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Identification of *Plasmodium Falciparum* Phase in Red Blood Cells using Artificial Neural Networks

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Abstract

Malariae is a medical emergency that must be treated at this time because it has been infecting millions of people. Parasite that causes malariae in human body consists of four types of plasmodium species: *P. falciparum, P. vivax, P. ovale, and P.malariae. P. falciparum* and *P. vivax* are the most common type, but the most malignant is *P. falciparum. P. falciparum* can lead to organ failure and abnormality of the patient's blood. *P. falciparum* also cause cerebral malariae, if not addressed promptly can lead to death. The analysis carried out by the doctors and the laboratory worker at the moment is still in the conventional manner, namely direct observation using optical microscopy. On the other hand, the need of convenience, practicality and accuracy at this time has become something that is regarded as a necessity in the treatment of malariae. This research was conducted to design the system such as hardware and software that can detect malariae automatically using microscopy imaging. The designed hardware is a modified form of a digital microscopy to acquire images of red blood cell samples, while the software is used to identify the phase of *P. falciparum* using back propagation artificial neural network. Neural network training process in this research using of 10 images data, consist of 14 *Plasmodium falciparum* (3 gametocyte phase, 3 schizont phase, 8 trophozoite phase). The neural network testing process using 9 images; consist of 12 *plasmodium falciparum* (4 gametocyte, 3 schizont, 5 trophozoite). The acuracy of system identification of *P. falciparum* phase was 87.5%.

Keywords: malariae, plasmodium falciparum, image processing, artificial neural network

1. INTRODUCTION

Malariae is a global problem that currently infecting millions of people in 90 countries annualy. Malariae is caused by a parasite that infects red blood cells that is transmitted through the bite of the anopheles mosquito. In addition, malariae can also be transmitted through blood transfusions [1]. Parasite that causes malariae in human consists of four types of plasmodium species: *P. falciparum*, *P. vivax*, *P. ovale*, and *P.malariae*. *P. falciparum* and *P. vivax* are the most common type, but the most malignant type is *P. falciparum*. The development of *P. falciparum* consist of three phases: *trophozoite* phase (growth), *shizont* phase (breeding), and *gametocyte* phase (formation of sex). *P. falciparum* can lead to organ failure and abnormality of the patient's blood. *P. falciparum* also causes cerebral malariae which, if not addressed promptly can lead to death [2]. Therefore, malariae is a medical emergency that must be treated at this time. The analysis carried out by the doctors and the laboratory worker at the moment still in the conventional manner, namely direct observation using optical microscopy. On the other hand, the need for convenience, practicality and accuracy has become a necessity in the treatment of malariae.

This research is develop automatic malariae disease identification system to diagnosis of malariae quickly and accurately. Besides, the issue of using local materials and affordable prices became major consideration in this research. In this research we developed detection system of malariae disease with microscopy imaging technique. The designed system consist of two main parts: hardware and software. The hardware development is done by modifying a conventional microscopy into a digital microscopy which its motion and image capture process are controlled by a computer in search for the red blood cells. The software development is done by implementing a method that has been developed previously. In the previuos work, we has been done implemented this methods in tuberculosis bacteria [3,4,5,6]. The morphological method is implemented as the parameter for image pattern recognition. Then the classification process was used Back Propagation Artificial Neural Network (BP-ANN) with three output classes which represent trophozoite phase, schizont phase, or gametocyte phase. Output of this research can provide faster, more practical and accurate analysis result than the conventional microscopy. It is also offer more affordable price than digital microscopy on the market, where digital microscopy on the market only for digital capture process without analysis software and microscopy motion controlled by computer.

2. THEORY

Several image processing researches for red blood analysis have been done by some researchers [7,8,9,10]. Diaz et al conducted a study to develop a semi-automated method for counting and classifying red blood cells infected by *Plasmodium falciparum*. The process of image segmentation used normalization method against the RGB color space to separate the red blood cells with the background. Stacked cells separation process used morphology based Clump splitting method. Classification process was performed using trained bank classifier method. Identification result of malariae infected in red blood cells showed a specificity of

99.7% and a sensitivity of 94%. While identification result of infection stage showed an average specificity of 91.2% and an average sensitivity of 78.8% [11].

Tek et al developed research to detect and identify malariae parasite automatically. The process of image proccessing was begun with improvement of image intensity so that the intensity difference between *foreground* and *background* becoming more clearly. Then the normalization proccess is done based on the average RGB values. The feature extraction is done based on the feature of the color histogram, *local area granulometry*, and *shape measurement vector*. The process of classification is done using *k-nearest neighbor classifier* algorithm. Classification results obtained in the study showed a very high accuracy [12].

Savkare and Narote developed a digital image proccessing system capable of counting and classifying red blood cells infected with malariae. The used segmentation method is *thresholding* toward the green components using otsu method. Feature extraction was done by using two methods: *Feature-Based Shape (Radius, Perimeter, compactness)* and *Statistical Parameters (Skewness, Kurtosis, Energy)*, while the classification of plasmodium type used *Support Vector Machine* algorithm. The system designed by Savkare and Narote for 20 blood images produced high accuracy [13].

Das et al conducted a study with the aim of characterizing and classifying malariae parasites (*Plasmodium vivax and Plasmodium falciparum*) microscopically. Image segmentation was done using *watershed* method and classification using several algorithms: *Bayesian learning*, and *Support Vector Machine (SVM)*. The results obtained by Das et al showed that the Bayesian learning algorithm has higher accuracy in the classification of the malariae parasite that is 84% compared with the 83.5% accuarcy of *SVM* algorithm [14].

3. METHOD

Identification of *plasmodium falciparum* development phase in this research included image acquisition, image enhancement, adaptive color segmentation with thresholding method, feature extraction based on binary pattern, and the classification of back propagation artificial neural network. The block diagram in this study is shown in Figure 3.1.

Figure 3.1. Block Diagram of Research

Image acquisition was done by capturing the image of the red blood cells infected with *plasmodium falciparum* using modified digital microscopy. Image processing was begun by converting the original color image based on RGB color

components (Red, Green, Blue) to grayscale. Then the image quality was improved to remove noise using median filter. Once the image quality was enhanced, the next process was image segmentation through thresholding proccess using *Otsu* method. Segmentation process performed to separate plasmodium and background. The result obtained from image segmentation process was plasmodium falciparum form of binary image. This binary image pattern was then used as input in the process of training and testing in the classification using back propagation artificial neural network algorithm. Artificial neural network used consist of three layers: *input layer, hidden layer* and *output layer*. The form of input layer was the binary pattern of morphological plasmodium, while the hidden layer connecting the input layer and the output layer using bipolar sigmoid activation function, and the output layer was the classification result of three plasmodium classes: *gametocyte, schizont* and *trophozoite*. Architecture of the artificial neural network in this study is shown in Figure 3.2.

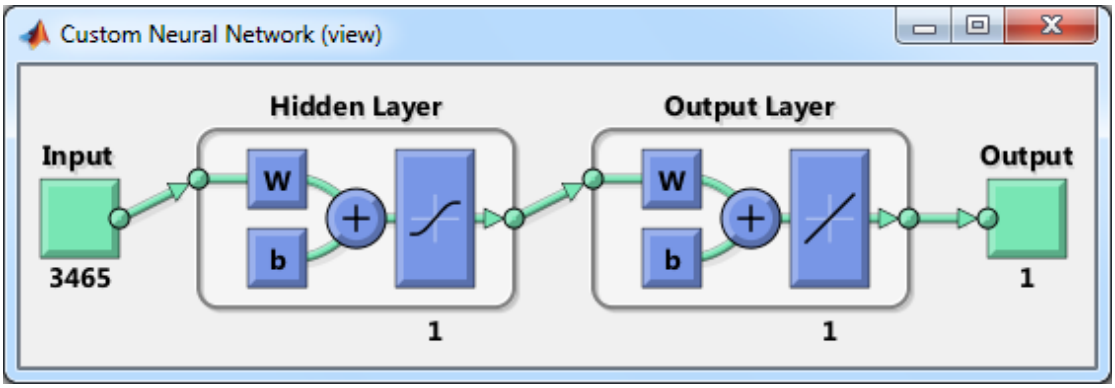


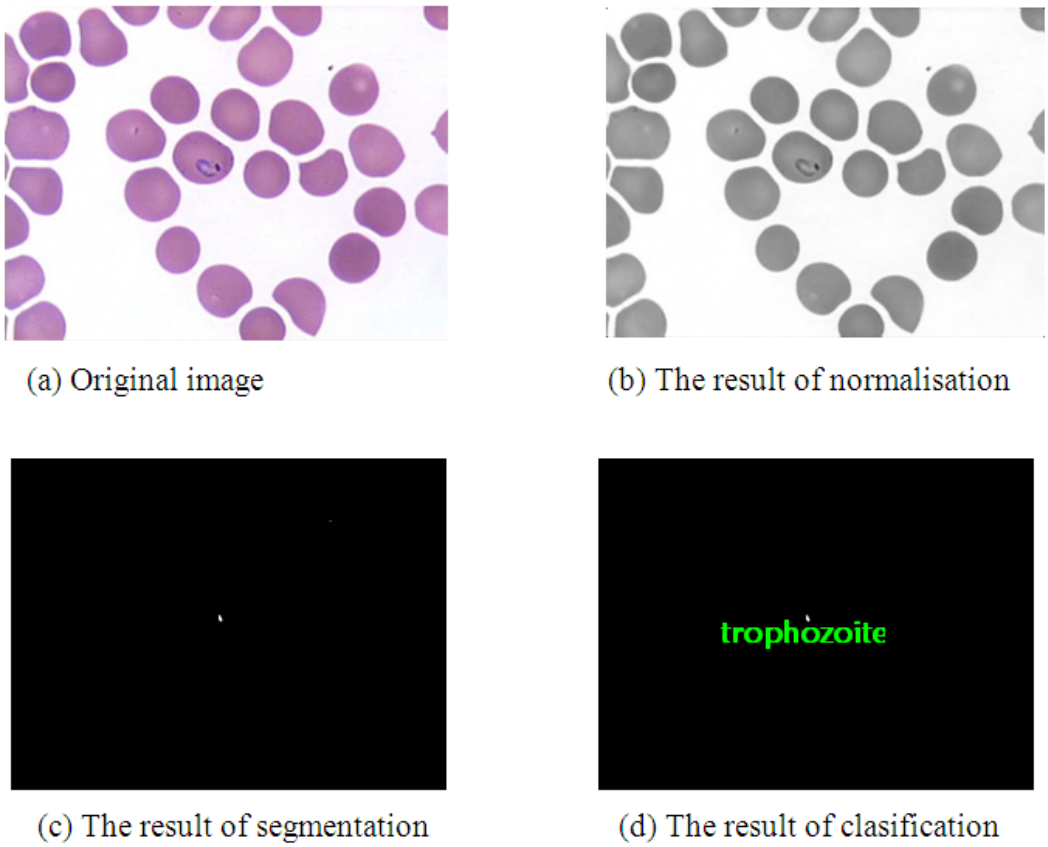
Figure 3.2. Architecture of back propagation artificial neural network

The training process of artificial neural networks in this study used 10 data of images consist of 14 *plasmodium falciparum* (3 gametocyte phase, 3 schizont phase, 8 trophozoite phase), while the testing process used 9 images consist of 12 *plasmodium falciparum* (4 *gametocyte*, 3 *schizont*, 5 *trophozoite*).

4. RESULTS AND DISCUSSION

The image acquisition process was done by capturing the image of the red blood cells infected with *plasmodium falciparum* using modified digital microscopy. The resulted image of acquisition process was the colorly image or RGB (Red, Green, Blue) image. Image processing was begun by converting the original color image based on RGB color components into grayscale image. In image acquisition process the noise was often found, therefore, it must be eliminated for the image enhancement using median filter. Once the image quality was enhanced, the next process was the image segmentation through *thresholding* process using Otsu method. The segmentation process performed to separate plasmodium objects and background. The result

obtained from image segmentation process was *plasmodium falciparum* form of binary image. Image processing in this study is shown in Figure 4.1.



(a) Original image (b) The result of normalisation

(c) The result of segmentation (d) The result of clasification

Figure 4.1. The process of image processing

Binary image from segmentation was then used as input in the classification process of training and testing using back propagation artificial neural network algorithm. The resulted image of the artificial neural network testing on each class is shown in Figure 4.2.

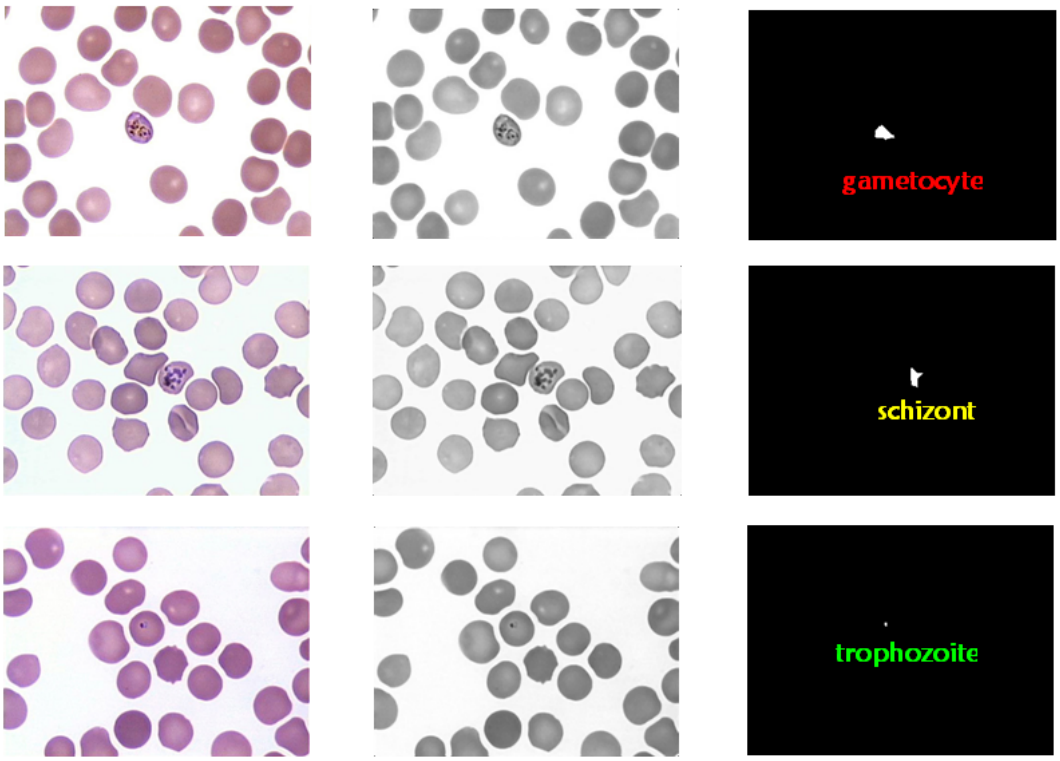


Figure 4.2. The image of artificial neural network test result

While the whole results of testing the artificial neural network in this study are shown in Table 4.1.

Table 4.1. The test results of classification using artificial neural network algorithm

No.	Automatic detection		Manual detection	
	The number of Parasite	**Development phase**	**The number of Parasite**	**Development phase**
1	1	*Gametocyte*	1	*Gametocyte*
2	1	*Gametocyte*	1	*Gametocyte*
3	1	*Gametocyte*	1	*Gametocyte*
4	3	*Trophozoite* *Schizont* *Schizont*	3	*Trophozoite* *Schizont* *Gametocyte*
5	1	*Trophozoite*	1	*Trophozoite*
6	1	*Trophozoite*	1	*Trophozoite*
7	2	*Trophozoite* *Trophozoite*	2	*Trophozoite* *Trophozoite*
8	1	*Trophozoite*	1	*Schizont*
9	1	*Schizont*	1	*Schizont*

Based on 12 development phases of *plasmodium falciparum* tested on system, 10 phases identified correctly, thus the accuracy of system is 87.5%.

4. CONCLUSION

From the study that has been done, it can be concluded that the developed system is able to perform image acquisition and identify development phase of *plasmodium falciparum* automatically. The process of image acquisition used modified optical microscopy that is integrated with digital computer. The designed system is able to provide faster, more practical, and accurate analysis results than the conventional microscopy. The identification process of *plasmodium falciparum* development phase was done using image processing technique and back propagation artificial neural network classification algorithms with an accuracy of 87.5%.

5. ACKNOWLEDGEMENT

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