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Automatic Thresholding with Otsu's Method to Identify *Plasmodium falciparum* Phase in Malaria-infected Red Blood Cells

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Abstract. *The most common and most harmful parasite that causes malaria in human body is plasmodium falciparum. P. falciparum can lead to cerebral malaria, which can be deadly harmful if it's not promptly cured. At this moment analysis that had been done by doctors and laboratorium workers are still using conventional device, by observing directly using optic microscope. Therefore it is necessary to develop an imaging system on a conventional microscope into a digital microscope. System is designed to have the ability to perform a segmentation image of plasmodium falciparum in an infected red blood cells by malaria. An algortihm that is develop in this research is automatic thresholding with Otsu's Method. Otsu's method have the ability to update the value of threshold automatically. The experitment result from algorithm that have been developed in detecting plasmodium falciparum has an accuracy of 84,21%.*

Keywords: *malaria, plasmodium falciparum, thresholding, Otsu's method*
PACS: 89.20.Ff

INTRODUCTION

The development of digital technology nowadays has grown very rapidly, especially in the health division. In this division many things that can be done for diagnosis and identification proccess. One of the applications in health division is identifying *plasmodium falciparum* phase in an infected red blood cells by malaria. During this examination proccess the red blood cells that is infected by malaria has to go through direct observation with conventional microscope. Therefore it is necessary to modify conventional microscope into digital microscope to one system for identifying the development of *P. falciparum* in an infected red blood cells by malaria. The application of image proccessing method have the ability to identify the development phase of *P. falciparum*. Several application of image proccessing method for health division especially on proccess identification research had been done previously [1,2,3]. On this research the application of image proccessing is used for identifying tuberculosis bacteria. On this research it also obtained an excellent result for identifying tuberculosis bacteria proccess. This research is develop by thresholding algorithm by using Otsu's method for identifying *P. falciparum* phase automatically. Otsu's method has the ability to do thresholding automatically, until the method is applied to binary feature extraction. Identification proccess development of *plasmodium falciparum* phase obtained an output result that consist of *trophozoite*, *schizont*, and *gametocyte*.

THEORY

Global thresholding can only be used by one value thresholding that already estimated by statistical or heuristic on global image attributes to classify the image pixel from an object and background. The main disadvantage of global thresholding technique is unable to distinguish the difference pixel between the same level of gray, however it is not included in the same group [4]. Otsu's method is one of the best global thresholding methods. Otsu's method can work well on scanned images, however it does not work well on poor quality images with low contrast and non-uniform illumination [5,6].

Otsu's method is also one of the oldest methods of image segmentation that is treated on statistical method according to the probabilistic implementation [7]. Otsu's method is one of the best automatic thresholding methods [8]. Basic principle of Otsu's

method is to divide image into two classes form object and background. Automatic threshold is obtained by finding the maximum variance between two classes [9,10]. If the [1, L] is known the degree of gray in the image f (x, y) and Pi is the probability of each level. The number of pixels with gray level i is symbolized by fi, thus the probability of gray level i in the image of equations is given [7,11]

$$P_i = \frac{f_i}{N} \quad (1)$$

If μ_T is the automatic thresholding that divide the class into two classes C_1 = [1, ..., t] and C_2 = [t + 1, ..., L] [10]. Therefore the probability distribution of the degree of gray for the two classes is:

$$C_1 \rightarrow \left[\frac{P_1}{\sum_{i=1}^{t} P_i}, \frac{P_2}{\sum_{i=1}^{t} P_i}, \dots \dots, \frac{P_t}{\sum_{i=1}^{t} P_i}\right] \quad (2)$$

$$C_2 \rightarrow \left[\frac{P_{t+1}}{\sum_{i=t+1}^{L} P_i}, \frac{P_{t+2}}{\sum_{i=t+1}^{L} P_i}, \dots \dots, \frac{P_L}{\sum_{i=t+1}^{t} P_i}\right] \quad (3)$$

So the average range for class C_1 and C_2 is:

$$\mu_1 = \frac{\sum_{i=1}^{t} iP_i}{\sum_{i=1}^{t} P_i} \quad (4)$$

$$\mu_2 = \frac{\sum_{i=t+1}^{L} iP_i}{\sum_{i=t+1}^{L} P_i} \quad (5)$$

If μ_T an overall average of the whole image. Therefore by adding up all the parts it became:

$$\beta_1\mu_1 + \beta_2\mu_2 = \mu_T \quad (6)$$

Whereas

$$\beta_1 = \sum_{i=1}^{t} P_i \text{ dan } \beta_2 = \sum_{i=t+1}^{L} P_i \quad (7)$$

Total probability will always be the same with one, so:

$$\beta_1 + \beta_2 = 1 \quad (8)$$

Therefore Otsu will define variant between two classes C_1 and C_2 by the equation:

$$\sigma^2 = \beta_1(\mu_1 - \mu_T)^2 + \beta_2(\mu_2 - \mu_T)^2 \quad (9)$$

Optimal value threshold T is the maximum value between variant classes σ^2 that is shown by this equation:

$$T = max\{\sigma^2(t), 1 \leq t \leq L\} \quad (10)$$

The following is an automatic threshold algorithm with Otsu's method [12]:

1. Calculate the probability of each level of intensity
2. Set the initial values β_i and μ_i
3. Calculate the optimal threshold value T with different values $1 \leq t \leq L$
4. Update the value of β_i and μ_i
5. Calculate the value of $\sigma^2(t)$
6. Desired threshold is the maximum value of $\sigma^2(t)$

Application on Otsu's thresholding method is shown in Figure 1.

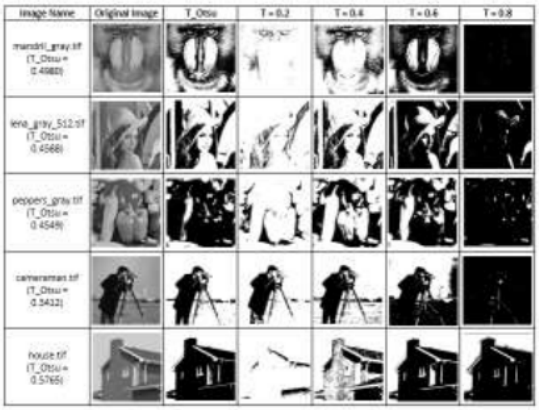

FIGURE 1. Application Otsu's method on thresholding process

METHOD

The research procedure on identifying development of *plasmodium falciparum* includes image acquisition, image enhancement, Otsu's Thresholding, and background extraction. Block diagram on this research is shown in Figure 2.

FIGURE 2. Block Diagram Research

Image acquisition is done by collecting the image of an infected red blood cell by *plasmodium falciparum* using modified digital microscope. Image processing begins by converting the original color image based on *RGB* color components *(Red, Green, Blue)* into a grayscale image. Then the image quality repairs carried out to remove noise using median filter. After enhancing image quality, the next proccess is image segmentation by using Otsu's thresholding method. Segmentation proccess is done to separate between *plasmodium* with *background*. The result that is obtained from this segmentation proccess is *plasmodium falciparum* image in the form of binary image. After that the proccess of background extraction with morphological closing operation. Binary image pattern of the image segmentation results can then be used as input pattern in pattern recognition process. Image proccessing in this research uses 19 image data that consist of 26 *plasmodium falciparum* (7 *gametocyte phase*, 6 *schizont phase*, *and* 13 *trophozoite phase*).

The following is an image proccessing algorithm in this research:

1. Median filter with a 3x3 kernel to remove noise that arises during the process of image acquisition.
2. Converting an RGB image into a grayscale image using the equation 0.2989*R + 0.5870*G + 0.1140*B
3. Converting grayscale image into a binary image with Otsu's Thresholding
4. Closing operation by 15 pixels fingered disk-shaped structure element

RESULT AND DISCUSSION

The process of image acquisition is done by capturing the image of the infected red blood cells with Plasmodium falciparum using a modified digital microscope. The resulting image of the image acquisition process is RGB (Red, Green, Blue). Image processing begins by converting the original color image based on RGB color components into a grayscale image. This conversion process produces output with the color image gray degree. Afterwards, improve the image quality process to eliminate noise using median filter. Once the enhanced image quality is improved, the next process is image segmentation using Otsu's thresholding. Thresholding process produces a binary image with 0 pixel intensity (black) and 1 pixel intensity (white). The process is carried out to separate the plasmodium with background objects. Image processing in this research is shown on Figure 3.

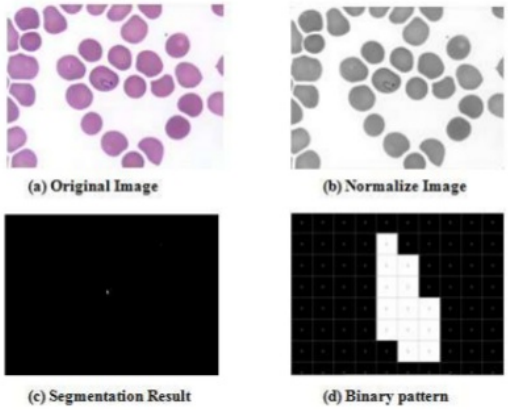

FIGURE 3. Image Processing

Binary pattern of image segmentation results can be used as input in the process of training and testing in the classification stage. Extraction process of each development Binary pattern feature of *Plasmodium falciparum* is shown in Figure 4.

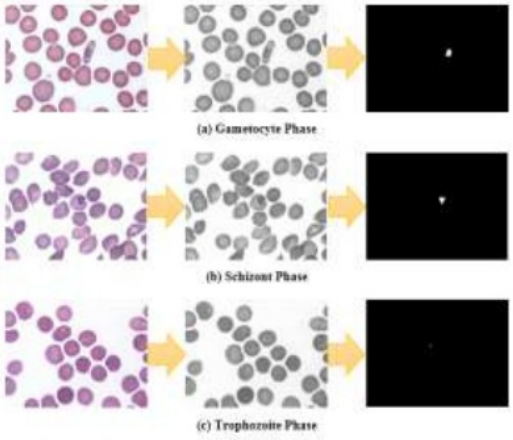

FIGURE 4. Image segmentation process of *plasmodium falciparum*

While the result of the detection of *plasmodium falciparum* overall is shown in Table 1.

TABLE 1. Detecting result of *plasmodium falciparum*

No.	Total *plasmodium falciparum*	
	Manual Detection	**Automatic Detection**
1	1	1
2	1	1
3	1	2
4	1	1
5	3	1
6	2	2
7	1	1
8	1	1
9	3	3
10	1	2
11	1	1
12	1	1
13	1	1
14	3	3
15	1	1
16	1	1
17	2	2
18	1	1
19	1	1

Overall, the algorithm that was developed in this research is able to improve the quality of the image, segmenting the image with Otsu's method, and extracting the binary pattern characteristic plasmodium. Forms of Plasmodium segmentation result according to the original form of the plasmodium in the original image so that the extracted binary patterns can be used as input pattern in the pattern recognition process of plasmodium falciparum. The results of detecting Plasmodium falciparum are shown in Table 1 it shows that the number of detection

is as many as 16 of 19 images with such accuracy that the algorithm developed in this research was 84.21%.

CONCLUSION

From the research that had been done can be concluded that the develop system is able to perform digital image acquisition and automatically extracting characteristic binary pattern of *plasmodium falciparum*. The process of image acquisition uses a modified optical microscope that is integrated with digital computer. The system that was design are able to provide faster analysis results, and practically accurate than the conventional microscope. Image processing for detecting *plasmodium falciparum* is done by using Otsu's method with an accuracy of 84,21%.

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