International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Automated Malaria Parasitemia Estimation from Thin Blood Smear Images

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Accepted 27 Dec 2016, Available online 29 Dec 2016, **Vol.6, No.6 (Dec 2016)**

Abstract

This paper presents an application of digital image processing in the medical field. Manual examination of the blood smear image for quantification of malaria is time consuming. Computer based approach not only atomizes the estimation process, but also increases the speed of computation, thereby reducing the efforts and the time. In this paper, an algorithm is proposed to automate estimating parasitaemia from thin blood smear images by image processing technique. The parasite infected and healthy (non infected) red blood cells are extracted and identified. The thresholding method is used for segmenting the red blood cells as well as cell parasites, in addition to morphological processing. Finally, the estimated parasitaemia was analyzed with manually acquired results. The analysis suggests that the accuracy of the method is comparable, promising and almost equal to manual method, computing result in fraction of seconds. The approach proposed is fast, accurate, effortless, simple and low cost.

Keywords: *RBC, Malaria, Parasitaemia, Thresholding*

1. Introduction

Malaria continues to be one of the major global health problem, despite the massive efforts put forth by WHO in eradicating it, worldwide. Approximately, 300-500 million peoples on earth suffers from malaria, yearly [WHO, 2005]. Malaria poses a diagnostic challenge to the medical community worldwide. Correct and timely diagnosis of this disease is the prior step to control the spread of the disease. The disease can be treated in just 48 hours, yet it can cause fatal complications if the diagnosis and treatment are delayed. The physical symptoms of malaria infection can be seen after more than a week. Therefore, screening of blood sample is one of the possible way of early diagnosis.

Parasitemia estimation is an important component of malaria diagnosis. To quantify the parasites, microscopic examination is widely relied on routine malaria diagnosis method. It is a gold standard, but requires trained technologist to examine and quantify the number of parasites. Manually, it is difficult to achieve accurate and reproducible parasite counts because of technical limitations. Moreover, it is a very time consuming process, subjected to human errors and inconsistency [O'Mera WP *et al* 2005, O'Mera WP, Barcus M *et al* 2008]. As a consequence, these disadvantages of manual microscopy bring many difficulties in mass blood screening (MSB) and controlling the spread of disease becomes a burden, especially in rural areas.

Automation using digital image analysis is the obvious potential solution over the tiring and tedious manual microscopy method [J Frean,2008].

In recent few years, many authors proposed computer aided malaria diagnosis to overcome few of these limitations.

The proposed method in this paper provides image analysis techniques for counting infected and non infected red blood cells. The parasitaemia estimated is highly correlated with manual microscopy and the method is highly effective in enumerating low to high parasitaemia.

2. Literature Review

S.Halim [S. Halim, *et al*, 2006] proposed an approach for quantification of malaria by using an artificial templates (pattern matching) of varying shapes and sizes for counting the number of RBCs, and color cooccurrence matrix and variance based technique for detecting parasite infected cells. In this approach the parasitamia measure was carried out by partitioning the uninfected and infected cells using an unsupervised and in comparison a training-based technique. The approach is not stable and sensitive to orientation, major axis and eccentricity.

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Sio,W.S.S, *et al* [Sio S W, Kumar S,.2006] presented an automated image analysis for quantitative evaluation of the level of parasites in the blood, has been described in The presented system is based on the detection of edges representing cell and parasite boundaries. The described technique includes a preprocessing step, edge detection step, edge linking, clump splitting, and parasite detection. The preprocessing of the image involves the enhancement of the image contrast via adaptive histogram equalization followed by edge detection. A pixel is determined to belong to the boundary edge of the red blood cells if a defined edge correlation coefficient exceeds an empirically determined threshold.

The system requires well-stained and well-separated cells in order to provide accurate result. Moreover, artifacts, 'holes' inside red blood cells and noise can lead to a false interpretation of a red blood cell.

Automated image analysis-based model Malaria Count for parasitemia determination for quantitative evaluation of the level of parasites in the blood, has been described in the research paper S. Raviraja et. al.[S. Raviraja *et. al*, 2006], the researchers explained the usage of image processing and statistical based approach to automatically identify and detect the number of malarial parasites per number of red blood cells and managed to do it by using colour, shape and size information. The presented system is based on the detection of edges representing cell and parasite boundaries. The described technique includes a pre-processing step, edge detection step, edge linking, clump splitting, and parasite detection

Di Ruberto *et al*., [Di Ruberto *et al*, 2002] proposed a technique of automatically detecting and quantifying malaria parasites infection in blood images of patients. The method employed a modified watershed algorithm to segment erythrocytes. The efficiency of the segmentation algorithm proposed reduces with the degree of clustering of erythrocytes. Similarly the accuracy of colour histogram similarity for classification of parasites would depend on the imaging parameters and illumination conditions under which the image being probed. The detection accuracy of parasitemia reported was relatively low, 50%.

3. Methods

Images of thin blood smear were collected from Centre for Disease Control malaria image library available on its website. These images are available in JPEG format in different sizes and magnifications. Image processing toolbox in MATLAB 2010 was used to implement the algorithm. Experiments on a set of 50 sample thin blood smear images with varying densities of malaria parasites were used for the purpose of parasitaemia estimation

A. Preprocessing

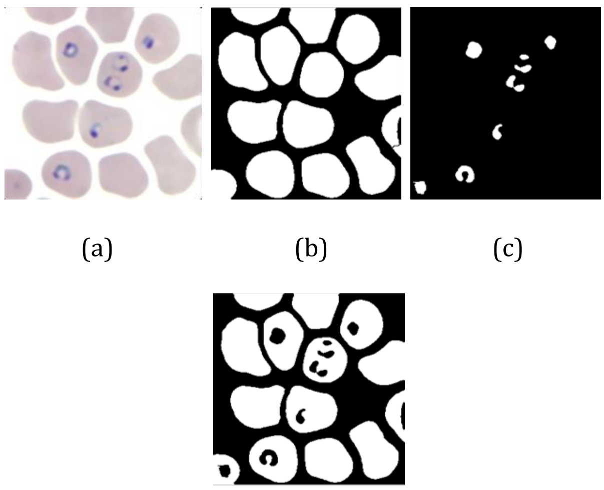
The RBC images collected from the source are raw images of different sizes and contain random noise. In this stage, the image is rescaled or resized to 300 x 300 pixels. The noise is removed by using 5 x 5 median filters to smooth out the image, preserving the variations in the image. Experiments were conducted on the input RBC colored images to select the color channel for histogram based segmentation and it was observed that green channel has highest variance amongst RGB color space along with good contrast. Therefore, green plane is selected which will be employed for segmentation in next stage.

B. Segmentation

Thresholding method is more effective for an image with bimodal histogram, spread widely, and have large valley [R.C.Gonzalez *et al*, 2009]. Malaria infected RBC image histogram is usually bimodal in nature. The highest peak is the principle mode and second highest one is the second mode. The principle mode is due to the background pixels in majority. The second mode is due to the objects (RBCs) in the blood cell image. Two different threshold levels are to be determined from image histogram to separate RBCs and parasites. RBCs are to be segmented from image background and the parasites are to be segmented not only from the background but also from the Erythrocytes. However, the selection of this threshold is very difficult.

The first threshold is obtained using global technique and second by local method [Ahirwar N *et al*, 2012]. The RBCs which have been already identified, provides the image regions to find the local threshold level. Therefore, the threshold is then found from the principal mode of the histogram incorporating only the RBCs [Ghosh M *et al* 2011,Heidi B *et al*,2011].

Mean level algorithm is used to find global threshold and Zack's algorithm [G W Zack *et al*,1977] is used for local threshold. Morphological processing was applied to the binary images. Union of both binary images and RBC mask compared to identify parasite infected and non infected RBCs.



(a) (b) (c)

(d)

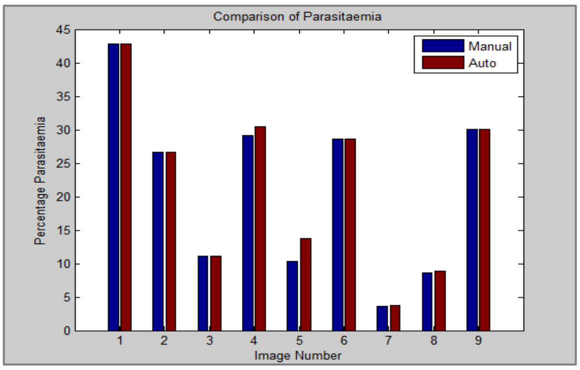
Fig.1 (a) Original image, (b) RBC segmented image, (c) Parasite segmented image, (d) combined binary image

Table 1 Evaluation of estimated parasitaemia using manual and automatic method

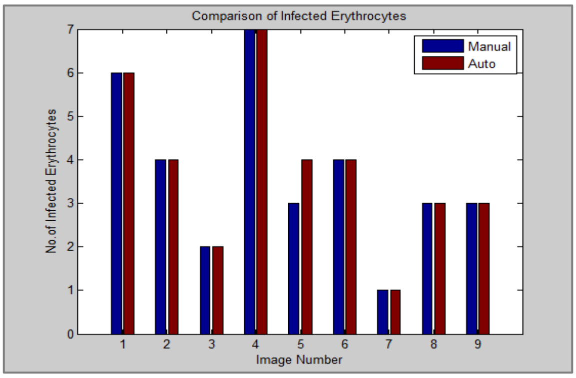
Image No.	Manual method		Our computerized method		Estimated Parasitaemia	
	Total RBC count	No.of infected RBCs	Total RBC count	No.of infected RBCs	Manual method	Our computerized method
Image 1	14	6	14	6	42.85 %	42.85
Image 2	15	4	15	4	26.66 %	26.66 %
Image 3	18	2	18	2	11.11 %	11.11 %
Image 4	24	7	23	7	29.16 %	30.43 %
Image 5	29	3	29	4	10.34 %	13.79%
Image 6	14	4	14	4	28.57 %	28.57 %
Image 7	28	1	27	1	3.57 %	3.70%
Image 8	35	3	34	3	8.57 %	8.82 %
Image 9	10	3	10	3	30 %	30 %

4. Experimental Results

Nine slides of malaria infected thin blood smear infected with Plasmodium falciparum and Plasmodium vivax were analysed. The results of running the algorithm on the test set up are shown in Table 1. A high correlation found in manual and automated method at low to moderate parasite densities.



(a)



(b)

Fig.2 (a) Comparison of estimated Parasitaemia, (b) Comparison of estimated Infected Erythrocytes

Conclusion

The parasitaemia estimated is accurate and the method has potential to use it in clinical laboratories for routine malaria quantification or estimation. A digital microscope camera and personal computer is needed in addition to stained thin blood peripheral blood smear slides.

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