White Blood Cells Detection Using Spectral Tresholding

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Abstract

The study of the morphology of White Blood Cells (WBCs) further contributes to the clinical diagnosis of blood diseases. In this research paper, we come up with an image segmentation enhancement by combining Fourier Fast Transform on smear blood capture and classical thresholding. The Fast Fourier Transform (FFT) is a very powerful tool in image processing and it was used to segment and extract the WBCs. Our image processing method uses a Fast Fourier Transform combined with filtering and an Inverse Fast Fourier Transform for the extraction and visualization of the high frequency region of the image. In order to remove residual Red Blood Cells acting as noise in the expected result, a final thresholding step is added at the end of the processing. The results presented in this article report the tests performed using our mathematical implementation. Moreover, we were able to detect and differentiate the sub-families of WBCs.

Keywords

Segmentation, Fourier Transform, White Blood Cell

1. Introduction

Blood is a liquid tissue that circulates throughout the human body via blood vessels. It plays an essential role in the transport of oxygen, nutrients, antibodies and hormones. A Cell Blood Count (CBC) and/or a blood smear are methods of studying its composition.

In the clinical laboratory, a blood smear is mainly performed when a CBC shows the presence of abnormal or immature cells. It may also be performed when the doctor suspects a deficiency, disease that affects the production of blood cells, such as anemia, decreased or abnormal production of cells in the

bone marrow, or increased cell destruction.

Figurative blood elements are Red Blood Cells (RBCs), White Blood Cells (WBCs) and platelets that are embedded in plasma. In a blood smear comprising these differentiated blood cells, the differences between the figured elements lie in texture, color and size. But they may also differ in morphology and composition of the nucleus and cytoplasm.

Generally round in shape, with a diameter of between 0.005 mm and 0.02 mm, there are 6000 to 8000 White Blood Cells (or leukocytes) per mm^3 of blood. They are larger than Red Blood Cells (RBCs) and perform a variety of purification and infection protection functions.

The study of the morphology of WBCs is essential for the correct diagnosis of certain form-related diseases. Much work has been done to automate the process of detecting WBCs from a blood smear image. The study conducted by Nabilah Mohd Safuan, Syadia; Razali Md Tomari, Mohd; Nurshazwani Wan Zakaria, Wan, deals with the detection of WBCs using a color-based segmentation method [1]. In contrast, Di Ruberto, Cecilia, Loddo, Andrea, Putzu, and Lorenzo, proposed a Region approach [2].

The automatic detection of WBCs could be facilitated by an algorithm that could extract WBCs from microscopic slide images and faithfully maintain their morphological appearance. This would be a considerable contribution to the work previously published.

Thus, we propose a spectral technique for the detection of WBCs using a Fast Fourier Transform juxtaposed with a thresholding segmentation.

2. Methodology

The goal of this algorithm is to detect the WBC. We have developed an algorithm that uses data from blood smears in the frequency domain.

A necessary prerequisite for the successful execution of the algorithm is the selection of a good quality, well-spread or diluted blood smear image where the features are well distinguished (Figure 1).

After acquiring a photograph of a blood smear, it is necessary to apply the following 4 steps.
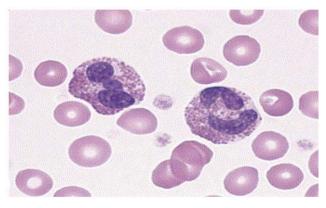

Figure 1. Blood smear.

2.1. Image Preprocessing

Image preprocessing has the effect of changing from a color image to a grey image, which is an elimination of the third color component of the image.

2.2. Segmentation by Fast Fourier Transform

Segmentation by Fast Fourier Transform (FFT) (1) is applied to get the frequency domain representation of the image. This spectral representation makes it possible to identify the different regions of the image represented by the high and low frequencies respectively.

The Fourier Transform is written as citation:

$$F(u) = \int_{-\infty}^{+\infty} f(x) e^{-i2\pi ux} dx \tag{1}$$

- u and F are the spectral coordinates, respectively frequency and amplitude of a pixel in the image.
- x and f are the spatial coordinates, respectively abscissa and ordinate of a pixel in the image.
- $f(x)$ represents the spatial domain image, $F(u)$ represents the frequency domain image.

2.3. Extraction of the High Frequency Region

Extract the high frequency region:

- Filtering is applied to the image to highlight the high frequency region and mask the low frequency region.
- Apply at the next step an Inverse Fast Fourier Transform (IFFT) (2) to find back the spatial domain where the cells are visible since the image produced by FFT was in the frequency domain.

The Inverse Fourier Transform is written as:

$$f(x) = \int_{-\infty}^{+\infty} F(u) e^{i2\pi ux} du \tag{2}$$

- u, F: spectral coordinates (frequency and amplitude respectively) of an image pixel.
- x, f: spatial coordinates (abscissa and ordinate respectively) of a pixel in the image.
- $f(x)$: the spatial domain image.
- $F(u)$: the frequency domain image.

2.4. Image Post-Processing

The image post-processing consists of the application of a classical thresholding method (3) to remove red blood cells from the image background, in order to improve the efficiency of WBCs detection (**Figure 2**).

The mathematical expression for thresholding is:

$$g(x,y) = f(x) = \begin{cases} 0, & \text{if } f(x,y) < T \\ 255, & \text{if } f(x,y) \geq T \end{cases} \tag{3}$$

3. Results

To execute our algorithm, we first acquired a blood smear image followed by a conversion of the original image into a grey-scale image (**Figure 3**).

The application of the Fourier Transform to the image, allowed us to have the graph of the representation of the image in the Fourier domain (**Figure 4**). On
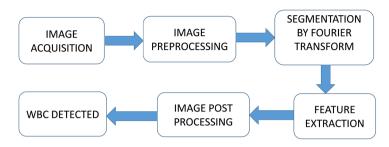

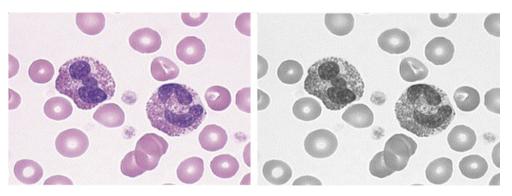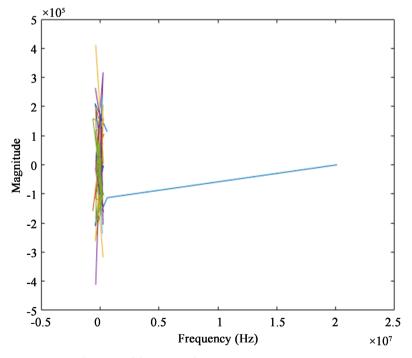**Figure 2.** Over all methodology of image processing.

Figure 3. Conversion of a colour image into a grey image.

Figure 4. Application of the FFT to the image.

the graph, we represented the frequencies on the abscissa axes and the magnitudes on the vertical axes.

Extraction of the high frequency region is possible by applying a convolution of the FFT of the image with a high pass filter. The resulting graph gives a frequency-domain representation of the convolution result (Figure 5).

In order to visualize the convolution result in an image, it was necessary to return to the spatial domain. We therefore applied an IFFT to this result.

The result is an image, where the low frequency regions are hidden and the high frequency regions are highlighted. Figure 6 shows the region-based segmentation. The highlighted region, in addition to the WBCs, also contains RBCs, which constitutes noise given our previous objective of isolating the WBCs.

Detecting WBCs requires morphological accuracy. Therefore, we applied a classical thresholding technique to the previous result. This technique has the effect of enhancing the contours of the WBCs and putting the RBCs in the background
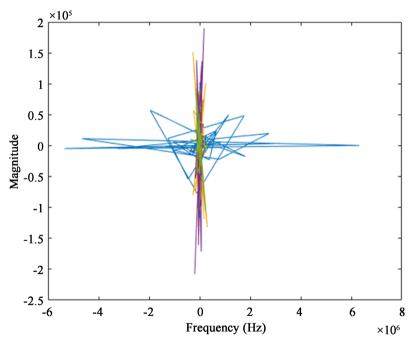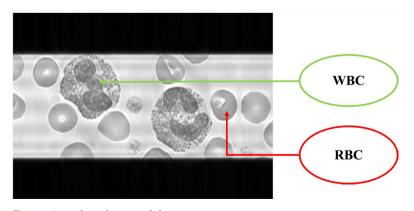

Figure 5. Extraction of high frequency regions.

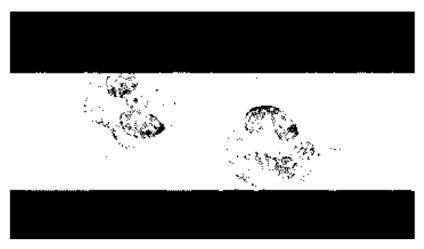Figure 6. Back to the spatial domain.

Figure 7. Morphological segmentation of WBCs.

(white background) (Figure 7).

4. Discussion

The overall objective of this study was to detect WBCs from a blood smear image. We therefore implemented an algorithm coded using Matlab version R2018a. The image processing technique used in this algorithm is the Fast Fourier Transform (FFT) combined with high pass filtering and an Inverse Fast Fourier Transform (IFFT) followed by thresholding.

The use of the FFT allowed us to represent the image in the frequency domain. Indeed, any function (matrix), periodic or not, can be decomposed into a sum of periodic functions. That is to say, any matrix (image) can be represented in the frequency domain via the Fourier Transform. The Fourier Transform responds to the repetition rate of each feature in an image. So what is the repetition rate of each biological feature?

In our starting image, the WBCs are located in the center. In addition, we have a strong presence of RBCs. So according to the application of the Fourier Transform, the high frequencies will be located at this level.

The result of applying the FFT to the image gave us a representation of the different frequencies noted within the image (Figure 4). The high frequencies of this result had to be collected by high-pass filtering (Figure 5).

Next, we returned to the spatial domain to visualize the result after filtering (Figure 6). This return to the spatial domain was made possible by using the IFFT composed of the phase of the image (the phase imaging).

The result is a region that contains WBCs in addition to residual RBCs. This is not sufficient in terms of the accuracy of WBC detection. It was therefore necessary to apply a post-processing technique to the result, called thresholding (Figure 7). Thresholding is one of the methods to extract and segment the object from the background by selecting any point, T. Any point (x, y) for which $f(x, y) \geq T$ is called an object point, otherwise the point is called background point. Thresholding normally results in the binary image [3]. The pixels labeled 0 is corres-

ponded to the object whereas the pixels labeled 255 are corresponding to the background. Finally, by applying, this algorithm, we have detected the WBC with morphologic precision.

We have combined an FFT with thresholding, whereas the work of Nabilah Mohd Safuan, Syadia; Razali Md Tomari, Mohd; Nurshazwani Wan Zakaria, Wan, [1] showed that with only color thresholding, his algorithm can detect WBCs. In fact, our aim was to evaluate the feasibility of using the fast Fourier Transform as a WBC detection technique. During our study, we realized that the FFT alone did not give a morphological segmentation of the WBCs but rather a regional segmentation of the high frequency zone where the WBCs are contained. We therefore used a combination of two techniques: FFT and Thresholding to achieve accurate detection of WBCs, taking into account their morphological aspects.

The limitations of thresholding in the spatial domain prevent the differentiation of WBCs. In contrast to the thresholding results of Nabilah Mohd Safuan, Syadia; Razali Md Tomari, Mohd; Nurshazwani Wan Zakaria, Wan, [1] and Pooja R. Patil, G.S. Sable, Gauri Anandgaonkar, [4] by applying our frequency thresholding technique, we obtain an image, where the WBC families are well discernible. Although the objective was to detect WBCs from a blood smear image, it turns out that our image processing procedure has the ability to recognize neutrophil, basophil, eosinophil and polynuclear cells, allowing digital counting.

5. Conclusion

We have implemented an algorithm (coded in Matlab) for WBC detection starting from blood smear images. Our algorithm processes the blood smear image information in the Fourier domain before returning to the spatial domain to give the result of WBC extraction while faithfully retaining their morphological information. Our method is thus a frequency domain thresholding. The advantage of this algorithm lies in the ease of observation of the morphological information requested and the optimization of the morphological study time.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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