Segmentation Based on Morphological Approach for Enhanced Malaria Parasites Detection

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***Abstract*—Malaria is one of the serious medical issues in the world, with a high frequency of cases in tropical and subtropical regions; further driven by dilapidated living conditions. In 2015, there were approximately 214 million cases of malaria and 438,000 deaths estimated globally, mostly among African children. Malaria develops to become life-threatening without immediate action. Therefore, this paper proposes an image segmentation technique via morphological approach in order to automate the detection of the presence of malaria parasites in malaria image. This technique based on a combination of filtering image and the morphological operator. The effectiveness of the proposed image segmentation approach has been measured by comparing this technique with other segmentation techniques namely, Otsu, Niblack, local adaptive, and Feng methods. Overall, the experimental results indicate that the proposed morphological approach has produced the best segmentation performance with segmentation accuracy and specificity of 98.52% and 99.62%.**

***Index Terms*—Detection; Malaria; Morphological; Normalization; Segmentation.**

I. INTRODUCTION

Malaria is an infectious disease, with a high prevalence in tropical and subtropical regions, caused by a blood parasite of the genus Plasmodium. In the recent decades, malaria disease has been one of the major interesting research subjects due to the proposed of several novel automated detection approaches. Segmentation of medical images such as blood image is a big challenging task in the image processing field and analysis due mainly to the appearance of the noise, shadow, random background, overlapping objects, and illumination problem [1]–[3]. In the past decades, many researchers have been primarily concentrated and focus on automated segmentation technique as it is more accurate and effective compared to the conventional methods [4]–[8]. The sensitivity and correct diagnosis information are very important to help doctors/pathologist to perform the analysis of the patient condition. Furthermore, the automated system is a faster process to identify the patient disease as compared to the conventional technique by using the microscope procedure [9]–[11].

Detection of malaria parasite requires the segmentation of the red blood cells (RBCs) in malaria image. To segment, the malaria parasite in malaria image, various conventional image processing techniques have been reported in the literature. Among the popular conventional techniques are a watershed [12]–[13], morphological operators [14], and thresholding [15]. One of the popular image segmentation using a watershed algorithm is the segmentation procedure proposed by Meyer and Beucher [16]. In this study, segmentation of RBCs was performed on the binary image by using a marker constrained watershed algorithm utilising the distance transform for obtaining markers and its negative as the constraint for watershed constructions. However, its performance is depending on choosing the right markers, otherwise under or over-segmentation can occur. As this method is only suitable to be processed using a binary image, the watershed could not fully coincide with the object junctions of the image objects. Therefore, this algorithm is unsuitable to be applied to the image that consisting irregular shape and overlapping RBCs.

Ruberto *et al.* [14] proposed a better approach for segmentation of malaria image by using the morphological operators instead of using the watershed algorithm. This method used the knowledge of the RBCs structure by assuming the RBCs are circular, in which is not considered in watershed segmentation. In the proposed method, the use of non-flat disk-shaped structuring element has enhanced the roundness and compactness of the RBCs. Meanwhile, the use of flat disk-shaped structuring element has successfully separated the overlapping RBCs. However, the circularity assumption for cell segmentation does not hold well, especially in the case of abnormal RBCs. Anggraini *et al.* [17] proposed histogram-based thresholding using Otsu's method to identify the presence of malaria parasites in thin blood smears of *P. falciparum* species. The grayscale malaria images were segmented using Otsu's thresholding to obtain the RBCs and other components of blood cells in each image. Then, the parasite and infected RBC components were obtained by applying multiple thresholds on the segmented image. This step is based on the knowledge that cytoplasm of the parasite appears lighter, while the nucleus of the parasite appears darker compared to the cytoplasm of the RBCs.

Some researchers have applied combined approaches of Otsu's thresholding and watershed segmentation for improving the segmentation results. Based on the study conducted by Das *et al.* [18] the normal and infected RBCs were segmented using Otsu's thresholding. Then, the watershed segmentation was performed on these segmented RBCs to separate the touching RBCs.Lee and Chen [19] proposes a method for segmentation of overlapped blood cells by combining the Canny edge detectors with Otsu algorithm.

Most of the previous work applied Otsu's thresholding for segmentation of malaria image. However, this method heavily depends on image quality and fails when the histogram does not have distinct valleys. To overcome the issue, Ghosh *et al*. [20] employed fuzzy divergence minimisation approach based on Cauchy membership function to perform the threshold selection for segmenting the malaria parasite from the infected RBC and the background regions. The proposed method was applied for segmentation of trophozoite, schizont and gametocyte regions in *P. vivax* images. This method aims to assist the thresholding technique by locating the deep valleys of the histogram, especially in the case when the histogram of the image is not crisp, and the regions are not well defined.

A number of researchers made a noticeable number of computer vision studies on segmenting the malaria images. The recent trends in segmenting the malaria images include Zack thresholding [21], active contour-based segmentation [22], clustering [6], [7], and edge detection algorithms [23]. Based on the previous reviews, it can be noticed that various research studies have developed segmentation techniques to automate the malaria parasite segmentation process. Hence, the current study will utilise the potential image segmentation technique via morphological approach for obtaining fully segmented malaria parasites.

II. RELATED WORK

In this paper, a few selected local segmentation approaches such as Otsu, Niblack, Local Adaptive, and Feng methods have been tested on the malaria image dataset as a comparable performance.

A. Otsu Method

In this technique, the threshold value is automatically obtained based on the global variance and between-class variance. In the non-uniform image, Otsu assumes the image contains two areas: dark and bright to propose final algorithm [24]. Finally, Otsu thresholding is determined by Equation (1).

$$k = \frac{\sigma^2 B}{\sigma^2 G} \tag{1}$$

where, k is a threshold value, $\sigma^2 B$ is a global variance of the entire image, and $\sigma^2 G$ is a between-class variance. However, this method has less accuracy and present many noises.

B. Niblack Method

The main purpose of Niblack method is to set the threshold value based on local standard deviation and local mean. The threshold for each pixel was determined by [25]:

$$T(x,y) = m(x,y) + k\delta(x,y) \tag{2}$$

where, standard deviation $\delta(x, y)$ and local mean $m(x, y)$ were determined by 80 x 80 windowing size [26], and normal k value is -0.2. This method has the capability to detect the entire target region. However, it may result in a lot of noise and artefact. Besides, this method does not work correctly if the image suffers from non-uniform illumination.

C. Local Adaptive

In this method, if the pixel value is below the threshold value, then it will be set to the background value. Otherwise, it assumes the foreground value [27].

$$T = \frac{\max + \min}{2} \tag{3}$$

This method has the advantages regarding simplicity and easy to be implemented, however, it requires determining window size manually.

D. Feng Method

This method is based on adaptively exploiting the local image contrast. Normalize the contrast effect based on local mean and standard deviation [28-29]. The main idea of this method is it is performed in two local windowing to obtain the statistical parameters.

$$T = (1-\alpha 1)\times m + \alpha 2 \times (\frac{s}{R_s}) \times (m - M) + \alpha 3 \times M \tag{4}$$

where, R_s is a dynamic range of grey value standard deviation, m is mean value, s is standard deviation, α is coefficient, and M is the minimum value of the grey levels. Interestingly, this approach is effective to detect the target region on the low contrast and non-uniform image. However, this method requires of finding the maximum coefficient and window size manually and also proposed complicated algorithm.

In this paper, a new novel segmentation method based on the morphological operator presented. This method uses a combination of a few filtering such as mean filter and Gaussian filter. The proposed method has been tested on 24 malaria parasites of *P. vivax* species. The input image was selected randomly from 4 slides dataset. To prove the effectiveness of the proposed method, five objective evaluation image quality assessment (IQA) which are f-measure, accuracy, The proposed method sensitivity, specificity, and misclassification error has been calculated. This paper is organised into the following sections: Section II describes the related work of the research. Section III explains the methodology of the proposed method. In section IV, the results based on the analysis of different segmentation methods and Section V gives the conclusion of the work.

III. PROPOSED METHODOLOGY

This section presents the proposed method for segmenting the malaria parasite region. The malaria images have been processed using several image processing methods to characterise the pixel based on the features and then segmented the target region. The sample malaria images contain low contrast, non-uniform illumination, and background problem. All the processed images are in colour images, and the size of each image is 808 × 608 pixels with 24-bit depth. All the programs were written in MatLab R2009a from an Asus laptop with AMD Athlon™ II P320 Dual-Core Processor 2.10GHz and 3.00GB RAM. The proposed segmentation procedures are illustrated in Figure 1. The main idea of the proposed method is a combination of filtering and morphological operator. The filtering process is used to perform the background normalisation and finally applied the superimposing process with the morphological result.

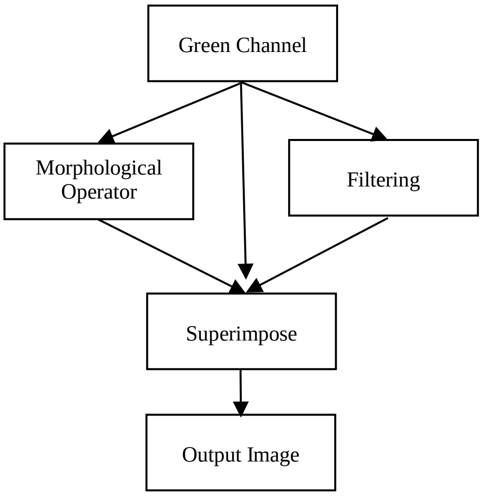
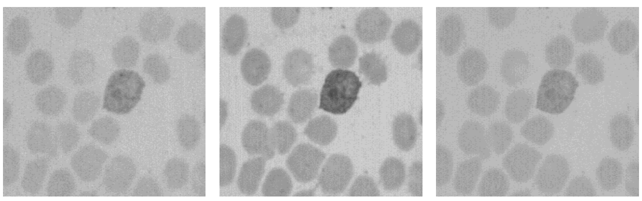


Figure 1: The block diagram of the proposed method.

A. Pre-processing

The green channel $G(x,y)$ is extracted from the original malaria image in RGB colour and is used for the further process. This colour channel is selected because it provides better contrast between the target region and background image. The pre-processing part has been performed to improve the quality of the image by reducing the artefacts or noise. This process is important to enhance the image as most of the malaria images consist of noise with varying illumination and low contrast. The results of images for each channel are shown in Figure 2. Based on observation on Figure 2, the malaria parasite in the Green channel appears clearer and darker compared to the other channels.



Red Green Blue

Figure 2: Comparison image based on channels.

Besides, malaria parasite usually appears darker than background as it has the lower reflectance. Since some of the images present with the unwanted light reflex, thus the step to eliminate the bright strip from the green channel image is performed. In this process, a morphological opening filter is used to remove the brighter strip that exists in the green channel image. Morphological opening generally smoothes the contour of the object which erosion gets rid of small objects and following by dilation to restore the shape of objects that remain. For this part, the 100-pixel diameter disc of the morphological opening is set to reduce the possibility of merging close and known as $M_{open}(x,y)$ which represents the resultant image that is used for the next step. The resulting image after applying the morphological opening process was shown in Figure 3. The background was normalised, and the malaria parasite shows darker compared to the background.

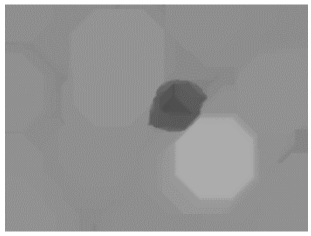


Figure 3: The resulting image after applying the morphological (opening operator) process.

B. Background Normalization

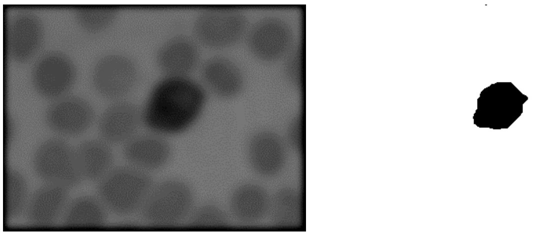
Next, the process continues with the homogenising of the background. Non-uniform illumination in the image creates the variation of background intensity in which it must be reduced, or it may affect the segmentation performance. As a result, the shade-corrected image is performed to enhance the background variations. Firstly, the mean filter is applied to remove the noise in the input image. In this case, the mean filter is performed by using the 30 x 30 windowing size to make the image smoother. After that, the Gaussian kernel is used as it provides smoothing effect and preserves edges better compared to a mean filter that similar size. This method uses theGaussian kernel of dimensions $m \times m = 30 \times 30$, mean $\mu = 0$ and variance $\sigma^2 = 0.5$. Then, the image is filtered again using 30 × 30 mean filters and the image is now considered as the background image $B(x,y)$. However, this filter causes the results that bias appeared at the border. Thus, to eliminate this bias, the average grey level in the remaining pixels are used to replace out-of-the-field of view grey level. Finally, the simple mathematical algorithm is applied to reduce the variation intensity of the background and show the contrast improvement as well. The proposed equation is shown in Equation (5).

$$I(x,y) = G(x,y) + M_{open}(x,y) + B(x,y) \tag{5}$$

The Equation (5) is a combination of green channel image $G(x,y)$ background correction based on morphological opening operator $M_{open}(x,y)$ and background correction based on filtering type $B(x,y)$. The result of images after applying this mathematical equation is shown in Figure 4(a). The image became blurred to reduce the background noise and any distortion. However, the target region which malaria parasite still clear and dark compared to the background

C. Malaria Enhancement

Next, the top-hat transformation is applied to enhance the malaria parasite region. Top-hat filtering computes the morphological opening of the image and then subtracts the result from the original image. This transformation aims to correct uneven illumination when the background is dark. After this process, the result presents satisfied to detect the malaria image. However, the low contrast was unsatisfied.



(a) The resulting image after applying superimpose

(b) The final image after improved using morphological (closing operator).

Figure 4: The result of applying the proposed method

Lastly, to improve the segmentation, the morphological using closing operator is applied to filling the gaps between pixels. This operation based on dilation and followed by an erosion using the same structuring element. Figure 4(b) shows the final result of the segmented malaria parasite image.

IV. RESULT

In this study, 24 malaria images prepared by Medical Microbiology & Parasitology Department, Hospital Universiti Sains Malaysia (HUSM) were tested. The input image was converted in the greyscale image for faster process. The segmentation process is complex as it needs to deal with the contrast problem as the intensity of the target region is approximate to the intensity of background images. As a comparison, four different segmentation methods namely, Otsu, Niblack, Local Adaptive, and Feng methods experimented. The example results of images after applying the segmentation methods are shown in Figure 5. Based on observation, Otsu and Niblack methods are unable to detect the correct malaria parasite as compared to other methods. Interesting, the proposed segmentation method has successfully segmented the malaria parasite without any appearance of any noises and distortion.

After segmenting the malaria parasite using the five image segmentation methods, a few selected quantitative analyses are conducted to assess the overall performance of each segmentation method. The performances of the segmentation method are evaluated by using five objective evaluations such as the f-measure, sensitivity, specificity, accuracy, and misclassification error (ME). The quality of the segmented image is determined based on the pixels similarity if the resultant segmented image against the manually segmented image. The sensitivity is known as a real positive rate, which measures the proportion of actual positives which are correctly identified. The specificity also called the true negative rate, which measures the proportion of negatives which are correctly identified and is complementary to the false positive rate [1]. The segmentation accuracy can be obtained by calculating the percentage of pixels that are correctly segmented as infected cell or background in the image [6]. All equation and details can be referred in [6]. Table 1 presents the result performance after calculating the objective evaluation

Table 1
The Comparison Segmentation Result based on A Few Objective Evaluation

Method	Objective Evaluation			
	F-measure	Sensitivity (%)	Specificity (%)	Accuracy (%)
Otsu	14.85	**99.23**	56.71	58.24
Niblack	13.38	82.32	60.68	61.45
Local Adaptive	73.20	66.22	99.46	98.23
Feng	76.72	88.70	97.96	97.61
Proposed Method	**77.37**	68.72	**99.62**	**98.52**

***bold** shows the highest value.

The result of f-measure, sensitivity, specificity, and accuracy should be higher to represent a good segmented image [30], [31]. From Table 1, it is shown that the proposed method achieved better performance regarding f-measure (77.37%), specificity (99.62%) and accuracy (98.52%). However, regarding sensitivity, it is slightly lower (68.72%) compared to the other methods. Logically, the specificity will be high since all malaria parasites which are detected similarly to the benchmark image. However, the sensitivity will be low since most of the detected black region is not correctly identifies as the background. Average, the Otsu method and Niblack method present the low segmentation performance, while the Local adaptive and Feng method shows the satisfied result. Besides that, to prove the effectiveness of the proposed method, the Misclassification Error (ME) has been calculated. Misclassification is defined as a variable for interpretation, analysis and leading to bias estimation if the misclassification is ignored [5]. The misclassification error (ME) is used to evaluate the performance of the methods, and the lowest value of ME indicates a good segmentation performance. The equation of ME can be referred in [32]. Figure 6 shows the misclassification error (ME) result compared to the four other methods.

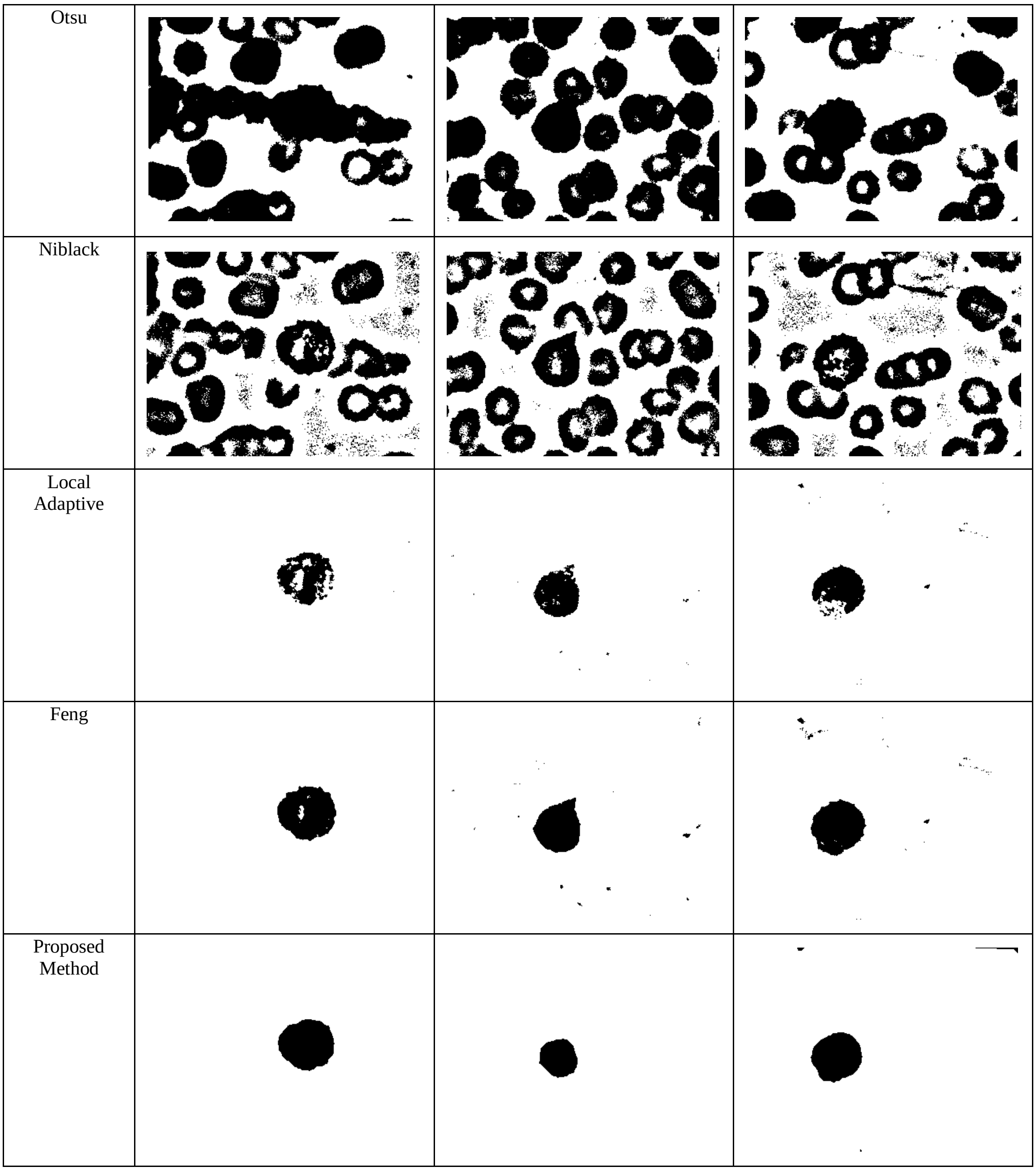


Figure 5: Comparison resulting malaria images

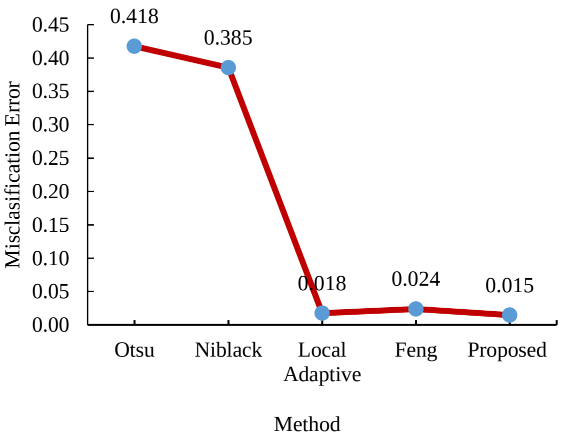


Figure 6: A comparison result based on ME.

The ME reflects the percentages of background pixels incorrectly specified as the foreground, and conversely, the foreground pixels are not properly determined as the background. According to Figure 6, the proposed method achieves the lowest result which is 0.015 and follow the local adaptive method is 0.018 respectively. The third-ranking came from Feng method (0.024), follows by Niblack method (0.385) and finally obtained from Otsu method (0.418). Therefore, the concept of segmentation using the morphological operator is capable and successful to provide the quality segmented malaria images by assigning a few filtering during the process.

V. Conclusion

Malaria is the one serious diseases in the world. The early phase of diagnosing the malaria disease is based on detection malaria parasite in the blood cell. In this paper, a segmentation malaria parasite using a combination of filtering type and the morphological operator was performed. A few filtering types such as mean filter and the Gaussian filter was applied to produce the background normalisation. To increase the performance, the morphological operator such as closing operator and the opening operator was used. Finally, a few objective evaluation techniques were calculated to check the effectiveness of the proposed method. Based on f-measure, accuracy and specificity, the proposed method achieved the highest result compared to Feng, Otsu, Local Adaptive and Niblack method. Conclusion, the proposed method is effective and efficient to segment the malaria parasite in the blood cells.

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