Automated Blood Counter (ABC): an Image Processing Solution

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Abstract— *Nowadays there are many types of research are going on the computer vision area. And there are some new trends for the Bio-medical area with computer vision. But for blood counting purpose there are still we can use image processing solutions for solving problems. To diagnosis of a huge variety of diseases usually, we tend to take a blood sample and reckoning and analysis of blood cells thereon sample. To calculate platelets or blood count, there are two techniques normally use namely, manual technique and an automatic machine technique. The manual enumeration of white blood cells, red blood cells and platelets in microscopic read is an extremely tedious, time intense, and inaccurate method and the count depends on the experience of the lab technicians. In the other hand, automated machines are very fast and highly accurate but, the main problem of this machine is the incredible price and also there are few numbers of units are obtainable in Sri-Lanka and most of these doesn't seem to be operate properly. Our solution can apply for the manual testing method to reduce the time delay (for counting) and will increase the accuracy of the ultimate output. In the manual process, using a microscope and searching the blood cells through that microscope and do the blood counting process manually. Basically, when we upload those microscopic images to the proposed system, then system will produce the cell count. In our system, we developed algorithm to produce the red cell count based on the image processing techniques. Algorithm used masking and edge detection techniques for identify the cells and for counting purpose it applied contour detection and ellipse fitting method. Challenging task in this research is splitting touching cells. Our proposed algorithm can identify touching cells and using contour detection and ellipse fitting algorithm can segment those touching cells.*

Keywords— **Image processing, Blood counting, Masking, Edge detection, Contour detection, Ellipse fitting**

I. INTRODUCTION

To diagnosis of a huge variety of diseases usually, we tend to take a blood sample and reckoning and analysis of blood cells thereon sample. This is the primary step to determine a patient has a diseases or not. There are two techniques we have a tendency to use for blood enumeration. Namely, manual technique and an automatic machine technique. If we take automated machines, they're very fast and highly accurate. We are able to get printed blood report within less than two minutes. The main problem of this machine is the incredible price. As a result, one automated unit is going to be more than 3500,000Rs in Sri-Lanka. Another drawback is there are few numbers of units are obtainable in Sri-Lankan Government hospitals and most of these don't seem to be operating properly. And if the particular blood sample has giant blood platelets (sometimes platelet size can increase for a few diseases or chemical change of the human body) or platelets were clustered, the machine offers wrong results. Most of those units use varied technologies to find the number of blood cells (Most of the time they using optical laser beams for cell count). If lab technicians who doing the blood enumeration work, determined the expecting result's wrong, then they are doing manual testing additionally. In other hand the manual enumeration of WBCs (White Blood Cell count) or RBCs (Red Blood Cell count) or platelets in microscopic read is an extremely tedious, time intense, and inaccurate method. In medical labs, most of the time uses this manual enumeration method for the blood count. Because we haven't automated machines for every hospital. Lab technicians have to do lots of process before calculative the count. And this manual count depends on the experience of the lab technicians.

Blood Cell identification has widespread interest particularly for clinics and medical laboratories. For instance, patient's blood cells investigation is used to extract information regarding alternative cells that aren't usually present in peripheral blood, however, could also be discharged in sure disease processes by the haematologist. One among the nice challenge to rework this human sensible task into computerized and primarily based that the system is comparable to human performance or higher. Thus, the system should be stable and able to handle the uncertainty. Furthermore, to doing this can apply image processing and computer vision which this is a sub-area of artificial intelligence in computer science. Basically, Image processing technique has five basic modules which are image acquisition, image pre-processing, image post-processing, image segmentation and image analysis. The most important and serious step in image processing is the segmentation part. This paper present how to use image processing for blood segmentation process and cell counting.

II. LITERATURE REVIEW

When the think about a blood sample there are four categories is found thereon. Particularly they are red blood cell (RBC), white blood cell (WBC), blood platelet and plasma. WBC can also be classified into five groups which are lymphocytes, neutrophils, eosinophils monocytes and basophils (Sharif et al., 2012). WBC count based on these white cells types percentage in the blood smear. These white cells deliver major protection against infections in viruses and their specific meditations can facilitate consultants to discriminate the presence or the absence of most significant relations of pathologies (Piuri and Scotti, 2004). Once infection takes place, the manufacture of WBCs upsurges. Abnormal high or low counts might show the occurrence of the many varieties of disease. The variations among these blood cell groups lie on the colour, texture, size and morphology of nucleus and cytoplasm. The number of red cells is greater than white cells. As an example, a picture can contain up to a hundred red cells however only one to three or four white cells. Flowing **Table 1** showing the normal blood count differentiation by gender.

Table 1. Normal blood count differentiation by gender

Blood cell type	Gender	
	Male	Female
RBC	4.5 - 6.0 million/microliter	4.0 - 5.0 million/microliter
WBC	4.5 - 11 thousand/microliter	4.5 - 11 thousand/microliter
Platelet	150 - 450 thousand/microliter	150 - 450 thousand/microliter
Haematocrit	42% to 50%	36% to 45%
Haemoglobin	14 - 17 grams/100 millilitres	12 - 15 grams/100 millilitres

There are various segmentation methods (Adollah et al., 2008) can apply for blood segmentation and cell splitting using image processing. Based on a homogeneity criterion, segmentation is the process of splitting a picture into disjoint regions. There are two methods of segmentation commonly used for blood analysis. Namely, cell level segmentation and component level segmentation. Image segmentation process can be divided into two parts. In region-based approach containing thresholding, region clustering, morphological segmentation with watershed algorithm etc. Likely in boundary-based approach containing edge dictation techniques and contour detection methods etc. (Dougherty and Lotufo, 2003)

A. *Thresholding based segmentation*

To segment an image, thresholding based technique is the simplest method. Using this method can separate objects from the background using a pixel feature value. This method also uses for colour splitting from RGB image to red, green and blue components. It is a very important feature for our application. Because for identifying red cells from the other objects we use the green component image. To detect cytoplasm and leukocytes some authors (Le et al., 2008) use blue component images. In 1979 Nobuyuki Otsu (Otsu, 1975) proposed a new method for optimal thresholding using exploiting the between-class difference through an exhaustive exploration. This approach was altered to multiple thresholds for splitting background, cytoplasm and nucleus. In most biological related image thresholding like in X-Ray and MRI images related applications use this Otsu’s algorithm for thresholding those images. In our proposed algorithm we use this Otsu’s algorithm technique for thresholding purpose.

B. *Cell segmentation using morphological operators*

Mathematical morphology operators provides a powerful tool for mining picture components that are valuable in the description and representation of region shape, such as textures, borders, skeletons (Di Rubeto et al., 2000; Dougherty and Lotufo, 2003). When we apply thresholding, we have to filling holes. To filling holes, many authors proposed this morphological operation like the opening filter. But using this filter there can be over filling errors and it is good for a particular image. If the problem getting general (mean if use this method for many images) we have to consider the iteration level also. Iteration level mean we need to apply this opening filter for several times to filling the different size of red cell holes. Since this can be getting overfilling or under filling errors and if we fit the number of iterations, it will effect to the other different images. Because we have to mechanize the number of iterations base on the picture and hole size. This is a critical issue. Therefore, this method is not good for filling holes. To handle this error, we propose masking method to filling holes.

C. *Cell segmentation using Watershed algorithm*

The execution of image processing in blood cell has carried a new indication to reduce the cost for a clinical decision. This concept comes from considering the picture as a topographic surface, in which grey levels parallel to terrain altitudes. Segmentation is done by rain falling or flooding simulation. J. M. Sharif and his members come up with a research about red blood cell segmentation using morphological operations and watershed algorithm (Sharif et al., 2012). The Watershed algorithm with distance function has been applied for red cells segmentation purpose. To Identify the overlapping red blood cells, they used the combination of Laplace of Gaussian (LoG) edge detection, gradient magnitude, morphological operation and marker-controlled watershed algorithm. One of the difficulties is there is some debris and unwanted objects seem in the picture which results in the lessening in

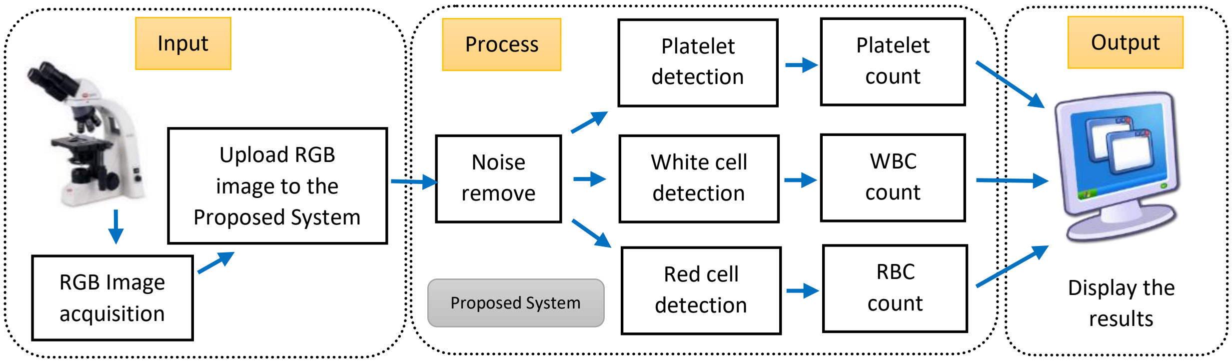


Figure 1. Automated Blood Counter proposed system.

accuracy. And also, this watershed algorithm is good for some applications. But many authors (Bai et al., 2008; Díaz and Manzanera, 2009) showing classical watershed algorithm usually have the problem of under-segmentation or over-segmentation.

D. Cell segmentation using Ellipse Fitting, Concave Points and clustering

Basically, classical edge detection methods are built on the discovery of unexpected neighbourhood changes in the pixel values. In many cases, the borders between cells and their modules are not clearly defined, and then edge finding performs poorly on these pictures (Wu et al., 2006). This edge detection performance can be enhanced when it is joint with other techniques. Concave point and ellipse fitting algorithms can be applied to separate circle or ellipse like overlapping cells (Bai et al., 2008; Kothari et al., 2009). Basically, their algorithm can be divided into two parts. They are contour pre-processing and ellipse processing. Contour pre-processing use to find the concave points of the contour and segment contour using these points while ellipse processing uses to identify touching cells. This ellipse fitting approach is very good solution for cell splitting purpose. And also it is very powerful than normal edge detection. Because of the using of the concave detection we can find cell borders more accurately. Therefore, we use this ellipse fitting approach for our proposed algorithm to cell identification purpose.

III. METHODOLOGY AND EXPERIMENTAL DESIGN

Our proposed system containing facility to Noise remove, White cell identification and produce the white cell count, Red cell identification and produce the cell count, and also for Platelet detection technique. Furthermore, system have small data base for store the patient's details. In **Figure 1** showing the block diagram of the proposed system.

In the input section we take microscopic RGB blood image from the microscope and upload the image to the proposed system. In the proposed system, the first step is the noise removing. After the noise removing step system applied different algorithms for cell detection.

In order to identify the platelets, we propose morphological operations. Using morphological

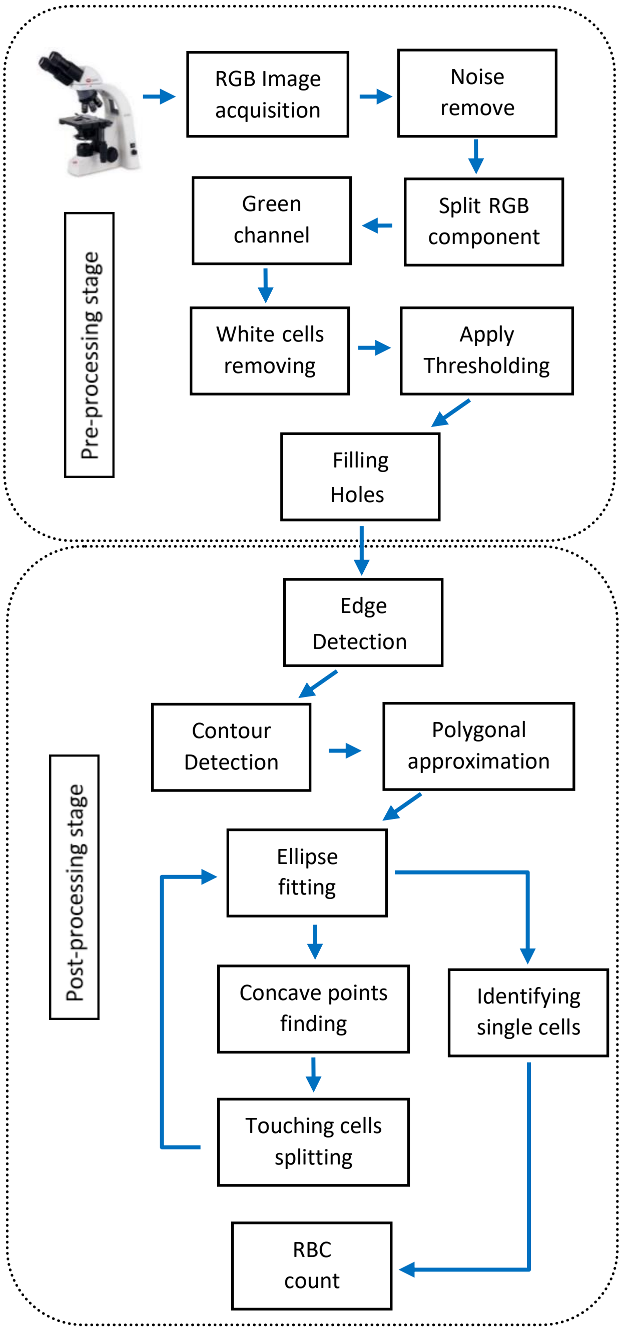


Figure 2. Flow chart of the proposed Red cell counting algorithm.

operations, we can easily identify small parts in the image. For counting purpose, we propose connected component labelling method. To separate the white cells, form red cells, in our system we using machine learning technique call Support vector machine algorithm. We propose to train a collection of white cell images and using those trained set will produce average white cell count to the user. In order to find the red cells, we develop an algorithm to count the red cells. In the output section, in other words we can say front end of the application, we use python to develop the front end as well as back end of the proposed system. Final results will display on the front end of the application and user can save those data to the SQLite database with the corresponding images and the patient's basic details. Flowing **Figure 3** showing the front end of the proposed system.

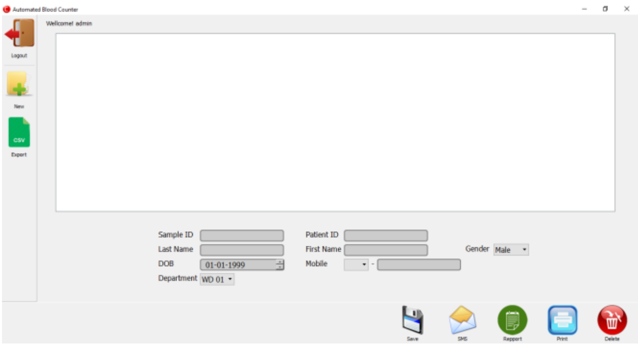


Figure 3. Front end of the proposed system.

Our proposed Red cell counting algorithm containing Noise remove, RGB channel splitting, white cell removing, thresholding, filling holes using masking, edge detection and segmentation and RBC counting techniques.

Basically, proposed algorithm can be separate into two parts. Namely, pre-processing stage and post-processing stage. In **Figure 2** showing the flow chart of the proposed algorithm.

A. *Pre-processing stage*

In pre-processing stage containing noise removing, white cell removing, RGB splitting like things. Before going to post-processing stage let's what are those steps in brief.

1) RGB Image acquisition: In this step using camera we take a microscopic RGB image and upload it to the proposed system.

2) Noise removing: Due to dust or low quality of the camera image may not be cleared. Therefore, need to clean the image before going to further steps. To noise removing algorithm apply median filter to the original image. Because of the median filter we can reduced the noises.

3) Split RGB components: In the next step RGB image will be split to three separate channels Red channel, Green channel and Blue channel. Purpose of the split is identifying Red cells and White cells separately.

4) Green channel: After the RGB splitting we take green channel for identifying the Red cells. According to other's works many researchers talking that accuracy for finding Red cells is high for green channel. And based on our testing samples with these three channels we found that above statement is true. So our proposed algorithm split the RGB image and get the green channel for Red cell detection.

5) White cell removing: Before going to Red cell detection we have to check particular image containing white cells. If so we have to remove them from the image. Algorithm use blue channel to doing this work. Because white cells are more sensitive for blue channel. After the removing white cells, next step is thresholding.

6) Apply thresholding: Thresholding technique is very powerful tool for image segmentation. In literature review section we mention that the efficiency of the thresholding method. We can use this technique for separate the cells from background. In other words, we can use thresholding for background remove purpose. Proposed algorithm using Nobuyuki Otsu's algorithm techniques for image thresholding. Because this Otsu's algorithm is more useful for medical related images thresholding purpose.

7) Filling holes: After the thresholding, image may be containing some holes inside the red cells. Before going to the edge detection stage we have to fill those holes. Otherwise edge detection step will produce wrong edges also. To accomplish that, can use morphological operations. But in literature review section we mention that morphological operations are not good for filling holes. In the propose algorithm we used masking technique for filling holes. This masking method omit the overfilling and under filling errors that are producing if we use morphological operations for filling holes.

B. *Post-processing stage*

In post-processing stage containing the core of the segmentation. Algorithm use contour detection, polygonal approximation, concave points finding and ellipse fitting, this containing in the post-processing stage.

1) Edge Detection: Post-processing stage will start with edge detection step. There are several high pass filter techniques can use for edge detection in OpenCV. We use canny edge detector for edge detection purpose. Next step invokes with the contour detection.

2) Contour detection: Contours can be explained simply as a curve joining all the continuous points (along the boundary), having same colour or intensity. The contours are a useful tool for shape analysis and object detection and recognition. For better accuracy, use binary images. So before finding contours, apply threshold and canny edge detection. These steps are done on pre-processing stage and beginning on the post-processing stage.

3) Polygonal approximation: As in next step we applied polygonal approximation to the funded contour points. The purpose of the polygonal approximation is to reduce the contour points without changing the actual shape of the red cells boundaries.

4) Ellipse fitting: After the polygonal approximation we applied ellipse fitting technique for the image based on the polygonal approximation points. Purpose of the Ellipse fitting is to identify the single cells and touching cells. Before applied the ellipse fitting we store a copy of polygonal approximation detected image. Let's say it *P2.* Reason for that is after the finding single cells, to find the multi cells we have to reduce the single cells form the polygonal approximation detected image. Next step is involving for single cell detection.

5) Identifying single cells: After the Ellipse fitting, our proposed algorithm will generate the areas of the fitted ellipse. After the calculate areas, algorithm produced the average ellipse area. We use this average ellipse area to find the single cells. We defined min and max rage for single cell area based on the average ellipse area. Let's say *S1* for detected single cells image.

6) Concave points finding: Before going to find the concave points we have to find the touching cells. To do that process we have to reduce the single cells form the all cells. Let's define T for touching cells.

$$T = P2 - S1$$

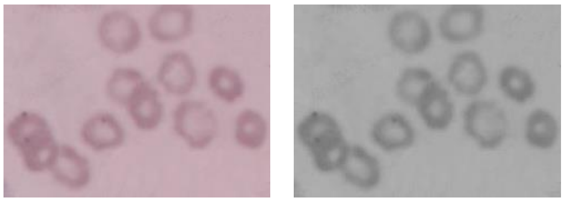
After the finding touching cells we can find concave points of those touching cells. We defined small algorithm to check the particular polygonal approximation point is concave point or convex point base on the curve of the cell edge. Then store those concave points and convex points separately on an array for splitting the touching cells.

7) Touching cells splitting: In this step algorithm split those touching cells using those concave points and convex points. We wrote small function to draw ellipses based on those points. Then finally algorithm return the Red cell count using counting ellipses.

Furthermore, in our front end application has some facilities to store patient details patient's name, age, sex, ward number, telephone number on a database. We used SQLite for develop the database. If we use oracle database or mysql database, we have to configure it on the customer's computer also. Therefore, we used SQLite because our database has simple infrastructure and can automatically develop it through the application.

IV. RESULTS

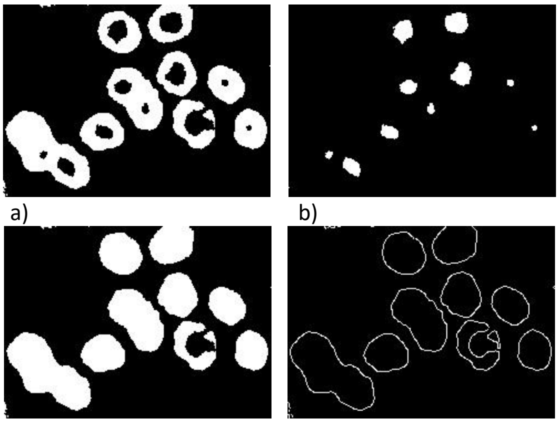
One of the main objective of this research is to identify touching cells and segment them using image processing techniques. Proposed algorithm was implemented using python programming language and for image processing part used OpenCV package for python. Algorithm tested on a windows 10 64-bit version OS laptop and the laptop having i5 processor with 4GB ram. Following figures showing the ultimate result of the research.



a) b)

Figure 4. a) Original RGB image b) Green channel of the image

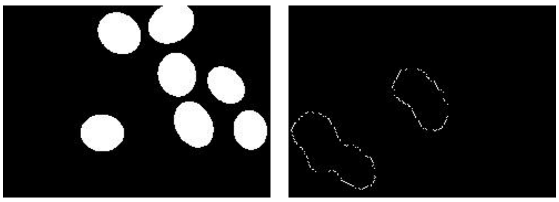
Above **Figure 4** a) showing the original RGB image taken from the microscope and **Figure 4** b) showing Green component channel after the RGB channel splitting. In **Figure 5** a) image showing after the applying Otsu's thresholding techniques to the green channel. In hear we can see holes inside the red cells.



a) b) c) d)

Figure 5. a) After the thresholding. b) Finding holes using masking. c) After the applying masking to the threshold image. d) Canny edge detection.

To fill those holes, we applied masking method rather than using morphological operations. In **Figure 5** b) and c) showing after the mask applied to the threshold image. **Figure 5** d) showing the canny edge detection.



a) b)

Figure 6. a) Identifying single cells. b) Identifying touching cells.

In above **Figure 6** showing the identification of the single cells and multi cells using our proposed algorithm explained in methodology section.

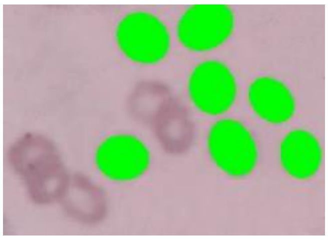
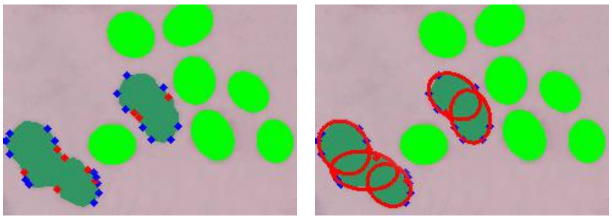


Figure 7. Identifying single cells.

Figure 7 showing the single cells with the green colour. In **Figure 8** a) showing after the concave points finding. Blue dots showing the polygonal approximation points or we can simply say contour points while red dots showing the concave points. **Figure 8** b) showing after the ellipse fitting using those concave points.



a) b)

Figure 8. a) After the concave points detection. b) Ellipse fitting using concave points.

Using number of ellipse, we can get the red cell count easily. According to our results this ellipse fitting method using concave points is giving high accurate results than other techniques. But there are some common limitations. These results are based on the input image quality. If the input image getting low, that will effect to the final output. And also we have to consider the intensity of the light source of the microscope before taking the image. For some images light intensity can be effect to the final output.

However, our proposed algorithm can produce the red cell result within less than two minutes. That is very helpful for reducing the manual enumeration time and high accurate than normal calculation.

V. DISCUSSION AND CONCLUSION

Basically, there are two techniques use for blood counting, manual technique and automated machine technique. Automated machines are high cost. Therefore, most of the time use manual technique for cell counting. In our research we consider two main objectives. Segmenting touching cells using concave points and ellipse fitting methods in image processing and reduce the manual enumeration time for red cell counting base on this proposed algorithm. Our proposed algorithm has two main stages pre-processing stage and post processing stage. Pre-processing stage use for cleaning original image, green channel splitting and thresholding while post-processing stage use for edge detection, contour detection, concave points finding and ellipse fitting. To filling holes, we applied masking method rather than using morphological operations like opening and closing. And also for identifying single cells we used average ellipse area after the ellipse fitting to the threshold image. Proposed algorithm can abele to segment touching cells and produce the red cell count within two minutes. Furthermore, we developing algorithm for white cell identification based on our proposed method.

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