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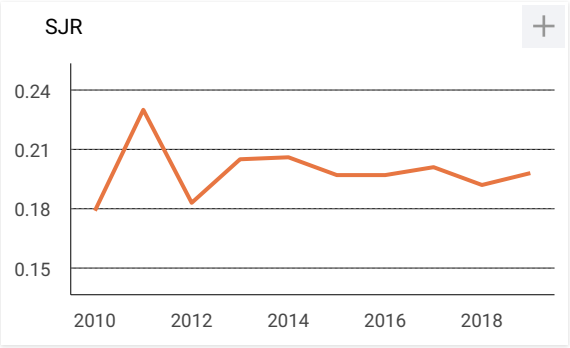
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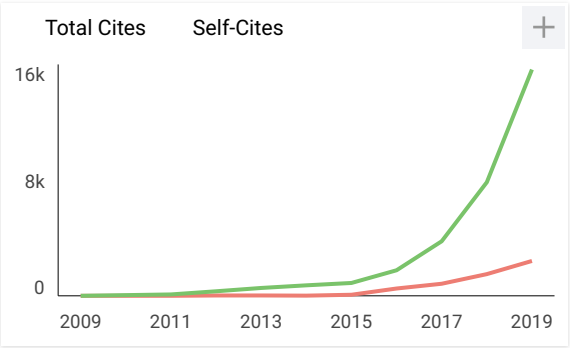
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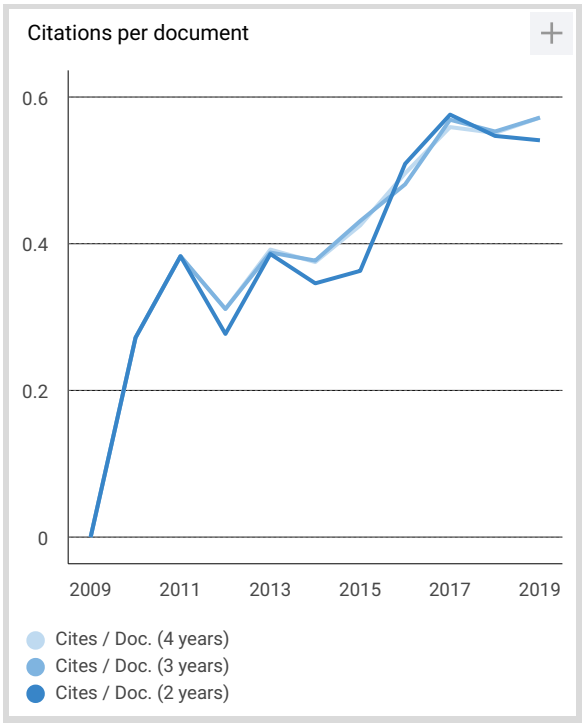
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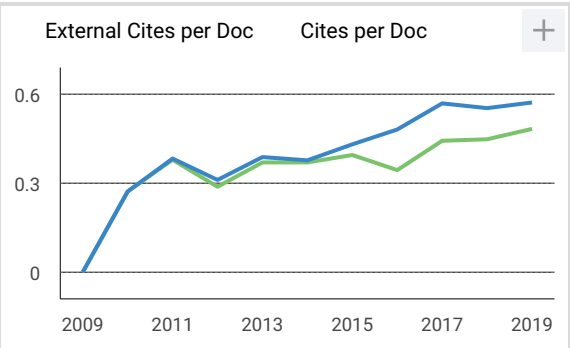
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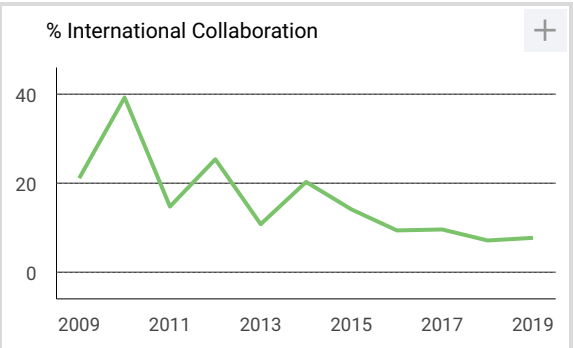
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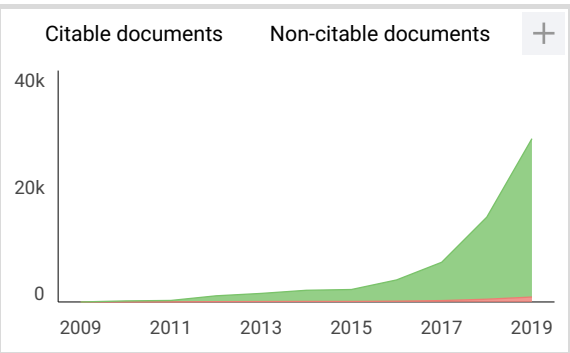
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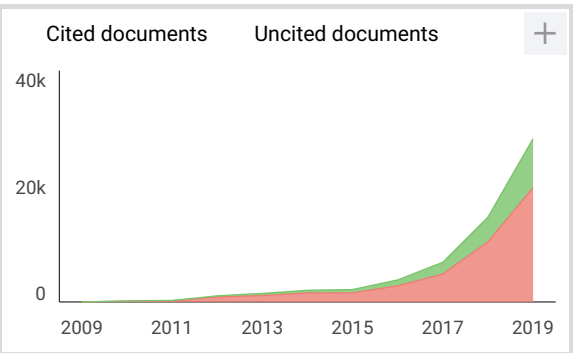
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Segmentation of White Blood Cell Areas from Colour Degraded Microscope Slide Images

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Segmentation of White Blood Cell Areas from Colour Degraded Microscope Slide Images

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Abstract. Advances in computer technology have increased in most aspects of medical analysis, such as for diagnosing diseases, treating drugs, analysing organs, and others. Computers are often used as a tool for analysis of medical images. This paper describes an automatic segmentation process of white blood cell areas on given microscopic images. The input of the system is microscope slide images with various staining conditions. Some images contain colour degradations due to imperfect staining process, while some images are in excellent staining condition. The Hough Transform method is applied for the segmentation process of the white blood cells detection. The system classifies each detected white blood cell area in one of the three defined categories (Small, Medium, and Large). The segmentation accuracy of the proposed system was 40.58% for images with colour degradation, while 100% segmentation accuracy was achieved by the system for images with excellent staining condition.

1. Introduction

Nowadays computers have shown a huge impact in medical analysis. One subject of the medical field that uses computer for analysis is blood cells. The analysis of blood cells could be used to detect blood disorder or to determine the presence of infectious diseases in human body. In order to identify the hematopoietic system disorders, hematologists need to perform the blood cells identification and counting for every blood elements, such as the erythrocytes (red cells), leukocytes (white cells), and platelets [1]. The process starts with data preparations which includes cell staining of the microscope slides. Cell staining is a technique that can be used to better visualize components of cells under a microscope, such as a nucleus or the entire cell [2]. The staining process involves immersing the sample in a dye reagent and then rinsing and observing the sample under a microscope. Since the task is often conducted by a human, mostly the images obtained from the microscopic slides are varied in colours; due to imperfection in staining process, changes in lighting during the image capturing process, and other factors. In some rural areas, these data are then processed by human technicians for manual identification and cell counting which are very time consuming and might contain human errors. Therefore, an automatic cell detection, identification, and counting application is really helpful.

Several researchers have proposed various methods to identify blood cells, such as the Support Vector Machine method [3] and EM algorithm [4]. However, the developed systems have not been tested for

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blood cells with various colour degradations. In this paper, an automatic white blood cell detection system that can detect the white blood cell areas from microscopic images is developed. The proposed system works based on the Hough Transform method. First, the system performs the white blood cells segmentations using Hough Transform method, then the system localizes the areas which contain the region of interests. The experiments are conducted for various colour degradation of microscope slide images. The remainder of this paper is organized as follows. In Section 2, the proposed segmentation system based on Hough Transform method is explained. Section 3 presents the experimental setup and results. Finally, the conclusion is presented in Section 4.

2. Segmentation Methods

In the proposed system, the Hough Transform method is applied to detect the white blood cell areas from the captured microscope slide images. The diagram of the proposed segmentation system is depicted in Figure 1. The system starts with an input image. Next, a preprocessing stage is performed by conducting a smoothing process, a sharpening process, a RGB to HSV colour transformation, a grayscalling process, a thresholding step, and a morphological transformation. The details of each method used in the preprocessing stage is described in section 2.1. Afterwards, the segmentation process is performed by applying the Hough Transform method. The detail process of Hough Transform is presented in section 2.2. The output of the system is the white blood cell areas which have been segmented.

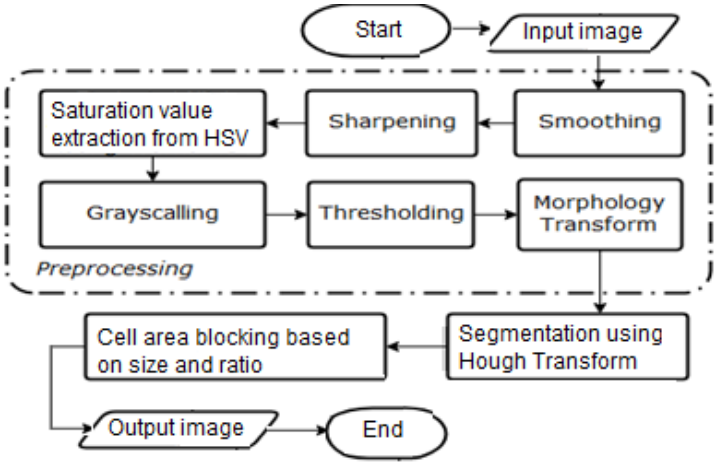

Figure 1. The diagram of the proposed segmentation system

2.1. Preprocessing

In the preprocessing step, the proposed system conducts processes as follows sequentially: smoothing, sharpening, saturation extraction, thresholding, and morphological transform. The median filter [5] technique is used as smoothing factor to eliminate noises in microscopic images, while Laplacian kernel [6] is used for sharpening. Furthermore, the processed images are transformed from RGB domain to HSV domain. The HSV domain consists of three characteristics, i.e. Hue, Saturation, and Value. In this paper, the most determining factors for cell detection is Saturation, while Hue and Value remain neutral. Thus, the microscopic images are processed only by Saturation score. After the thresholding step, the morphological transformation is applied to the system. Morphological image processing uses combination of operations related to shape features in an image. Some fundamental operations in morphological transform are represented by erosion and dilation calculations.

2.1.1. Erosion

Erosion removes small-scale details from a binary image and simultaneously reduces the size of regions of interest. Erosion combines object nodes or pixels with 1 score and turns them into the background. The equation for erosion step is as follows [7]:

$$g(x,y) = f(x,y) \ominus SE \tag{1}$$

where *g(x,y)* is pixel value after erosion step, *f(x,y)* is pixel value after thresholding step, and *SE* is the structuring element.

2.1.2. Dilation

In contrast with erosion, dilation combines object nodes or pixels with 0 score and turns them into parts of the region of interest. The equation for dilation is as follows [7]:

$$g(x,y) = f(x,y) \oplus SE \tag{2}$$

where *g(x,y)* is pixel value after dilation step, *f(x,y)* is pixel value after thresholding step, and *SE* is the structuring element.

2.2. Hough Transform

The Hough Transform algorithm [8-11] is an algorithm for image features generation which are invariant to image translation, scaling, rotation and partially invariant to illumination changes and affine projection. In this paper, the Circle Hough Transform is applied to detect circle shapes of the blood cells from microscopic images. The final decision of a detected circle adopts a voting technique in Hough space; Thus the area with the highest score represents a real circle. The equations for the Circle Hough Transform are as follows:

$$x = x_o - r\cos\theta \tag{3}$$

$$y = y_0 + r\sin\theta \tag{4}$$

where (x_0, y_0) is the coordinate center of the circle, r is the radius of the circle, and (x, y) is the pixel coordinate. The detail algorithm of the Circle Hough Transform [9] is depicted in Figure 2.

```
Accumulate the circles in gray-tone image S to accumulator A.
S[R, C] is the input gray-tone image.
NLINES is the number of rows in the image.
NPIXELS is the number of pixels per row.
A[R, C, RAD] is the accumulator array.
R is the row index of the circle center.
C is the column index of the circle center.
RAD is the radius of the circle.

    procedure accumulate_circles(S,A);
    {
    A := 0;
    PTLIST := 0;
    for R := 1 to NLINES
      for C := 1 to NPIXELS
        for each possible value RAD of radius
          {
          THETA := compute_theta(S,R,C,RAD);
          R0 := R - RAD*cos(THETA);
          C0 := C + RAD*sin(THETA);
          A[R0,C0,RAD] := A[R0,C0,RAD]+1;
          PTLIST(R0,C0,RAD) := append(PTLIST(R0,C0,RAD),[R,C])
          }
    }
```

Figure 2. The detail algorithm of the Circle Hough Transform

3. Experimental Results

This section describes the experiments conducted for the proposed white blood cell segmentation system using the Hough Transform method. We developed our own database, called the FTI-Untar blood cells database, which consists of a total of 69 blood cell images with 38 neutrophils images, 17 lymphocytes images, 8 monocytes images, 6 eosinophils images, and 0 basophils images. The images were taken using a digital camera with 1600 x 1200 pixels that was attached to a microscope. Figure 3 shows the GUI examples of blood cell images used in the experiments.

First, we evaluated the performance of the proposed system for detecting the white blood cells from images with various colour conditions as shown in Table 1. We classified the detection results in 3 categories: 1) S when the detected part contains 1-30% white blood cell areas, 2) M when the detected part contains 31-60% white blood cell areas, and 3) L when the detected part contains 61-100% white blood cell areas. Table 1 shows that the segmentation accuracy of the proposed system was 40.58% for images with colour degradation, while 100% accuracy was obtained for images with excellent staining. Both image types spent 0.95 seconds/image for the segmentation process.

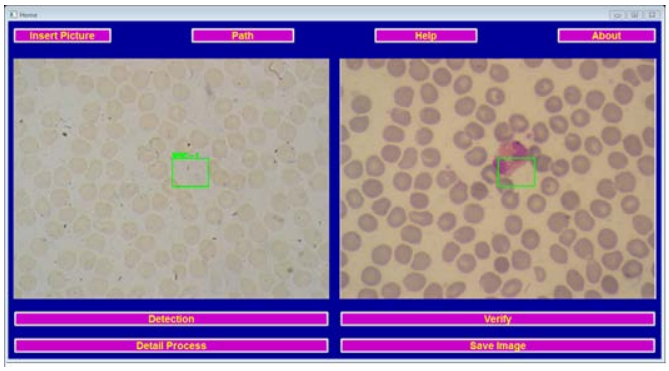

Figure 3. GUI examples of a color degraded cell image (left) and a stained cell image (right)

Table 1. The results of white blood cell detections using Hough Transform

Image Type	Detection			Not Detected	Accuracy (%)	Time (second)
	S (1-30%)	M (31-59%)	L (60-100%)			
Colour degraded	4	7	17	41	40.58	0.95
Excellent staining	0	7	62	0	100	0.95

Table 2. The segmentation results of white blood cell types from colour degraded images

Blood Cell Type	Detection			Not Detected	Accuracy (%)
	S (0-30%)	M (31-59%)	L (60-100%)		
Neutrophil	1	5	12	20	47.37
Eosinophil	2	0	3	1	83.33
Basophil	-	-	-	-	-
Lymphocyte	1	1	0	15	11.76
Monocyte	0	1	2	5	37.5

Next, we calculated the segmentation results of white blood cell types from colour degraded images. Table 2 shows that the obtained segmentation accuracy from colour degraded images was 47.37% for neutrophil, 83.33% for eosinophil, 11.76% for lymphocyte, and 37.5% for monocyte. As the basophil data were not found in the collected database, the segmentation accuracy for basophil cells could not be calculated in this experiment. In general, the proposed system presented good segmentation capability as 60.71% of the detected areas were in L category. It was also shown that eosinophil is the easiest cell type to detect both in the controlled environment (i.e. excellent staining) and in various image conditions (i.e. colour degraded image).

4. Conclusion

We have presented the Hough Transform method to automatically detect the white blood cell areas from various conditions of the microscope slide images. The detection results of the white blood cell images are highly dependent on the colour feature with 40.58% accuracy was obtained by the proposed system for colour degraded images, while 100% accuracy was achieved by the system for images with excellent staining condition.

In the future, we consider to improve the system performance by the addition of texture feature along with the colour feature, the use of other colour domains, and the implementation of a dynamic window model as a segmentation method of white blood cell areas.

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Acknowledgments

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