Automated System for Detection of White Blood Cells in Human Blood Sample

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Abstract Determination of the WBC count of the body necessitates the detection of white blood cells (leukocytes). During an annual physical checkup, generally doctors prescribe for a complete blood count report. WBC count is required to determine the existence of disease for symptom like body aches, chills, fever, headaches, and many more. The existence of autoimmune diseases, immune deficiencies, blood disorders, and hidden infections within human body can also be alerted by the report of WBC count. The usefulness of chemotherapy or radiation treatment, especially for cancer patients, is also monitored by this report. This paper introduces an automated system to detect the white blood cell from the microscopic image of human blood sample using several image processing techniques.

Keywords WBC · RBC · Thresholding · Region labeling · Erosion · Dilation

1 Introduction

An important component of the immune system is leukocytes. Attacking of the body by viruses, bacteria, germs, and many others is controlled by these leukocytes. After the production of white blood cells in the bone marrow, it circulates through the bloodstream. The test of WBC count reveals the number of white blood cells in human body. A complete blood count (CBC) includes this test. A percentage of

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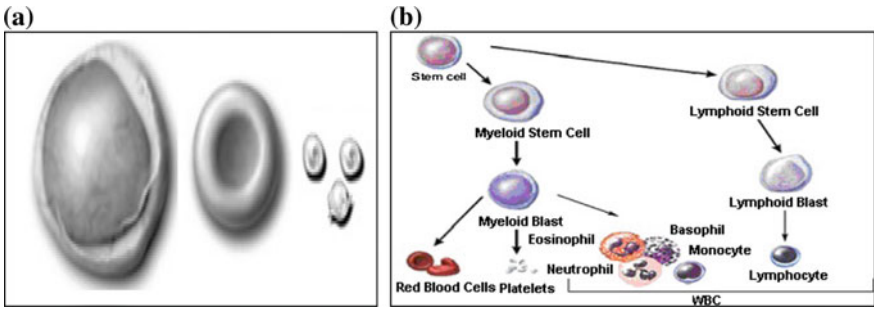

Fig. 1 **a** Blood cell **b** stem cell type

each type of white blood cell is present in human blood. However, white blood cell count can increase or decrease from the healthy range.

Stem cells get mature and create some kind of new blood cells. Each and every blood type has its own function. Blood components are shown in Fig. 1(a). It consists of four parts **red blood cells** (erythrocytes), **white blood cells** (leukocytes), **platelets,** and **plasma.**

After becoming old or damage, the cells die and are replaced by new cells. After getting matured, the stem cells change to several components of blood, as shown in Fig. 1b. They grew up either as myeloid stem cell or as lymphoid stem cell. After getting mature, the myeloid stem cells become myeloid blast. Platelet, red blood cell, and several types of white blood cell are formed during this blast. A mature lymphoid stem cell can form lymphoid blast, and this blast creates a type of white blood cells. The characteristics of white blood cells formed from these two blasts are different. There are five major types of white blood cells, namely neutrophil, lymphocyte, eosinophil, monocyte, and basophil. The study will focus on detection of white blood cells in a given highly magnified microscopic blood smear images.

The rest of this paper is organized as follows. After this small introduction, some related works are presented in Sect. 2. Section 3 describes the proposed methodology. Experimental results of the proposed method are discussed in Sect. 4. Finally, Sect. 5 draws the conclusions and future work.

2 Related Work

Sonali C. Sonar et al. [1] have detected WBCs. Original image was converted to grayscale image. Contrast enhancement techniques such as linear contrast stretching (L) and histogram equalization (H) are applied. Three images R1, R2, and R3 are obtained, such that $R1 = L + H$, $R2 = L - H$, and $R3 = R1 + R2$. A 3×3 minimum filter is implemented three times on the image R3. Global threshold value is determined by Otsu's method. Morphological opening with disk structuring element is used to remove small pixel groups. The radius of disk is considered to be

nine pixels. Finally, the neighboring pixels are connected. The objects that are less than half of average RBC area are finally eliminated.

The white blood cells are identified using knowledge base learning by Rajwinder Kaur et al. [2]. In the first approach, the input image was followed by Hough transform, snake body detection algorithm was applied, and the cells were counted. Then, in the second approach, the image went through k-means clustering method followed by histogram equalization, the blood cells were extracted in image segmentation, and the cells were counted.

Nurhanis Izzati et al. [3] have segmented white blood cell nucleus using active contour. First, image segmentation based on the partial differential equation is mainly carried out by active contour model or snakes algorithm, and the parameter of WBC is calculated. The segmented images are converted into binary image. In order to calculate circularity of the object roundness to classify the shape of the WBC nucleus, ratio of the area of an object to the area of the circle is calculated.

Miss. Madhuri G. Bhamare et al. [4] have converted RGB image to gray scale by eliminating the hue and saturation information while retaining the luminance and enhanced the image by using median filter. Image segmentations such as Otsu adaptive thresholding method, watershed transform method, as well as segmentation by K-means clustering followed by EM-algorithm are compared and have followed with Hough transform. The two fundamental morphological operations such as erosion and dilation are used, thereby filling holes and noise spikes and ragged edges are eliminated. Shape, color, and texture features are analyzed by local binary pattern and sequential forward selection algorithm or by artificial neural network and support vector machine.

S. Pavithra et al. [5] applied different image processing techniques to extract white blood cells. After converting a grayscale image, edge detection using Sobel operator is carried out. Median filter is used for image smoothing. After that, unsharp masking and gradient magnitude watershed techniques are applied. Finally, morphological operation and circular Hough transform are used for final count.

Some authors also used different morphological operations for identification and classification of WBC from microscopic image [6–9].

3 Proposed Method

The following steps are applied to detect the white blood cell from the microscopic image of the human blood cell.

3.1 Image Acquisition

The first step in the process requires an image sensor to digitize the signal for acquiring a digital image, or images can be obtained in RGB color format from

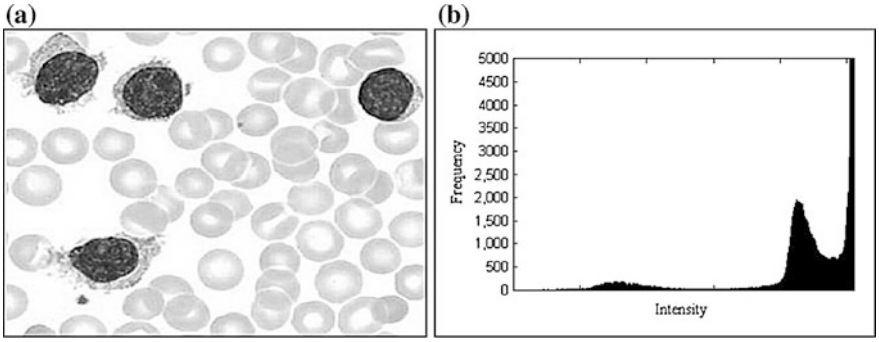

Fig. 2 **a** Microscopic image of human blood cell **b** histogram of the image

online medical library or hospital blood samples images and are converted to grayscale level. Figure 2a shows a representative microscopic image of human blood cell with four WBCs and many RBCs.

3.2 Segmentation

After image acquisition, partition is made from an input image into its constituent objects or parts using following steps.

Nucleus Identification: It is clear from the microscopic image of blood cell shown in Fig. 2a that the nucleus in WBC has the lower intensity compared to any other part. Figure 2b shows the histogram of the image. The histogram consists of three peaks. Two peaks at the two ends describe the low-intensity nucleus and high-intensity background. The peak in the middle shows the blood cells excluding the nucleus. From these observations, simple thresholding technique is applied to detect the nucleus. The intensity of the leftmost peak is identified and used as threshold value. The image after nucleus detection is shown in Fig. 3a.

Blood Cells Identification: From the histogram, it is quite obvious that the rightmost peak represents the white background of the microscopic image. To obtain the blood components, i.e., RBC, WBC, and platelets, leaving the background, the thresholding technique is also applied. To choose the threshold value, the valley between the rightmost two peaks is considered. The threshold value is chosen at the intensity where minimum frequency occurs in the valley. Figure 3b shows the identified blood cells.

WBC Detection: WBC of the blood contains a nucleus in its center. Thus, after detecting the blood cells, the WBC is identified by inspecting both the identified blood cells and the identified nucleus. First, each identified blood cells are assigned unique label using region labeling [10] algorithm. The labeled components that contain nucleus are considered as WBC. The detected WBCs are shown in Fig. 4a. But it is clear from the figure that the identified WBC may be attached with some RBC(s).

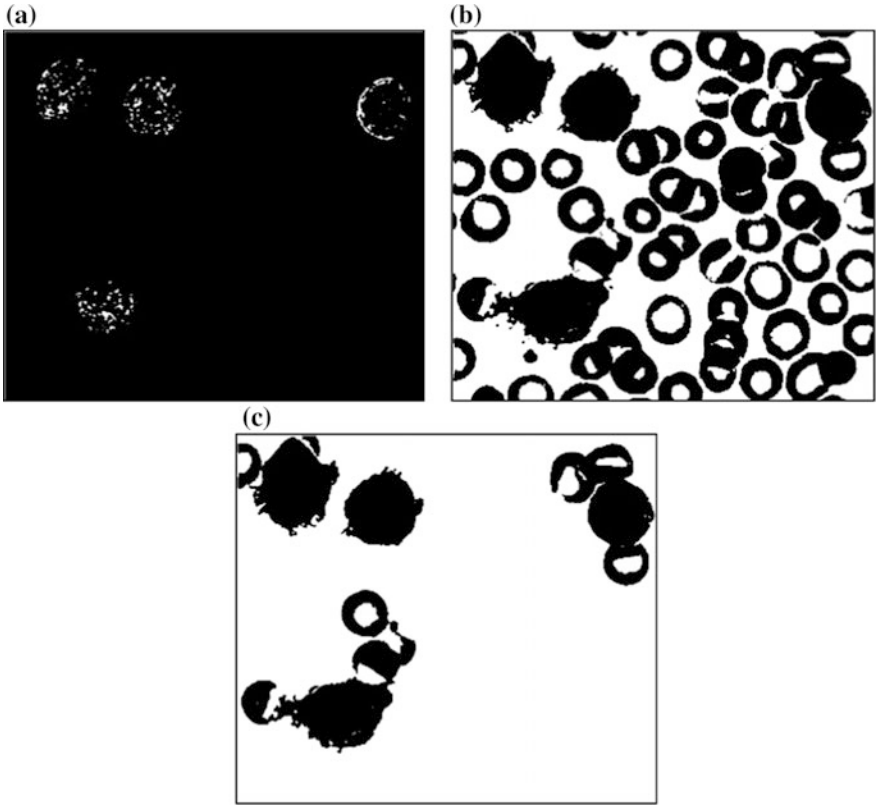

Fig. 3 Image of Fig. 2a after **a** nucleus identification **b** blood cell identification **c** WBC detection

3.3 Refinement of WBC

As shown in Fig. 3c, the detected WBCs may be connected with neighboring RBC(s). Thus, some refinement is needed to extract the WBCs by separating them from connected RBC(s). To achieve this, following steps are applied.

Elimination of White Patches: Detected WBCs contain small white patches inside them. These small patches should be removed before separating the RBCs from WBC by using erosion [11] operation, because these white patches will be increased after erosion operation. To do this, each WBC is considered separately. The size of each white patch is determined. If the size of the white patch is less than '***S,***' the patches are converted to black. '***S***' is experimentally chosen as 40. Figure 4a shows the WBCs after removing the white patches.

Separation of the WBCs: A layer of pixels from both the inner and outer boundaries of regions is stripped out by the morphological erosion operation. The holes and gaps between different regions become larger, and small details are eliminated. In this experiment, a disk-shaped structuring element is used with radius 27 to separate the RBCs from the WBCs. Figure 4b shows the result.

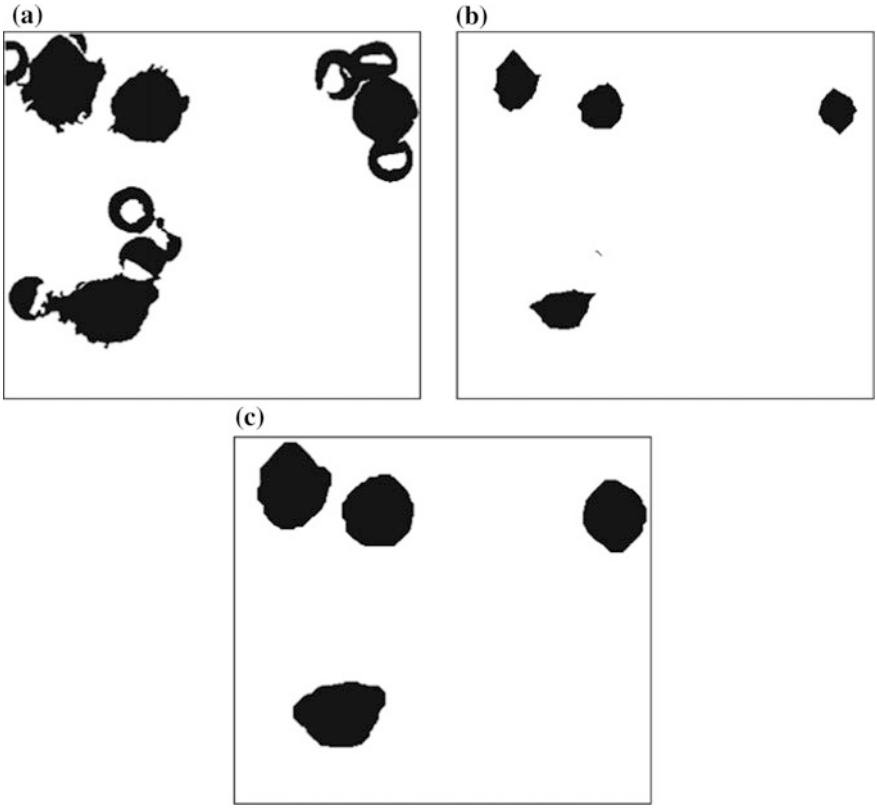

Fig. 4 **a** Elimination of white patches **b** separation of WBCs **c** formation of WBCs

Formation of WBCs: From Fig. 4b, it is clear that the WBCs are now separated from the RBCs. But the sizes of the WBCs are reduced. It is also the fact that some small components of RBCs may be present after dilation. These small black regions are eliminated by criteria on size. The average size '***A***' of all regions is calculated. The region with size less than '***A***' is eliminated from the image.

To increase the size of WBCs, the dilation [11] operation is applied. Dilation has the opposite effect to erosion—it adds a layer of pixels to both the inner and outer boundaries of regions. Same disk-shaped structuring element with radius 27 is applied to increase the size. The result is shown in Fig. 4c.

4 Result

The proposed method is applied on 200 blood samples. The results generated by this method are compared with human visualization. It is found that the results match with the manual observation in high percentage (97.57%). Figure 5 shows

six blood samples as representatives. Figure 6 shows the detected WBCs for these six samples. In all cases, it detects the WBCs successfully. To test the strength of this method, some blood samples without WBC are given. The method satisfactorily produces output without detecting any WBC. One such sample is given in Fig. 5f, and the corresponding output is given in Fig. 6f.

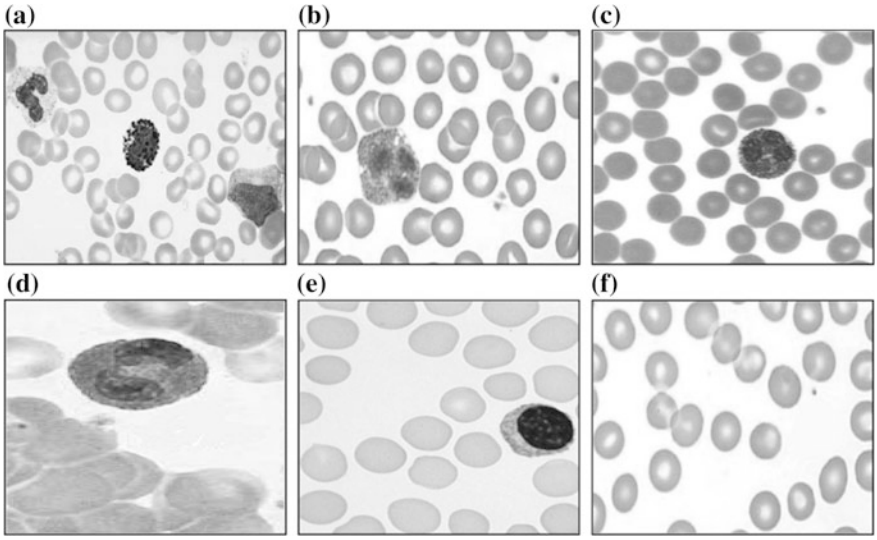

Fig. 5 **a–f** Six blood samples

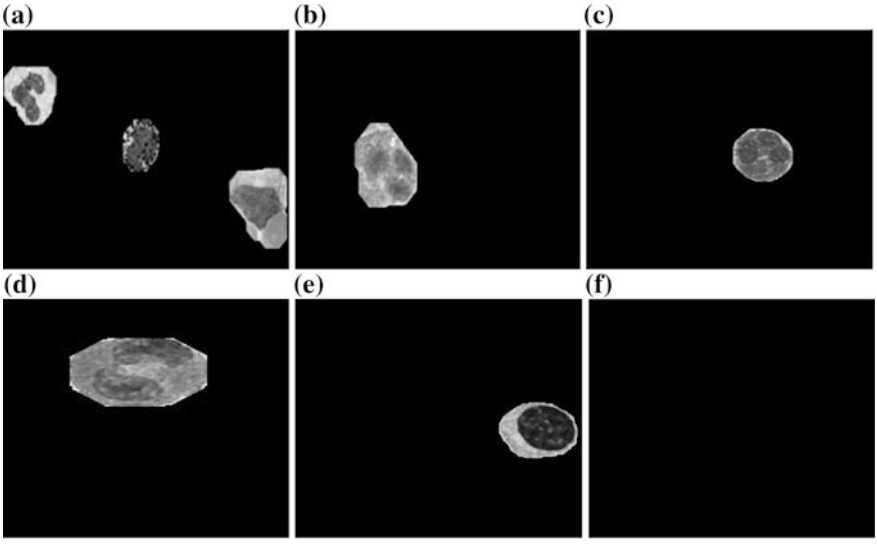

Fig. 6 **a–f** Detected WBCs of Fig. 5a–f

5 Conclusion

This technique may facilitate work flow in biomedical science by replacing tedious and monotonous work with automation. This can be a developmental step to create an automated solution in a larger scale to detect a mere human killing disease as fast as possible. The methodology achieves an automated system for the detection of WBCs and can be used for better and accurate classification of WBCs. The time associated with the pathologist's views can be decreased. The speed and accuracy can be increased by applying this automated analysis prior to the pathologist spending any time on it.

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