Notes on Recognizing Echinocyte by the Top-Hat Transform

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Abstract. In diagnostic of hematology, one of a most important informations is to infer about echinocyte presence. The top-hat transform and its application on echinocyte detection were briefly introducted in [2]. This paper suggests a new improvement based on random method to reduce number of computation for above purpose. We explain the relation between an upper bound of number of the blood cells to perform top-hat transform and number of echinocyte in image.

Keyword: Blood cells · Echinocyte · Top-hat transform

1 Introduction

For many types of images, from satellite images to medical images, the interesting information is given by irregular structures of the objects such as texture. In images of blood cells [3–5], the contour of cells with thorn provides the location of an echinocyte which is particularly meaningful for recognition purpose [1, 6]. The detection of texture of the echinocyte is strongly motivated by purpose of this application. Until now, the top-hat transform is a main mathematical tool for extracting texture from a complex structure of objects in images. In our previous paper [2] an irregular structure of the echinocyte is typically detected by using the top-hat transform. In hospitals, the detection of echinocyte have to implement not only in large number of images but also in a thousand cells per each image. The method we mention above (see [2]) provides only performing top-hat transform all blood cells in image therefore it does not provide simple strategies for detecting an echinocyte presence in a blood cell image with very high density of cells. This is major motivation for studying random methods for collected echinocyte problem.

2 Extract an Irregular Structure by Using the Top-Hat Transform

Denote Gray – scale erosion by

$$(I \odot B)(x, y) = \min\{I(x + s, y + t) - B(s, t)\}, \tag{1}$$

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where I is a gray scale image. The domain of $I \odot B$ is the erosion of the domain of I by the domain of B.

Dilation of a grey-scale image $I(x, y)$ by a grey-scale structuring element $B(s, t)$ is denoted by

$$(I \oplus B)(x, y) = \max\{I(x - s, y - t) + B(s, t)\} \tag{2}$$

The domain of $I \oplus B$ is the dilation of the domain of I by the domain of B. Dilation expands image set and erosion shrinks it. In closing process, erosion follows dilation. In opening process, dilation follows erosion. Opening generally smoothes the contour of an image, breaks narrow gaps. As opposed to opening, closing tends to eliminate small holes, and will gaps in the contours. The small feature of image I, denoted by $F_d(I)$, is defined as the difference set of the opening of an image $I(x, y)$ and the domain of I [7]. This is also known as dilation residue edge detector:

$$E_d(I) = (I \odot B) \oplus B - I$$

Figure 1(a) is an original blood cell image. There are some small features on all abnormal cells in this image. These are also morphological characters of blood cell image and these features make it possible to recognise a echinocyte.

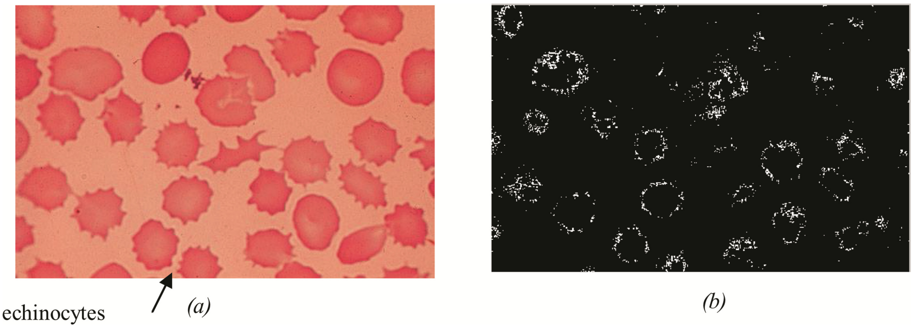

Fig. 1. Blood cells image

These features are extracted with the method suggested here. Morphological operations erode in Eq. (1) then morphological operations dilate in Eq. (2).

A difference between a dilated image and the original image makes it possible to extract the feature of echinocyte from the blood cells binary image [7]. An irregular feature of the echinocyte is reflected in Fig. 1(b). All of normal blood cells are disappeared in Fig. 1(b). This result will help observer focus on echinocyte. The extraction of feature of an echinocyte can be explained as follow (Fig. 2).

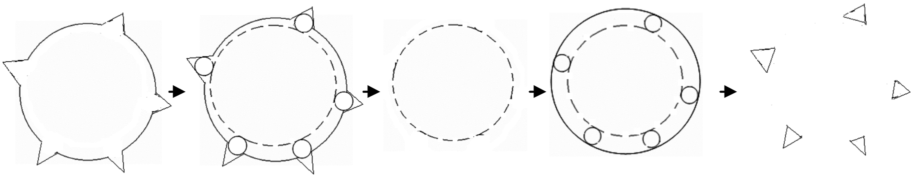

Fig. 2. A description of the irregular structure extraction using top-hat transform

In fact, the top-hat transform of blood cells image with large number of cells has a great computation, it has been shown that a present problem is how to detect echinocyte with minimum cost.

3 Determination of a Presence of an Echinocyte Using Random Texture Extraction Method

An important issue is to minimize time to collect an echinocyte. Suppose that there are n echinocyte in image, equally likely. The problem which have to solve: we need at least how many blood cells do you need to perform an irregular extracting on it to infer the presence of echinocyte. In following section, we show that: for detect all n echinocyte in image of blood cell, the maximum number of the extraction is $n\ln(n) + 13n$. This approach is based on the work of Weiyu Xu and A. Kevin Tang for solving a Generalized Coupon Collector Problem.

Let T be the time to recognize all n echinocyte, and let t_i be the time to recognize the *ith* echinocyte after $i - 1$ echinocyte have been recognized.

Think of T and t_i as geometric random variables. Observe that the probability of recognizing a new recognize given $i - 1$ echinocyte is $p_i = \frac{n-(i-1)}{n}$. Therefore, t_i has geometric distribution with expectation $\frac{1}{p_i}$. By the linearity of expectations we have:

$$\begin{aligned} E[T] &= E(t_1) + E(t_2) + \ldots + E(t_n) = \frac{1}{p_1} + \frac{1}{p_2} + \ldots + \frac{1}{p_n} \\ &= n\left(1 + \frac{1}{2} + \ldots + \frac{1}{n}\right) \\ &= nH_n \end{aligned}$$

where $H_n = \sum_{k=1}^{n} \frac{1}{k}$

Using the independence of random variables t_i, we obtain: $Var[T] = \sum_{i=1}^{n} Var[t_i]$

$$\sum_{i=1}^{n} Var[t_i] \leq \sum_{i=1}^{n} \frac{1}{p_i^2}$$

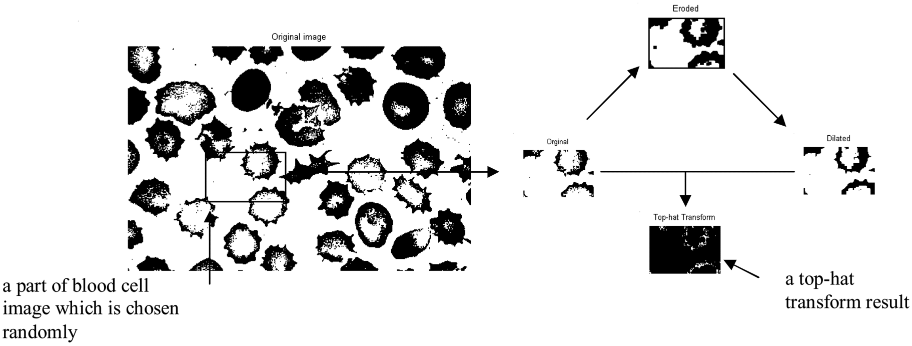

Fig. 3. A description of the top-hat transform performing on a part of the blood cell image

$$\sum_{i=1}^{n} \frac{1}{p_i^2} = n^2 \sum_{i=1}^{n} \frac{1}{i^2}$$

$$n^2 \sum_{i=1}^{n} \frac{1}{i^2} \leq n^2 \sum_{i=1}^{\infty} \frac{1}{i^2} \;\Rightarrow\; Var[T] \leq \frac{n^2\pi^2}{6}$$

Now we can use the Chebyshev inequality to bound the desired probability:

$$P\left(\left|T - nH_n\right| \geq cn\right) \leq \frac{2}{c^2}$$

$$\Rightarrow P\left(\left|T - nH_n\right| \geq \frac{c\sqrt{6}}{\pi}\sqrt{\frac{n^2\pi^2}{6}}\right) \leq \frac{\pi^2}{6c^2}$$

For recognizing n echinocyte with probability of success is 0.9999 we need to perform $nH_n + 12.84n \approx n\ln(n) + 13n$ top-hat transform on blood cells. Following numerical example illustrate the mathematical results. The top-hat transform is performed on a part of the blood cells image which are chosen randomly as box in Fig. 3.

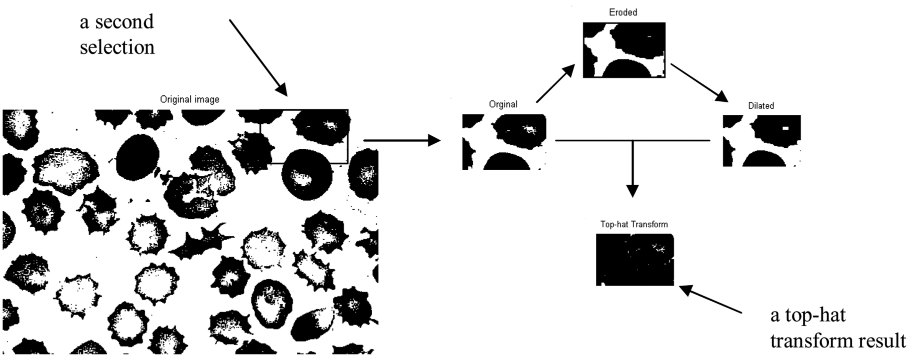

Fig. 4. A description of the top-hat transform performing on a second part of the blood cell image

In a top-hat transform result (Fig. 3), some of speckles reflect a echinocyte presence. The top-hat transform have a echinocyte detection in other part of that blood cell image (Fig. 4).

We performed these simulations over 25 images of blood cell with echinocyte for supporting results in the last section. Table 1 also show that there is much decreasing for computation to detect echinocyte when use our propose.

Table 1. The result of the echinocyte detection over 25 images with echinocyte

	Total of blood cells in image (estimate)	Number of Echinocyte in image n	Upper bound (Rounding of $n\ln(n) + 13n$)	The number of the extraction
1	1000	10	153	55
2	995	11	169	60
3	1005	15	236	45
4	1010	16	252	60
5	998	12	186	56
6	1500	20	320	45
7	1125	14	219	59
8	1229	22	354	15
9	800	5	73	55
10	1120	10	153	57
11	1525	9	137	60
12	1455	11	169	65
13	1112	9	137	45
14	1025	8	121	75
15	925	25	405	12
16	875	21	337	15
17	1002	10	153	30
18	1235	9	137	65
19	1225	10	153	58
20	1015	15	236	25
21	775	36	597	5
22	1300	6	90	80
23	885	40	668	5
24	773	45	756	5
25	1129	8	121	39

Following figure show that a needed extraction for detecting echinocyte always lower than the upper bound that i proposed in Sect. 3. The results in Table 1 and Fig. 5 are showed that the upper bound of the echinocyte $nH_n + 12.84n \approx n\ln(n) + 13n$ is good result for detection time decreasing.

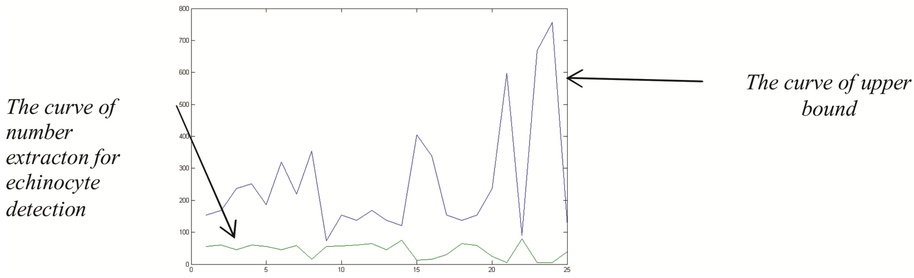

Fig. 5. A description of the distance between upper bound and number of extraction for echinocyte detection

4 Conclusion

This study provides a basis for designing an algorithm for detecting echinocyte from blood cells images. This result motivates a development of intelligent microscopes. Echinocyte or abnormal cells can be recognized not only with accuracy but also with low cost.

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References

1. Pierre, R.V.: Red cell morphology and the peripheral blood film. Clin. Lab. Med. **22**(1), 25–61 (2002)
2. Ha, H.M., Nga, T.T.: Extract an irregular structure of an echinocytes using morphological operations. In: Toi, V.V., Khoa, T.Q.D. (eds.) The Third International Conference on BioMedical Engineering in Vietnam. Springer, Heidelberg (2010)
3. Ranzato, M., et al.: Automatic recognition of biological particles in microscopic images. Pattern Recognit. Lett. **28**, 31–39 (2007)
4. Sonca, M., et al.: Image Processing, Analysis and Machine Vision. Chapman & Hall Computing, New York (1993)
5. Semmlow, J.L.: Biosignal and Biomedical Image Processing Matlab-Based Applications. Marcel Dekker Inc., New York (2004)
6. Mukhopadhyay, R., Gerald Lim, H.W., Wortis, M.: Echinocyte shapes: bending, stretching, and shear determine spicule shape and spacing. Biophys. J. **82**, 1756–1772 (2002)
7. Gonzalez, R.C., Woods, R.E.: Digital Image Processing. Addision-Wesley, Reading (2000)