An Image Processing Approach for Accurate Determination of Parasitemia in Peripheral Blood Smear Images

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ABSTRACT

An interactive automatic procedure for detection of malaria from microscope blood images is presented. The user is required to select image from data set and the algorithm detects whether the blood is infected with malaria or not automatically. This method will help in reducing the time taken for diagnosis and the chance for human errors. A general framework to perform detection of malaria parasite, which includes an image pre-processing, extracting infected blood cells, morphological operation and highlighting the infected cells, is described. We have evaluated our algorithm using a dataset of 76 microscopic blood images from different patients (both infected and uninfected).Experimental results show that the proposed algorithm achieves 94. 87% sensitivity and 97. 3% specificity for the malaria parasite detection. This methodology may serve as a rapid diagnostic tool for malaria, even in microscopically negative cases. We also present open research problems.

Keywords

Malaria, microscopic diagnosis, erythrocytes, parasitemia.

1. INTRODUCTION

Malaria is one of the most common infectious diseases and a great public health problem worldwide, particularly in Africa and south Asia. According to the World Health Organization, it caused more than 1 million deaths arising from approximately 300 to 500 million infections every year [1], mostly in children under five years of age. Several international organizations have set up ambitious objectives for large-scale malaria control. The targe t set by the World Health Organization (WHO) in 2005 is to offer malaria prevention and treatment services by 2010 to at least 80% of the people who need them [2]. By doing so, it aims to reduce at least by half the proportion of people who become ill or die from malaria by 2010 and at least by three quarters by 2015 compared to 2005.

The definitive diagnosis of malaria infection is done by searching for parasite in blood slides through a microscope. Although there are newer techniques [3], manual microscopy examination of blood smears [4] (invented in the late 19th century), is currently "the gold standard" for malaria diagnosis. Diagnosis using a microscope requires special training and considerable expertise [5]. It was shown in several studies that manual microscopy is not a reliable screening method when performed by non experts due to lack of training especially in the rural areas where malaria is endemic [6]. The sample malaria microscopic blood image as shown in Figure 1.

Detection is the most important task whereas the species identification is necessary for an appropriate treatment. There are so many numbers of vision studies address the automated diagnosis of malaria [7]-[12]. However, none of these works provide a complete solution (100%) to detect malaria parasite in blood images. This paper is the most comprehensive work up-to-date from a computer vision perspective addressing the entire required essential task for the diagnosis. Two main contributions of this study must be highlighted. We propose a malaria parasite detection method. We compare our proposed method with previous five methods for malaria detection and then conclude that the detection can be performed successfully with more accuracy.

2. MOTIVATIONS AND OBJECTIVES

Malaria laboratory diagnosis becomes a hard task particularly in its final stages where microscopic specialists make efforts to specify disease stage parasite morphology. In addition, laboratory diagnosis is time consuming. As we know, computer is a useful tool in many applications particularly in clinical and technical medical activities. So it is reasonable to use computer

advantages such as speed and accuracy to make malaria diagnosis.

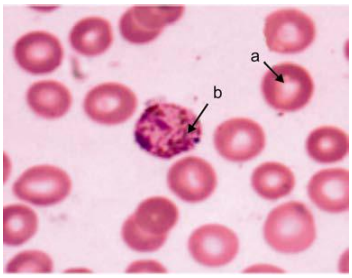


Figure 1: The microscopic image [13] of (a) normal, and (b) malaria infected cells

The main objectives of our system includes extremely fast detection of the parasite within seconds, highly accurate in true detection, simple to execute and operate and serves as a reliable second opinion to pathologists and microbiologists.

The organization of the rest of this paper is as follows. Section 3 briefly reviews related earlier studies. Section 4 introduces the proposed method. Section 5 described the experiments and then presents the evaluation results. Section 6 provides the conclusion and future works.

3. LITERATURE REVIEW

In the literature, detection of malaria methods are available such as: T.Jelinek[19], Boray Tek[20] Vishnu.V [21], and Gatti.S [22] using image processing techniques. Apart from these various detection algorithms are available by using various classification techniques and are described as follows.

D. Ruberto et. al. [24] follow morphological method for detection of parasites in Giemsa stained blood slides. Different objects in blood are identified using their dimensions and color. The parasites are detected by means of an automatic thresholding based on morphological approach, using Granulometrices to evaluate size of RBCs and nuclei of parasites. A segmentation method using morphological operators combined with the watershed algorithm.

Silvia Halim et. al. [23], proposed a technique for estimating parasitemia. An approach of template matching is used for detection of RBCs. Parasites are detected using the variance based technique from grayscale images and second approach is based on color co-occurrence matrix which is based on the individual color index of pixel and color indices of its eight neighboring pixel.

Tomasz Markiewicz et. al. [25], presented the feature characterization and assessment of the blasts that leads to the best performance of the recognizing and classifying system. The cells are classified by using the geometrical, textural and statistical features. The features categorized by using linear SVM network using SVM classifier.

Nicola Ritter et. al. [26] used stained blood images to present unsupervised blood cell segmentation. Algorithm finds all objects cells, cell groups and cell fragments that do not intersect the image border, and identifies the points interior to each object, finds an accurate one pixel wide border for each object, separates objects that just touch. Statistical analysis based by borders that have clusters of pixels is used to refine the borders by pruning stubs and thinning the border to one pixel width.

Gloria Diaz et. al. [27], presented a method for quantification and classification of erythrocytes in stained thin blood films infected with Plasmodium Falciparum. It uses three main phases a preprocessing step, which corrects luminance differences. A segmentation step that uses the normalized RGB color space for classifying pixels either as erythrocyte or background followed by an Inclusion-Tree representation that structures the pixel information into objects, from which erythrocytes are found classified as infected or normal erythrocytes and differentiates the infection stage, by a trained bank of classifiers.

These approaches still do remained some drawbacks namely no method having 100% sensitivity and specificity, which are needed to be improved. For example, S.Gatti et. al. [22] approach having highest sensitivity 94.4% so far. Our proposed method yields sensitivity of 94.87%.

4. METHODOLOGY

The basic aim our system is to read microscopic blood image from dataset and detect whether the blood is infected with malaria or not.

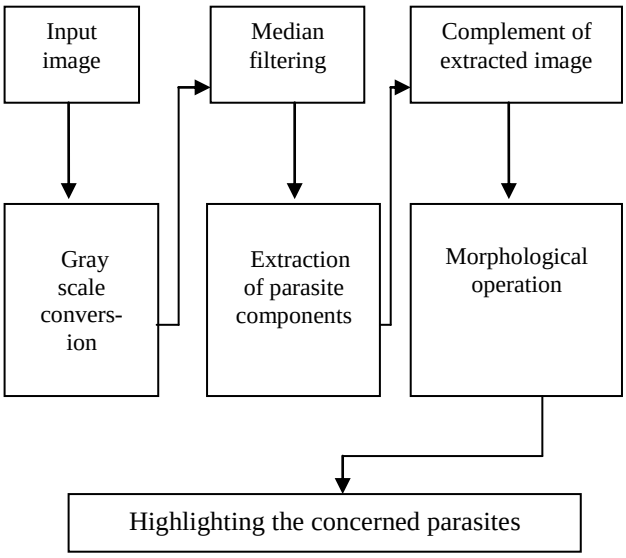


Figure 2: General workflow of the proposed malaria detection method

The digitized images of erythrocytes are obtained from various sources [16] and stored in the computer for further processing. The sequence of procedures for detecting the malaria in blood images is given in Figure 2.

In microscopic image processing, it is usually necessary to perform high degree of noise reduction in an image before performing higher-level processing steps, such as extracting parasite components. The median filter is a non-linear digital filtering technique, often used to remove noise from images.

The median filter is given by

$$g(x,y) = \underset{(s,t)\varepsilon S_{xy}}{\text{median}} (f(s,t))$$

Where g(x,y) is the restored image at point (x,y) of the original image f(x,y) and S_{xy} represents the set of coordinates in a rectangular sub image window[14].

Applying the median filter for smoothing and noise removal led to better results than using the averaging or Gaussian low pass filters. Median filtering is known to be better able to remove the outliers without reducing the sharpen of the image. Figure 3 shows the original image after applying a 5X5 median filter.

The basic aim of next step is to extract the cells which are infected with malaria. The extracted components of a parasite and its histogram are shown in Figure 4. The algorithm for extracting parasite infected components used in this paper is show as Algorithm 1.

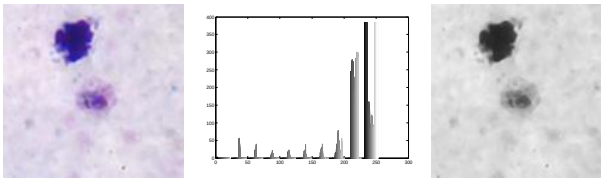


Figure 3. (left) the input blood image,(middle) its histogram, (right) image after noise reduction

The basic aim of next step is to extract the cells which are infected with malaria. The extracted components of a parasite and its histogram are shown in figure 4. The algorithm for extracting parasite infected components used in this paper is show as Algorithm.

Granulometry is the size distribution of the input image as shown in figure 5. Each resulting image of extracted parasite components was then processed with morphological operator so that the holes inside the blood cells can be removed. The basic idea in binary morphology is to probe an image with a simple, pre-defined shape, drawing conclusions on how this shape fits or misses the shapes in the image [15]. This simple "probe" is called structuring element and is itself a binary image.

Algorithm 1: Infected Parasite components extraction

Initialize:

- Count=sum=sum1=add=add1=p=0
- for i=1 to m and j=1 to n
  if(Im(i,j)>=190)
  Im(i,j)=180
- T= mean of max. and min. pixel values in an image

Run:

```
Repeat
      Count++
FOR each i FROM 1 to m and j FROM 1 to n
      If (Im(i,j)>=T)
        sum += Im(x,y) and sum1 ++
      Else
        add += Im(x,y) and add1 ++
End For
      Total=sum/sum1
      Total1=add/add1
       P= (Total+Total1)/2
       D= |T-P|
Until (D>=0.5)
```

The basic morphological operation used in this method is image erosion. Let *E* be a Euclidean space or an integer grid, and *A* a binary image in *E*. The erosion of the binary image *A* by the structuring element *B* is defined by:

$$A \omega B = \{ z \in E / B_z \subseteq A \}$$

Where B_z is the translation of B by the vector Z.
i.e.,B_z= {b+Z/b ε B} for all Z ε E

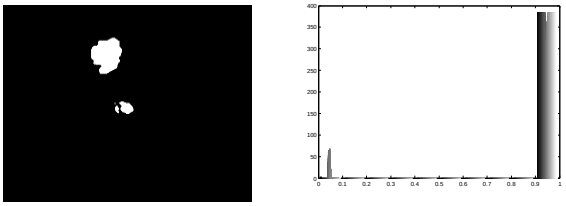


Figure 4. (left) extracted parasite components,(right) histogram of infected cells

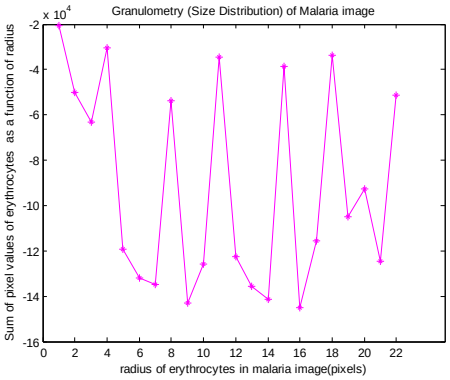
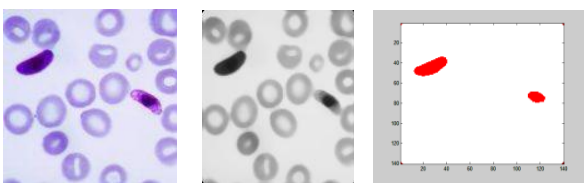


Figure 5: granulometry using disk shaped structuring elements

The concerned parasite can be highlighted by using the resultant image after morphological operation applied. The various results of applying the proposed method and its evaluation, comparison with other previous methods are presented in the next section.

5. RESULTS AND DISCUSSIONS

To evaluate the performance of the proposed algorithm, we made some experiments using MATLAB version 7.10.0.499 (R2010a). The tested images were selected from the malaria image library [16] and Google images for malaria microscopic images [17].



(a) (b) (c)

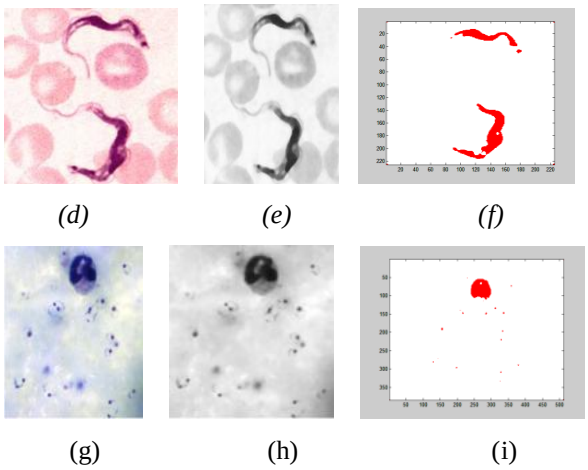


Figure 6: Positive malaria test. (a,d,g) original blood microscopic images, (b,e,h)gray scale images after applied median 5X5 filter, (c,f,i)final results(red colour cells indicating malaria infected cells)

The proposed method is applied to several microscopic blood images as indicated in the figures given below. Part (a) and part(b)of figures 6 to 7 shows a raw images and the gray level images after applied 5X5 median filter respectively and the final detection result is given in part(c). We can notice that the result of these tests is positive where the algorithm detects the infected cells.

In order to evaluate the performance of our method we apply it to some uninfected images. Figure 4 shows the result of testing uninfected blood cells. In these figures, the result is satisfactory where the system indicated that the cell is not infected, i.e. negative test.

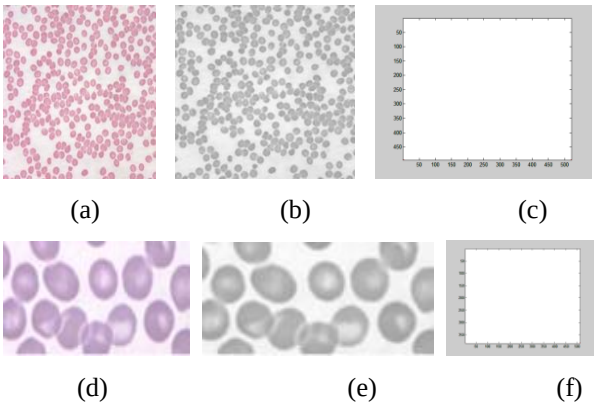


Figure 7: Uninfected cell. (a,d) original images ,(b,e) gray scale images after applied median 5X5 filter,(c,f) final results.

However, in some cases, the proposed method indicated that the result is positive while the cell is not infected with malaria as indicated in figure 8 and the result is negative while the cell is infected with malaria as shown in figure 9. In fact, these erroneous results can be caused due to white blood cells, other impurities which carry the same colour as malaria parasite.

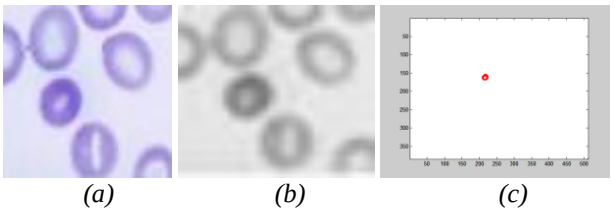


Figure 8: Uninfected cell. (a) Original image,(b) gray scale image, (c) final result

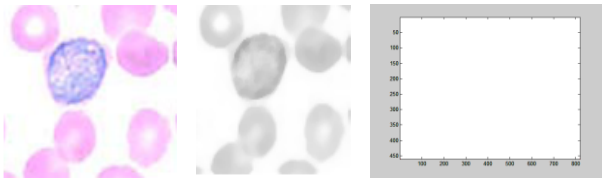


Figure 9: Infected cell. (a) Original image, (b) gray scale image,(c) final result

There are two measures [18] used to judge the quality of the method in the case of malaria detection which are:

Sensitivity: percentage of malaria detection among all malaria cases.

Specificity: percentage of detecting non-malaria among all non-malaria cases.

Table 1: Results of applying our method to the whole data set we have

		Detection Results	
Blood Images	No. of test images	Malaria	Non-Malaria
Malaria	39	37	2
non-malaria	37	1	36
	Sensitivity=94.87%, Specificity=97.3%		

On applying the proposed algorithm to the malaria images data set, the resulting accuracy is enhanced with 94.87% sensitivity and 97.3% specificity. Table 1 shows the results of applying the proposed method to the whole data set we have (76 blood images). Among those 73(39 infected and 37 uninfected) images are detected correctly by the proposed system, true positive and only 3 images were missed (false negative).

In addition, a comparative study has been made with five well known previous methods. Table 2 shows a quantitative comparison between the proposed method and five of other methods found in the literature survey. However, our method uses more images to test the accuracy and still can obtain better results.

Table 2: Quantitative comparison between our method and some of other methods

Method	Sensitivity (%)	Specificity (%)	Data Used
T.Jelinek[19]	92.5	98.3	Not-mentioned
Boray Tek[20]	74	98	9 images
Vishnu.V [21]	83	98	55 images
Gatti.S [22]	94.4	94.5	Not-mentioned
Halim[23]	92	95	Not-mentioned
Our Method	**94.87**	**97.3**	**76 images**

6. CONCLUSIONS AND FUTURE WORK

An efficient method for detection of malaria parasite from microscopic blood images has been introduced in this paper. This automated computer based system is interactive, hence is faster and accurate than manual process. The results are promising and the sensitivity of the proposed method outperforms most of the other reported methods. Further work still needs to be done in order to improve the accuracy (in particular the sensitivity) of the proposed system. This can be achieved by investigating the use of other features. In future work, we will try to identify the infecting species [16] (five species of malaria namely P.falciparum, P.knowlesi, P.malariae,P.ovale and P.vivax) and degree of parasitemia .

7. ACKNOWLEDGMENT

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