Identification of Biomedical Blood Cell Irregularity Distribution Based on Cumulative Matching Distance

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ABSTRACT: Computer aided diagnosis method have been more and more widely used in biomedical area. A novel particle matching scheme is presented to quantitatively analyze the irregular level of biomedical particle images in relationship with the predetermined standard image. The specific cumulative matching distance is defined to evaluate the irregular effect, which shows great ability to classify different irregular images such as non-uniform distributed, marginally distributed, and seriously irregular distributed particle images. Both methods have been embedded in a machine vision software, which can act as an assistance for disease diagnosis.
KEYWORD: Computer aided diagnosis; biomedical image; irregularity; cumulative matching distance

1 INTRODUCTION

Traditionally, observation on biomedical images, mainly depends on microscope, which assists the doctor to study the properties of the possible disease from the microstructure observation[1]. Biomedical microscopic images have been widely used in the following areas: pathology, immunology, clinical diagnosis and genetics, etc[2]. For example, In clinical application, to analyze the particle image of the patient's blood samples while doing routine blood tests, detection of red blood cells and white blood cells in a certain proportion, the platelet count, average red blood cell volume, average hemoglobin content and average haemoglobin concentration and lymph cell percentage, allows the physician to judge the person's health basically[3]. In deciding whether the body has inflammation, a blood test particle image can also be applicable, to observe whether the number of white blood cells exceed standard amount, or whether the cell shape changes[4][5]. Also in some intestines and stomach and digestive system disease detection, the detection and analysis of particle image of a urine sample will be very helpful for diagnosis.

For these test samples, such as pathological tissue section as well as a variety of body fluids and blood smear, will eventually be processed as a biomedical image with different shapes and distribution of particles. These microscopic image enables physicians observe all kinds of cells in human body, the status of pathogen, the proportion of cells in the image, or the distribution of important components. Combining the testing data generated by biomedical images, with other pathological features, doctors will be able to perform clinical diagnosis correspondingly.

In biomedical imaging aided diagnosis, accurate detecting of the particle image is very important to the final judgment of doctors. Previously, studies on detection of some kinds of particles and basic methods or systems have been developed, such as specific cell count statistics systems[6], automatic segmentation and recognition of dual-core cell microscopic images[7], automatic recognition of bone marrow cell images[8], etc. These testing system has their specific applicability. In this paper, a more general XAVIS software platform for detecting biomedical particle image is presented. In the software, a new evaluation method for particle image detection and distribution is proposed, which is able to classify images with different non-uniformity distribution.

The structure of the paper is as follow. The next section introduces the irregularity phenomenon in biomedical particle images. Section III presents a novel point evaluation coefficient based on matching distance, to calculate the irregularity levels of non-uniformity images compared with a presumed standard distributed image, according to the statistical characteristics of particle image recognition. Finally, the test results and conclusions are presented in Section IV an V, separately.

2 IRREGULARITY PHENOMENON IN PARTICLE IMAGES

Typically, for a particle image, the arrangement of particles might have different possible distribution on the image. For a given number of particles, the distribution can be uniform, or seriously irregular, e.g. an image with nine particles, there can be four roughly classified pictures as shown in Figure 1.

It can be seen in Figure 1(a) that, the uniform distribution of nine point particles fill the whole picture, with equidistant intervals between each two adjacent particles. Comparing to Figure 1(a), all nine particles in Figure 1(b) still occupy the whole image, but the distance between adjacent two particles in various, therefore, it is classified as a non-uniform distribution. The nine particles in Figure 1(c) seem to locate near the edge of the image, with large part of blank area in the center, which is named as marginal distribution. Figure 1(d) has the most serious non-uniformity than others because all the nine points are occurred at the lower left corner of the image, and the distance between adjacent particles is not constant value also, which is called seriously irregular distribution in this study.

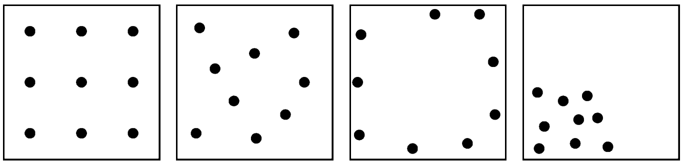

Figure 1 Image classification with different irregularity schemes: (a) Uniform distribution; (b) non-uniform distribution; (c) marginal distribution; (d) seriously irregular distribution.

In practical disease diagnosis applications, different distribution of particles, may reflect the existence of some potential diseases. Similar to the subjective evaluation by a doctor, a standard distribution should be selected as the basis of evaluation, according to the pathological characteristics and experience of image-aided diagnosis. It is very important to set a standard image, e.g. if the subjective evaluation are performed with Figure 1(b) as the standard distribution, the evaluation result for images in Figure 1(c) and (d), may be quite different from that of Figure 1(a) as the reference image.

3 EVALUATION OF IRREGULAR IMAGES BY CUMULATIVE MATCHING DISTANCE

In order to evaluate biomedical particle images with irregularity, a novel method is proposed by calculating the matching distance between the target image and the standard one. Take Figure 1 for example, set the image (a) as a standard figure, and assume that particles in (a) is the uniform distribution. The evaluation for image (b) can be conducted by calculating the matching distance between non-uniform image (b) and the standard image (a).

The summation of nine shortest distance, is chosen as the similarity measurement value for evaluation the irregular images, according to the image (a) that assumed to have a standard distribution. A cumulative matching distance is defined:

$$CMD = \sum_{i=1}^{N} d_i = \sum_{i=1}^{N} \min\left\{\vec{D}_{bi} - \vec{D}_{a'i}\right\} \qquad (1)$$

where: d_i is the minimum distance for particle i in image (b) during every matching step, $\vec{D}_{bi}$ is the coordinate vector for all the particles in target image (b), $\vec{D}_{a'i}$ denotes the coordinates of remaining particles in image (a) after each matching step.

The detailed particle image evaluation process for the proposed matching distance approach is shown in Figure 2.

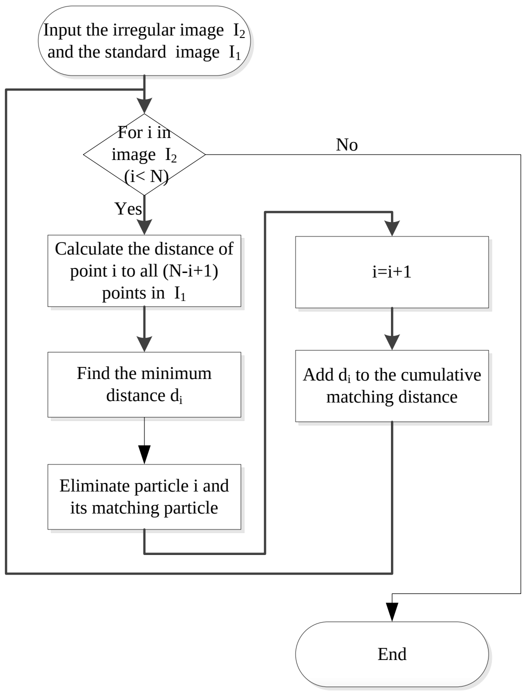

Figure 2 Matching distance evaluation for irregular particle images

4 EXPERIMENTAL RESULTS

Applying cumulative matching distance method in the XAVIS software framework, to find the irregularity of Figure 1(b) from Figure 1(a), the nine pairs of matching particles are illustrated in Figure 3.

As shown in Figure 3, the blue particles marked with circles are from image (b) of the irregular distribution, and the red particles marked with stars are from (a) with the uniform distribution. In the process of minimum distance calculation, the first particle B1 in the non-uniform image (b) is mapped to the first point A1; the second point B2 is mapped to the third point A3; then the whole mapping relationship of particles is described as:

$$B1 \to A1, B2 \to A3, B3 \to A2, B4 \to A4, B5 \to A6,$$
$$B6 \to A6, B7, \to A8, B8 \to A7, B9 \to A9 \quad (2)$$

Collecting all nine pairs of matching distance in Figure 3 (unit: pixels): 5.0000, 21.2132, 10.0000, 5.0000, 21.2132, 11.1803, 28.2843, 20.0000, 25.0000; and it is easy to calculate the cumulative value of the minimum distances (unit: pixels) as :147.6695, according to Equation (1).

In the same way, the mapping relationship of particles from marginally distributed image (c) to uniform distributed image (a) can be obtained:

$$B1 \to A2, B2 \to A1, B3 \to A4, B4 \to A7, B5 \to A8,$$
$$B6 \to A9, B7, \to A6, B8 \to A3, B9 \to A5 \quad (3)$$

The mapping results is plotted in Figure 4, and all nine pairs of matching distance (unit: pixels) in Figure 4 are: 20.6155, 15.5242, 11.1803, 20.6155, 15.5242, 37.4833, 29.1204, 30.4138, 50.0000. Then the total distance comes to a pixel value of 235.6441.

Also, we can find the mapping relationship of particles from seriously irregular image (d) to uniform distributed image (a):

$$B1 \to A4, B2 \to A1, B3 \to A2, B4 \to A5, B5 \to A3,$$
$$B6 \to A6, B7, \to A8, B8 \to A7, B9 \to A9 \quad (4)$$

The mapping results is plotted in Figure 5, and all nine pairs of matching distance (unit: pixels) in Figure 5 are: 11.1803, 30.0000, 38.0789, 11.1803, 30.0000, 58.3095, 66.7083, 52.0000, 67.2681. Then the total distance comes to a pixel value of 440.1591.

The matching results of above three case studies from Figure 3 to Figure 5 are summarized in Table1. Comparing with the similarity measurement value for image (c) and (d), it can be seen that image (b) has the minimum matching evaluation distance, which indicates that image (b) is closest to uniform distributed image (a). Image (d) shows a maximum matching evaluation distance, which may have the largest possibility of disease for the particular blood cell sample.

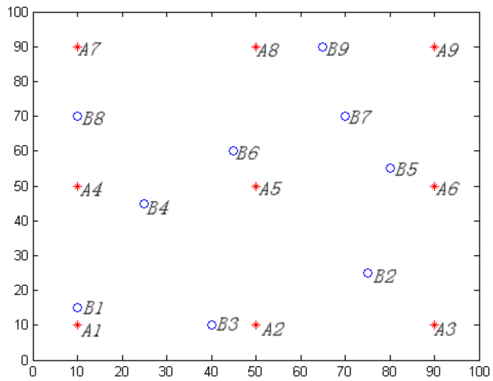

Figure 3 Particle image matching from non-uniform image (b) to standard image (a)

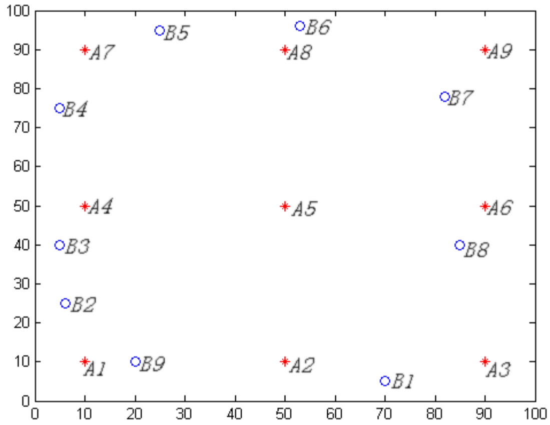

Figure 4 Particle image matching from marginally distributed image (c) to the standard image (a)

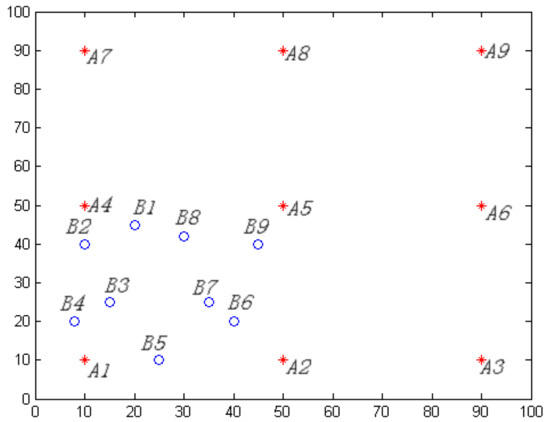

Figure 5 Particle image matching from seriously irregular distributed image (d) to the standard image (a)

It should be noted that, the matching process for particles in an irregular image is performed in a previously arranged order. When the order is different, it may cause the result of the matching distance be slightly different. Further tests have been conducted to illustrate the matching results when the particles in image (b) has different sequence numbers.

Originally, the coordinates for the 9 particles in Figure 1(b) from 1 to 9 are: *(10,15), (75,25), (40,10), (25,45), (80,55), (45,60), (70,70), (10,70), (65,90)*. If we change the sequence of nine points randomly, there should be a total of $9! = 362880$ different orders to analyze; the following three combinations are selected to evaluate the irregularity of image (b) to standard image (a):

Order 2: (75,25), (25,45), (40,10), (45,60), (70,70), (80,55), (10,70), (65,90), (10,15);

Order 3: (25,45), (80,55), (75,25), (40,10), (10,15), (70,70), (45,60), (65,90), (10,70);

Order 4: (75,25), (25,45), (40,10), (80,55), (70,70), (45,60), (10,70), (65,90), (10,15).

Table 1 Matching results of irregular image

	Image(b)		Image (c)		Image (d)	
Matching particles	Matched points	Distance (pixels)	Matched points	Distance (pixels)	Matched points	Distance (pixels)
1	1	5.0000	2	20.6155	4	11.1803
2	3	21.2132	1	15.5242	1	30.0000
3	2	10.0000	4	11.1803	2	38.0789
4	4	15.8114	7	15.8114	5	51.6140
5	6	11.1803	8	25.4951	3	65.0000
6	5	11.1803	9	37.4833	6	58.3095
7	8	28.2843	6	29.1204	8	66.7083
8	7	20.0000	3	30.4138	7	52.0000
9	9	25.0000	5	50.0000	9	67.2681
CMD	/	147.669	/	235.644	/	440.159

It can be seen from Table I that the final matching distance is slightly different with various matching orders of particles in image (b). This phenomenon is obvious, because when a point on the standard image is matched, it will be eliminated from the standard image, and different pairs will be matched under various matching sequences. Figure 6 and Figure 7 illustrates the matching results for the original order and order 2, separately, and the total matching distance changes from 147.6695 to 162.8898.

Therefore, the change of particle order in the target image will not affect the final classification of images, which is able to demonstrate the feasibility and effectiveness of the proposed matching method. When there are more particles per unit area, the variation of matching distance will be even much smaller. Also, one can use the average matching distance for all possible sequence orders so as to obtain a more accurate result, correspondingly it will bring in great computational burden.

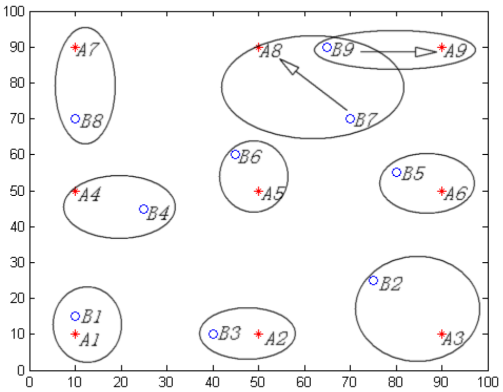

Figure 6 Matching pairs for the original order of Fig.5(b)

5 CONCLUSION

Digital image processing methods have been more and more widely used in biomedical diagnosis recently. A cumulative matching distance is defined to evaluate the irregular effect, which shows great ability to classify different irregularity such as non-uniform distributed, marginally distributed, and seriously irregular distributed particle images. Both methods have been embedded in a machine vision software, which is able to act as an useful assistance for disease diagnosis.

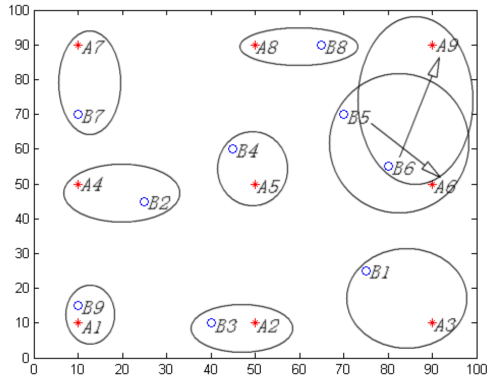

Figure 7 Matching pairs for order 2 of Fig.5(b)

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