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Segmentation of erythrocytes infected with malaria parasites for the diagnosis using microscopy imaging ☆

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ABSTRACT

Malaria, one of the deadliest diseases, is responsible for nearly 627,000 deaths every year. It is diagnosed manually by pathologists using a microscope. It is time-consuming and subjected to inconsistency due to human intervention, so computerized image analysis for diagnosis has gained importance. In this article, an edge-based segmentation of erythrocytes infected with malaria parasites using microscopic images has been developed to facilitate the diagnostic process. The color space transformation and Gamma equalization reduce the effects of colors and correct luminance differences of images. Fuzzy C-means clustering is applied to extract infected erythrocytes, which is further processed for the final segmentation. The experimental results showed that the proposed method can gain 98%, 93.3%, 98.65% and 90.33% of sensitivity, specificity, prediction value positive and prediction value negative, respectively. In conclusion, the proposed method provides a consistent and robust method of edge-based segmentation of parasite infected erythrocytes using microscopic images for diagnosis.

1. Introduction

Malaria being an infectious disease and is one of the largest global health threats that reported about 3.4 billion cases of infection and was responsible for 627,000 deaths according to the world malaria report, 2013 published by the WHO [1]. Among the deceased, 77% individuals were children of less than five-year age. It is considered as endemic in 104 countries. It is caused by fives species of the parasite Plasmodium viz. *P. falciparum*, *P. knowlesi*, *P. vivax*, *P. ovale* and *P. malariae*. It spreads to humans via biting of infected Anopheles mosquito vectors. Of the five species, *P. falciparum* is the most deadly.

For the diagnosis of malaria, pathologists use light microscopy to identify infection based on color and morphological changes in the erythrocytes. However, it is a time consuming process, requires expert technicians and prone to be erroneous. Though some of the problems associated with manual microscopy can be overcome by using computer based methods. In modern diagnostics, digital image processing has considerably increased the accuracy in the medical imaging. In this regard, segmentation plays a vital role. The Segmentation methods can be classified as: region-based, edge-based, histogram thresholding, clustering, morphological, model-based, active contours and soft computing [2]. There are some difficulties in edge-based segmentation of parasite infected erythrocytes in microscopic images: low contrast, lack of clear edges in infected erythrocytes due to similar intensity profiles, colors, noises and irregular edges. In the current study, an edge-based

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segmentation of infected erythrocytes is proposed to address the above problems to accurately segment infected edges in microscopic images for the diagnosis.

The significant contributions of this paper are as follows:

I. We propose an edge-based segmentation method for malaria infected erythrocytes in microscopic blood images.
II. We examine the effect of the proposed method with other seven traditional edge-based segmentation methods and then conclude that the proposed method is successful in segmenting parasite infected erythrocytes. Hence, segmentation outperforms others traditional edge segmentation methods.
III. The necessity of illumination correction for low contrast images to get accurate segmentation through gamma equalization is presented. In addition, adaptive median filter was selected for noise minimization based on the quantitative measure of performance of 8 noise removal filters.
IV. The comparison between proposed segmentation performance and state-of-the-art methods for diagnosis of malaria is realized.

The rest of the paper is organized as follows: The earlier studies on malaria diagnosis are briefly summarized in Section 2. The methodology of the proposed segmentation is detailed in Section 3. In Section 4, we describe the diagnosis process. Experimental results are shown in Section 4. Section 5 presents a discussion. Finally, conclusions are drawn in Section 6.

2. Earlier studies

There are several studies suggesting a computer vision approach for the diagnosis of malaria through microscopic blood smear images [3–21]. Ross et al. [3] proposed malaria parasites detection and classification by means of the principal component analysis and back propagation neural network. Kaewkamnerd et al. [4] presented a method for malaria parasite detection and a classification system for the parasites based on thick blood images. Prasad et al. [5] proposed a digital image analysis decision support system for the parasite detection. Frean [6] introduced a reliable enumeration of malaria parasites using digital image analysis in thick blood films. Boray Tek et al. [7] used a pattern recognition frame work for the diagnosis of malaria. Besides this, they proposed parasite detection, identification of the infecting species and the life cycle stages [8]. Daniel et al. [9], to detect plasmodium parasites from microscopic blood images, used an artificial neural network. Lai et al. [10] proposed a protozoan parasite extraction technique for the microscopic images to solve and reduce the problem of the images with poor quality and complex background. Diaz et al. [11] proposed a method for the classification of erythrocytes and identification of infection stage. Salena et al. [12] proposed malaria infected erythrocytes counting for diagnosis in which adaptive histogram equalization used for enhancement of the image and separating overlapping infected cells was carried out by clump splitting.

Tek et al. [13] used *k*-nearest neighbor classifier for the malaria parasites classification. Vishnu et al. [14] proposed malaria parasite segmentation in an HSV color space model by detecting dominant hue range. In a recent study, Das et al. [15] introduced a machine learning approach for the malaria parasite classification and characterization. Yunda et al. [16], used a combination of AGNES and morphological gradient techniques for segmentation of malaria parasites and a neural network for the classification. Unsupervised malaria parasites detection in microscopic images by using Chan-Vese segmentation to extract boundary of RBC, has been described in [17]. Determination of plasmodium parasitemia and segmentation in thin blood smears for the diagnosis has been described [18,19]. Detection of malaria parasites using CBIR approaches for Diagnosis of malaria was introduced in [20]. Recently, Linder et al. [21] propose segmentation and parasite estimation through digitized blood smears.

Finally, to the best of our knowledge, the edge-based segmentation of erythrocytes infected with malaria parasites has not been demonstrated on microscopic blood images. Herein, we propose a method for segmentation of infected erythrocytes edges through microscopic imaging for the diagnosis of malaria. Besides, a comparison between the proposed segmentation and common edge segmentation methods, presented.

3. Methodology

In this section, we describe the methodology that facilitates the edge-based segmentation of malaria parasite infected erythrocytes through microscopic blood images. The proposed scheme applies the following methods sequentially: (a) color space transformation, (b) Illumination correction, (c) noise reduction, (d) edge enhancement, (e) fuzzy C-means clustering, (f) connected component analysis and (g) Minimum Perimeter Polygon. The flowchart of the proposed method as depicted in Fig. 1, wherein, a microscopic image of the blood sample is the input. The details of the proposed method are shown in following subsections.

3.1. Color space transformation

Microscopic blood images are commonly acquired using a digital camera with a blood smear attachment having different color tones. An input RGB (Red–Green–Blue) microscopic blood image is converted into a gray scale one for the simplicity and convenience of scalar processing (single channel) by using the following method.