Classification of White Blood Cell Using Adaptive Active Contour

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Abstract: The differential white blood cell count plays an important role in the diagnosis of different diseases. It is a tedious task to count these classes of cell manually. An automatic counter using computer vision helps to perform this medical test rapidly and accurately. Most commercial-available automatic white blood cell analysis composed mainly 3 steps including segmentation, feature extraction and classification. In this paper we concentrate on the first step in automatic white-blood-cell analysis by proposing a segmentation scheme that utilizes a benefit of active contour. Specifically, the binary image is obtained by thresolding of the input blood smear image. The initial shape of active is then placed roughly inside the white blood cell and allowed to grow to fit the shape of individual white blood cell. The white blood cell is then separated using the extracted contour. The force that drives the active contour is the combination of gradient vector flow force and balloon force. Our purposed technique can handle very promising to separate the remaining red blood cells.

Keywords: Active contour, active contour, White Blood Cell, Differential Blood Count

1. INTRODUCTION

White Blood cell composition reveals important diagnotic information about the patients as well as patient follow-up. One of the important counts required by hematologist is differential blood count in which an expert counts 100 white blood cells on the smear at hand and computes the percentage of occurrence of each type of cell counted. The result gives important information about patient's health status and plays an important role in diagnosis. Counting each classes of the white blood cell manually is a tedious, time consuming and qualitative process. An automated differential white blood cell counter is attempting to perform the counting process automatically by analyzing smear images of white blood cell. The process of counting blood cells on smear image requires three steps (1) segmentation, (2) feature extraction and (3) classification. This paper concentrates on the first step of automatic analysis, the segmentation step. This step is very crucial because the accuracy of the subsequent classification depends on the correct segmentation of the solitary white blood cell. It is also a difficult and challenging problem due to the complex nature of the cells and uncertainty in the microscopic images.

Automatic white blood cell analysis requires good segmentation algorithm to locate white blood cell. Many conventional image segmentation methods are based on thresholding selection, edge detection or region growing. Thresholding techniques always can't produce meaningful results since no spatial information is used during the selection of the segmentation threshold. They usually combined with mathematical morphology operation to improve the accuracy of segmentation [1-3]. Edge detection performs poorly on cell images because not all cell boundaries are sharp and hence it is difficult to get all the edge information and locate the cell accurately [4]. In this paper we introduce a novel method of segmentation the white blood cell by utilizing the active contour. We first convert the smear image to binary image using double thresholding [5]. We then scan the binary image searching for the nucleus of individual chromosome of which the intensity exceeding the thresholding value. Once the rough location of the individual white blood cell's nucleus is found, we roughly place an initial circular shape (active) inside the white blood cell and apply active contour model until the active contour fits the white blood cell . The white blood cell is then separated using the extracted contour. The external force that drives the balloon is the combination of gradient flow vector force and balloon force. Gradient flow vector force has been successfully used as external force for active contour [7-8]. Gradient flow vector force, however, suffer from the problem in which the contour remain unchanged at the point where the gradient flow vector force is vanished. To bypass the problem we add balloon force at the force-vanising point. The strength of balloon is adjusted inversely with the strength of gradient flow vector force. Our purposed method has a promising result for separating the touching red blood cell.

This paper is organized as follows. A brief overview of active contour is given in Section II. The segmentaition process is thoroughly discussed in section III. Experimental results are shown in section IV. Discussion and conclusion are presented in section V.

2. ACTIVE CONTOUR

A parametric active contour or active is a curve, $v(s)$ with parameter $s\in[0, 1]$. The curve can move on the image plane under the influence of two types of forces – internal and the external forces. The former constrains the active to be smooth while the latter guides the active to seek desirable image properties, such as edges. The external forces are computed from the image data. Such an active contour model seeks to minimize the following functional [6]:

$$\int_0^1 E_{int}(v(s)) + E_{ext}(v(s))ds \quad (1)$$

where E_{int} and E_{ext} are internal and external force respectively.

In order to attract actives to salient features in images, the external energy is needed. The typical external energy designed to lead an active contour toward object boundaries [1] are

$$E^1_{ext}(x,y) = -\left|\nabla I(x,y)\right|^2 \quad (2)$$

$$E^2_{ext}(x,y) = -\left|\nabla G_\sigma(x,y) * I(x,y)\right|^2 \quad (3)$$

Where I(x,y) is a gray-level image, $G_\sigma(x,y)$ is a two dimensional Gaussian function with standard deviation σ and ∇ is the gradient operator. The key problem of a traditional external force is its limited capture range. Increasing σ can enlarge the capture range but the larger σ will result in inaccurate boundary localization. Several methods such as distance potential force [7], gradient flow vector force [8] has been proposed to significantly increase the capture range of a traditional active. But they all use only edge information.

Gradient flow vector force is derived by the following energy function

$$E_{GVF}(u,v) = \frac{1}{2}\iint g(|\nabla f|)(u_x^2 + u_y^2 + v_x^2 + v_y^2)dxdy + \frac{1}{2}\iint (1 - g(|\nabla f|))((u - f_x)^2 + (v - f_y)^2 dxdy \quad (4)$$

where f(x) is the edge map, and g is a decreasing function of the gradient magnitude defined as

$$f(x,y) = -\left|\nabla G_\sigma(x,y) * I(x,y)\right|^2 \quad (5)$$

$$g(|\nabla f|) = \exp\left(-\left(\frac{|\nabla f|}{k}\right)\right) \quad (6)$$

and where K is constant controlling the smoothness of the result field [7-8]. Calculus of variation is applied to minimize (4) leading the following Euler equation [8]:

$$g\nabla^2 u - (1-g)(u - f_x) = 0$$
$$g\nabla^2 v - (1-g)(u - f_y) = 0 \quad (7)$$

Solving (7) derives the Gradient Vector Flow Field (GVF) force field (u,v) that minimize (4)

Although gradient vector flow force can increases the capture range of a traditional active contour, the method suffers from the zero gradient vector flow force in which the contour remains stationary at particular location. To bypass the problem, we purpose the adaptive active contour in which the balloon forces or the normal-vector forces on the balloon is combined with gradient vector flow force. The magnitude of balloon force varies inversely with the magnitude of the gradient vector flow force.

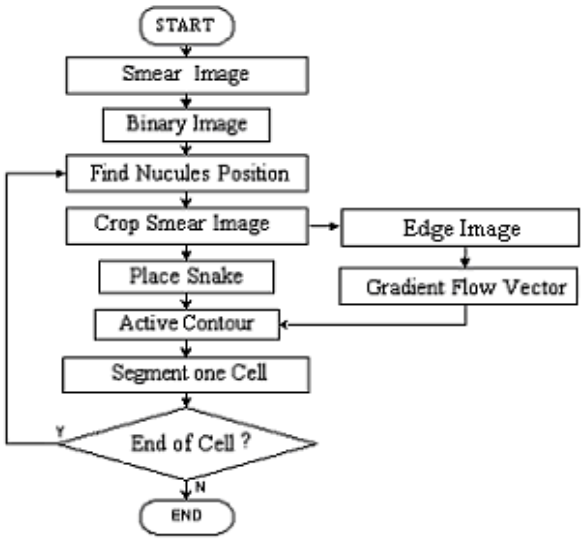


Fig. 1. Flowchart

3. SEGMENTATION

The objective of segmentation is to isolate individual white blood cell from smear image. The process is explained as follows (Figure (1)). (i) The chromosome image is converted to binary image using double thresholding [10]. (ii) Cell nucleus is located by searching for the binary value of "1" in the background. (iii) The smear image in the vicinity of found nucleus is cropped. (iv) The initial round-shaped contour is placed at the center of the nucleus inside the white blood cell. (v) Once the initial balloon is placed, gradient vector flow force around the 8-neigboring point of particular point on the balloon is summed. If the summation is less than some threshold, we declare that point as a point of zero gradient vector flow force. The factor of balloon force is increased in the external force of equation to drive a still contour and vice versa. The active contour algorithm is applied using the combined forces. Once the activated active contour reaches an equilibrium shape which is the shape of the white blood cell. The white blood cell can then be easily extracted from smear image. The step (2) is then repeated for the next white blood cell until the entire white blood cell is segmented and separated.

4. EXPERIMENTAL RESULT

Demonstration of the segmentation process is shown in figure 2. Figure 2.a shows the cropped image of neutrophil. The location of the cell can be determined by converting the color smear image to binary smear image. The intensity of nucleus exceeds the threshold level and hence provides the cell location. Figure 2.b show the binary image in the vicinity of interesting cell. To compute the gradient vector flow that used to drive the active algorithm the edge image is required. Figure 3.a shows the edge image of cropped neutrophil image. Figure 4 shows the gradient vector flow of the cropped image. The image is magnified for clarity. Observe that the gradient vectors point toward and outward the edge derived in figure 3.a. Figure 4 also shows the initial active (smallest Circle) and the growing active contour. The final active contour (the biggest contour) is used to segment only the neutophil leaving behind the group of red blood cell. The segmentation result shown in figure 3.b implies that the performance of active algorithm with gradient vector flow driving force combined with balloon force in the segmentation is very promising even in the presence of touching neighboring blood cell

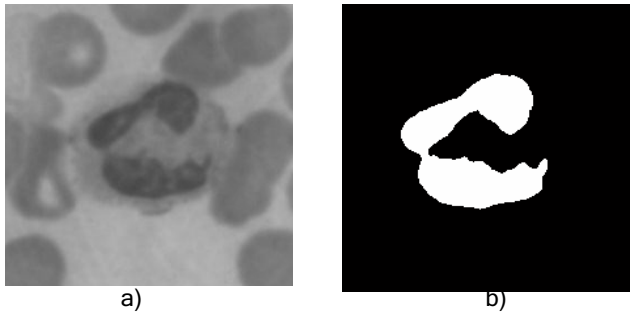
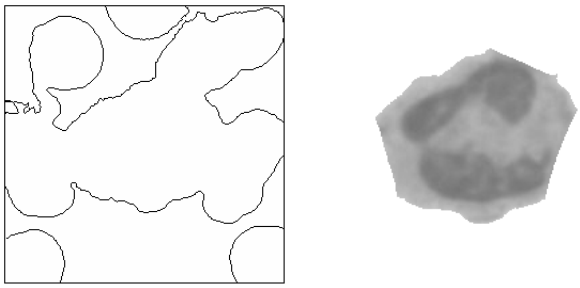


Fig 2. a) Cropped Neutrophil Image b) Binary Image of Nucleus



a) b)

Fig 3. a) Edge Image b) Segmented Neutrophil

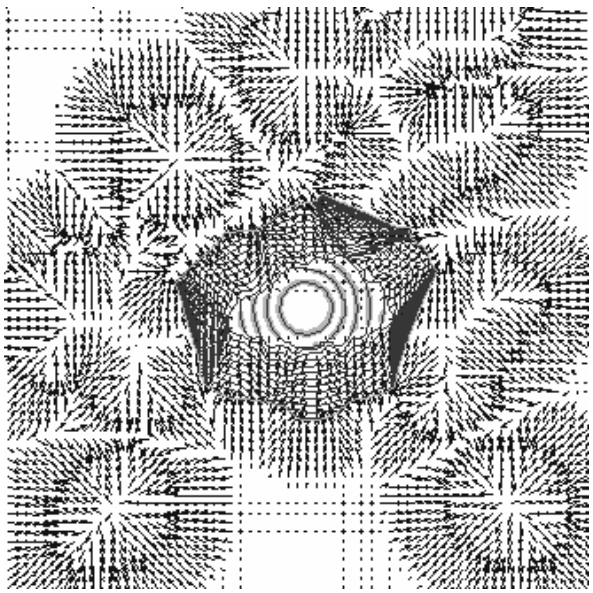


Fig 4. Gradient-Vector Flow (Line with arrow) and Growing Active fitting Neutrophil (Solid Line)

5. DISCUSSION AND CONCLUSION

This paper presents a robust segmentation scheme for automatic white blood cell analysis. The segmentation algorithm utilizes the active contour using balloon model and the gradient-vector flow as the driving force. The initial inflated balloon placed inside the white blood cell is allowed to grow and fit the shape of white blood cell. . The initial inflated balloon placed inside the chromosome is allowed to grow and fit the shape of chromosome. The force that drives the balloon is combination of balloon force and gradient vector flow force. The magnitude of balloon force varies inversely with the magnitude of the gradient vector flow force. The problem of stationary balloon due to the zero gradient vector flow force can then be solved and hence the active contour algorithm is not sensitive to initial position of the balloon. Experimental results show that our purpose method can handle well with the problem of touching red blood cell

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