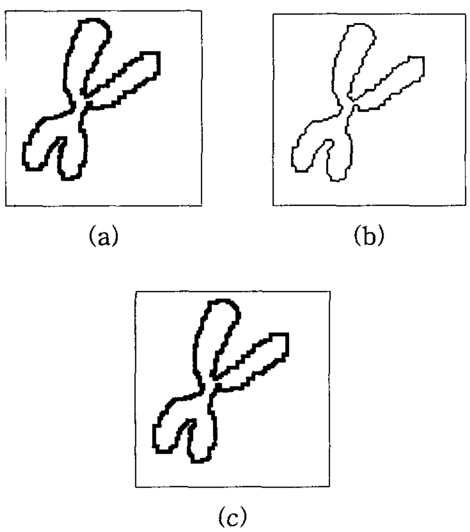


Fig.6 Results of Sobel(a), Laplacian(b), and Kirsch template matching(c) operation on Fig.2(b).

As can be seen in the figure one-pixel thickness requirement is not satisfied in Sobel and Kirsch template matching but Laplacian operator produces the boundary that the two requirements are satisfied, which is identical to the result in Fig.4(b) obtained from algorithm proposed in this paper. But three edge operators above are based on differencing method thus a sequence of operations are executed in every pixel location. On the other hand the algorithm proposed in this paper has decision procedure which examine the current pixel is on the boundary or not, thus no operation is executed in the case where the current pixel is not on the boundary. Another difference is that the three operators execute arithmetic operations which includes subtractions and additions but the algorithm proposed in this paper have only to count pixels in the window. Thus the computational burden of algorithm is lower than the other three operators.

In comparison with boundary extraction by morphological filtering [3], this method have much lower computational complexities.

As stated so far the method presented in section 2 satisfies the two requirements proposed in introduction and its advantages can be summarizd as in abstract. This boundary extraction method can be used effectively in detecting the abnormal chromosome exposed by radioactivity.

We should confess that the performance of this method depends completely on the thresholding technique. Once the thresholding is taken entire boundary informations can be extracted but the lost boundary informations are beyond the ability of this method. Thus more study of thresholding techniques are required.

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