Hemopoietic Cell Detection and Tracking

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Abstract

Detecting and tracking cell with computer vision technology will assist in biology research. I attempted to solve the problem of detection and tracking of cell. I achieved to detect hemopoietic cell by using multi-radius ring filter. The hough transformation is very sensitive to the selected radius and needs a good edge detection so it did bad job for detection of hemopoietic cell. I track cells by detecting frame-by-frame and regard circle at most closest position as the same cell.

1. Introduction

Cell has very small size -- Prokaryote's size is around 1 to 5 μm and eurokaryote's size is around 10 to 100 μm. Although with the invention of microscope, we can see it, it is still small for human to do the observation. On the other hand, culturing cells for biology research usually contains large amounts. Thus, like cell track, mitosis or apotosis detection, such tasks are tiring work for human to do. If computer sIScience can apply to do these jobs, it will be an exciting news for biologists.

To achieve the ambition, there are many problems needed to solve step by step -- how to detect cell with different shapes, how to detect the process of cell, how to track cell and so on. In this project, I wanted to achieve the goal of detecting and tracking cell with different shape -- round shape and irregular shape. However, I just achieved the goal of detecting and tracking cell with round shape. I used hemopoietic cell as my detecting object.

2. Methods

2.1 Previous work

Sungeun Eom et al. once concluded the job of detection of hemopoietic cell, and they developed a effective method to achieve this job -- multiple-radius ring filtering. And before there are another two work-on methods -- hough transformation and correlation [1].

2.2 Methods

First, I used the method -- hough transformation to do the detection. However, I got the bad results. Later, I tried to use multiple-radius ring filtering algorithm to do the detection and got a better result. Sungeun Eom et al. used this method to detect the hemopoietic cell with over 90% successful rate. But I didn't achieve such high accuracy. The main problem is that I couldn't eliminate the false caused by the fact that circle is outside the cell but at the middle of two cells and this situation can also produce local maxima.

3. Technical Solution

3.1 Summary

I first used hough transformation for the round shape detection. Secondly, I used multi-radius ring filtering to detect hemopoietic cell. For the cell tracking, I used a method of detection by frame-by-frame.

3.2 Details

3.2.1 Hough Transformation

1. Algorithm

We can change the circle equation(1) into its polar form(2). According to the equation(3), we can get a point in the image corresponding to a circle in (a,b) parameter space (assuming r is known here for the easy implementation of the algorithm and actually I set up a range of radius according to the radius of detecting circle).

$$(x - a)^2 + (y - b)^2 = r^2 \quad (1)$$

$$\Downarrow$$

$$x = a + r\cos\theta$$
$$y = b + r\sin\theta \quad (2)$$

$$\Downarrow$$

$$a = x - r\cos\theta$$
$$b = y - r\sin\theta \quad (3)$$

where (a,b) is center coordinate of a circle, r is radius of the circle

Then, I set to vote for (a,b) with (x,y) to pick up the one which is voted most as the detecting circle center.

2. Implementation

Before voting, it is necessary to find the voting points. Points are selected from edges of the image.

1) Use built-in function edge(image,'canny') to do the edge detection;

2) Build "voting" function (houghcircle.f) by myself and do the voting for (a,b) to pick up the maxima for the circle center.

3.2.2 Multi-radius ring filtering

1. Algorithm

Based on the characteristic of existing bright halos around cell in the microscope image(Fig.1), multi-radius ring filtering algorithm was proposed [1]. Use the same size of ring filter to correlate the image, it can produce local maxima at the cell center.

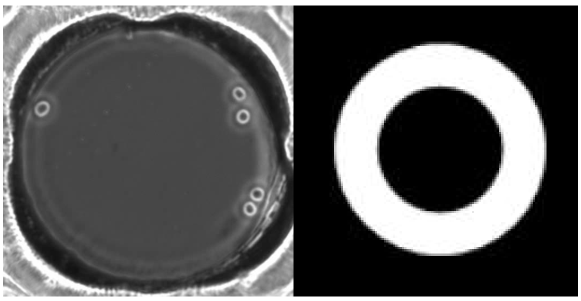

Figure 1: Left is cell microscope image; right is the ring filter model

Denotig the outer radius of the ring by r_c and the width of the ring by w, then the ring filter model has the following form [1]:

$$\mathrm{Cell}(x, y; r_c, w) = \mathrm{circ}(x, y; r_c) - \mathrm{circ}(x, y; r_c - w) \quad (4)$$

where

$$circ(x, y; r) = \begin{cases} 1 & \text{if } \sqrt{x^2 + y^2} \le r \\ 0 & \text{otherwise.} \end{cases} \quad (5)$$

$$\mathrm{RingFilter}(x, y; r_f, w) = \frac{\mathrm{Cell}(x, y; r_f, w) - M}{S(1 - M)} \quad (6)$$

2. Implementation

1) Construct multi-radius ring filter based on the equations (4)-(6);

2) Set up a threshold to eliminate noise (Fig.2a)

3) Use mean shift to cluster for the remaining overlapping detecting circles for I found that those circles can do a good clustering (Fig.2b) and then use a method talking in [2] to find the maxima for each clustering;

4) Among the results of different radius ring filter(Fig.2c), I compared the values and selected the maxima as the final cell circle detection result(Fig.2d).

3.2.3 Cell track by frame-by-frame

Because cell moves very slowly, we can track them by detecting multiple frames and comparing the detecting results to track their movements. I regard circles in different frames at most closest position as the detection of same cell. I just calculated their distances and matched them with smallest distance.

4. Experiments

I did the job in matlab.

4.1 Hough Transformation for Circle detection

I used a image containing circle to test my algorithm of hough transformation. I set up three ranges of radius -- almost-same size as the radius of detecting circle; smaller size than the radius of detecting circle; larger size than the radius of detecting circle (53 to 54 pixels ; 47 to 48 pixels; 55 to 56 pixels. Their intervals are all 0.5 pixels). The results (Fig.3) show that this method is very sensitive to the set up radius for the detection.

For the detection of hemopoietic cell, I set up radius range with 12 to 13 pixels. However, the results are so bad (Fig.4a) and I tried to do some debugs and improvement but did not work therefore I finally gave up this method for detecting hemopoietic cells. Analyzing the reason, I thought the bad edge construction (Fig.4b) make explains.

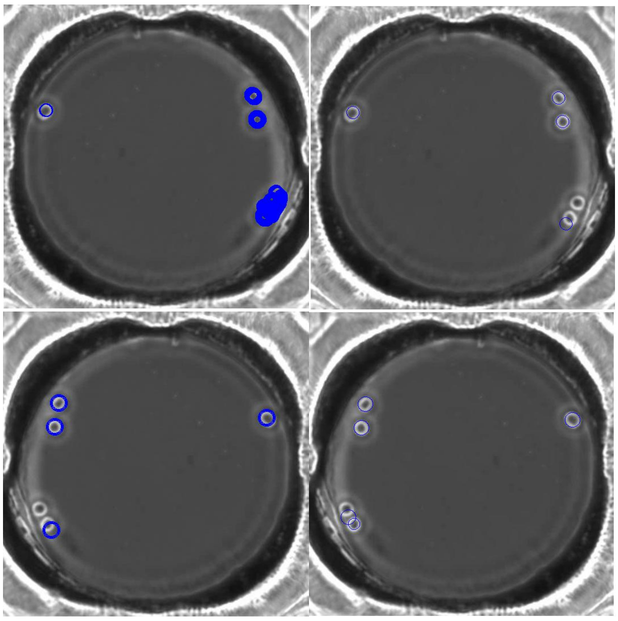

Figure 2: (a) Cell detection using 12 to 13 radius ring filter after thresholding; (b) Cell detection using 12 to 13 radius ring filter after picking up local maxima; (c) Cell detection using different radius ring filters; (d) Final results of cell detection (Blue circle means the detection)

4.2 Multi-radius Ring Filtering

The image data I used for detecting hemopoietic cell is from Data using by Seungil Huh in his program of Mitosis Detection of Hematopoietic Stem Cell Populations in Time-lapse Phase-contrast Microscopy Images (http://www.cs.cmu.edu/~seungilh/).

I set up 11 to 14 radius ranges for the detection of hemopoietic cell (Fig.2).

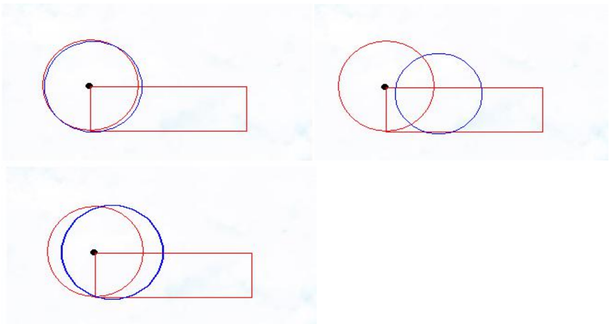

Figure 3: Circle Detection by hough transformation. (a)Using almost-same size as the radius of detecting circle; (b)Using smaller size than the radius of detecting circle; (c) Using larger size than the radius of detecting circle

However, there exist some bad detection results like detecting circle not matching the cell thoroughly or

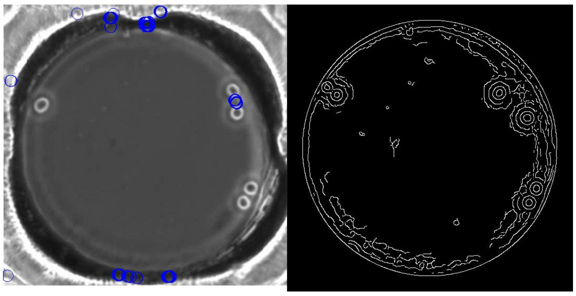

Figure 4: (a) Hemopoietic cell detection by hough transformation; (b) Edge construction for hough transformation

detecting circle at the middle of two cells (Fig.2d). Such mistakes can be eliminated by circle feature with round edge [1]. I will further try this.

4.3 Cell Tracking by frame-by-frame

I used 9 sequential images of hemopoietic cell to do the tracking (Fig.5). Because of some mistaken detection, there are some erroneous tracking.

5. Conclusion

I successfully detected hemopoietic cells using multi-radius ring filtering though its speed and accuracy can still have improvements. Based on the detecting method, I did the tracking by detecting frame-by-frame. Further work, I will try to achieve the goal of detecting cells with irregular shape.

In this project, I achieved hough transformation for detecting circle and multi-radius ring filtering algorithm by myself. For the edge detection for hough transformation, I used built-in function in matlab.

6. Acknowlegements

Thanks for Professor Chen's suggestion and help when I did this project.

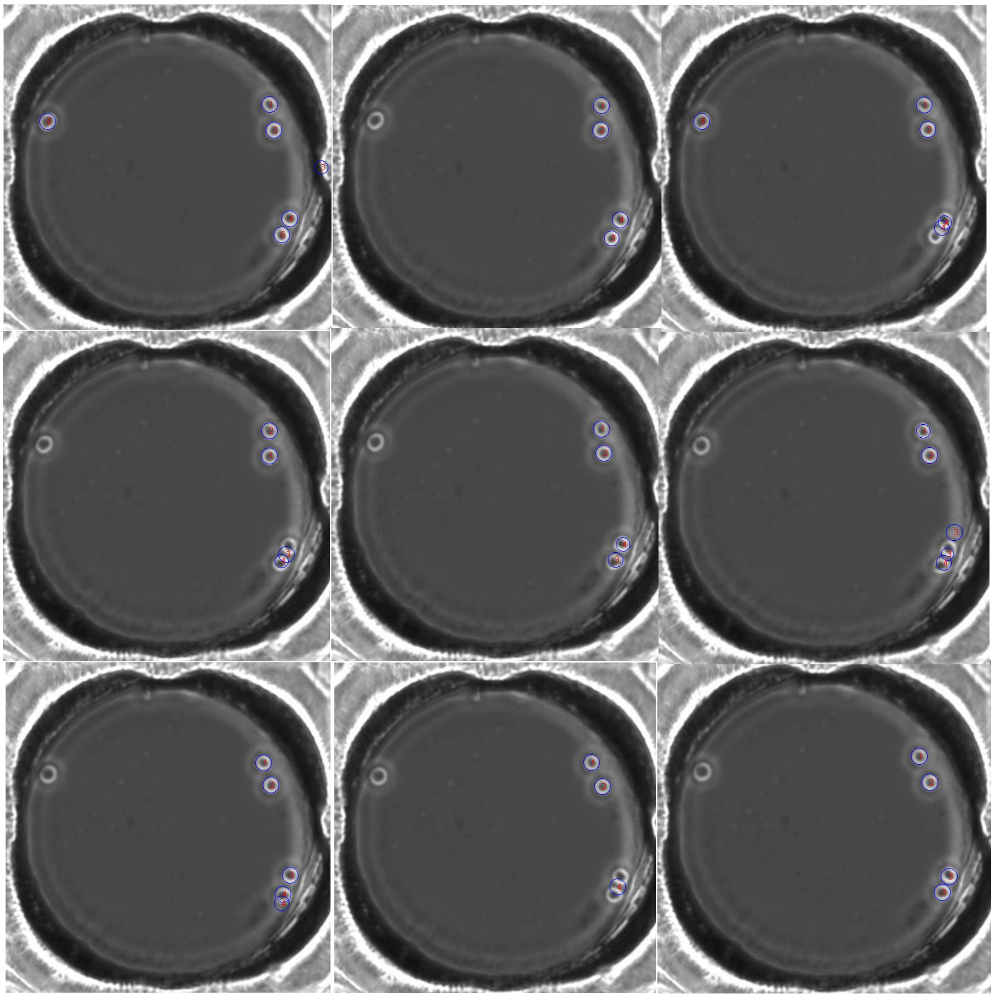

Figure 5: Cell tracking of 9sequence images (Use integer to number different cells in one image; same integer in different images means same cell)

7. Reference

1. Sungeun Eom, Seung-il Huh, Dai Fei Elmer Ker, Ryoma Bise, Takeo Kanade. Tracking of Hematopoietic Stem Cells in Microscopy Images for Lineage Determination. JOURNAL OF L ATEX CLASS FILES, VOL. 6, NO. 1. JANUARY 2007

2. Sungeun Eom, Ryoma Bise, Takeo Kanade. DETECTION OF HEMATOPOIETIC STEM CELLS IN MICROSCOPY IMAGE USING A BANK OF RING FILTERS. IEEE. 2010