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Automated detection of malaria parasites on thick blood smears via mobile devices

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Abstract

An estimated 214 million cases of malaria were detected in 2015, which caused approximately 438 000 deaths. Around 90% of those cases occurred in Africa, where the lack of access to malaria diagnosis is largely due to shortage of expertise and equipment. Thus, the importance to develop new tools that facilitate the rapid and easy diagnosis of malaria for areas with limited access to healthcare services cannot be overstated. This paper presents an image processing and analysis methodology using supervised classification to assess the presence of *P.falciparum* trophozoites and white blood cells in Giemsa stained thick blood smears. The main differential factor is the usage of microscopic images exclusively acquired with low cost and accessible tools such as smartphones, using a dataset of 194 images manually annotated by an experienced parasilogist. Using a SVM classifier and a total of 314 image features extracted for each candidate, the automatic detection of trophozoites detection achieved a sensitivity of 80.5% and a specificity of 93.8%, while the white blood cells achieved 98.2% of sensitivity and 72.1% specificity.

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Keywords: Image analysis; Malaria; Computer-aided diagnosis; Microscopy; Mobile Devices;

1. Introduction

Malaria is a leading cause of death and disease in many developing countries [1]. In 2015, there were an estimated 214 million cases of malaria, which caused approximately 438 000 deaths. Around 90% of malaria cases occurred in Africa, where the lack of access to malaria diagnosis is largely due to a shortage of expertise, the shortage of equipment being the secondary factor. In a recent report [1], the WHO considers that the current funding distribution of malaria control commodities (US$ 1.6 billion in 2014) is not addressing the fundamental weaknesses in health systems of developing countries, suggesting that innovative ways may be required to rapidly expand access to malaria interventions. It is worth underlining that the mobile phone is currently Africa's most important digital technology [2], and just as African telecommunications largely skipped over landline infrastructure and went straight to mobile phones, some experts say African medicine can skip over centralized labs [3]. Moreover, the combination of mobile devices

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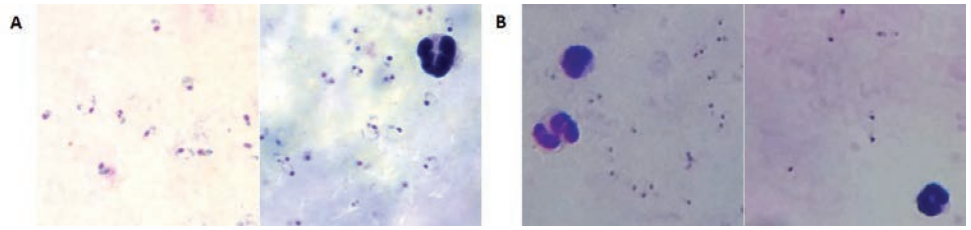

Fig. 1. Cropped microscopic sub-images of *P.falciparum* trophozoites and WBC on thick blood smear acquired with: (a) proper microscopic equipment[4]; (b) smartphone coupled to a Optical Magnification Prototype (see Section 3).

with image processing for malaria diagnosis can bring several advantages, like potentially reducing the dependence of manual microscopic examination, which is an exhaustive and time consuming activity, simultaneously requiring considerable expertise of the laboratory technician. Microscopy examination remains the gold standard for laboratory confirmation of malaria[4], which can be made through microscopic examination of thin and thick blood smears. While the thin smear consists in a single layer of red blood cells, the thick smear is 6-20 times thicker, allowing for a greater volume of blood to be examined. Thus, thick smears are firstly used to check the presence of malaria parasites (MP), while thin smears are subsequently analyzed for the identification of MP species.
This paper presents an image processing and analysis methodology using supervised classification to assess the presence of *P.falciparum* trophozoites and White Blood Cells (WBC) in Giemsa stained thick blood smears, using microscopic images acquired exclusively with smartphones.

2. Related Work

Image processing approaches have been proposed in order to identify parasites in malaria-infected thick blood smears[5,6,7,8,9]. *Kaewkamnerd et al.*[5] used an adaptive threshold computed from the V-Value histogram using only 20 images, thus requiring further validation. *Elter et al.*[6] have used a SVM classifier with a RBF kernel to identify objects containing chromatin, with reported sensitivity of 97%. Also, co-occurrence matrix and wavelet transform have been used by *Yunda et al.*[7], for detection of *P.vivax* in thick blood films, combined with the usage of Neural Networks. In a different approach, *Purnama et al.*[8] used Genetic Programming to detect different species and stages, with reported accuracy of 96% using 180 manually cropped sub-images. More recently, *Quinn et al.*[9] have extracted moment and connected component features for classification with Extremely Randomized Trees with stated results of AUC=0.97 for the ROC curve, being the only work found that uses smartphone-acquired images. Indeed, promising results for malaria diagnosis. Nevertheless, most of these methodologies are based on two criteria: i) images acquired under well controlled conditions; ii) the need of proper microscopic equipment. Both criteria are difficult to accomplish in endemic areas of Malaria, where this type of equipment is scarce or nonexistent in healthcare facilities. Alternatively, here, we present a different methodology approach for image processing of malaria-infected thick blood smears by using images exclusively acquired with low cost and accessible tools such as smartphone (see Fig. 1). The list of

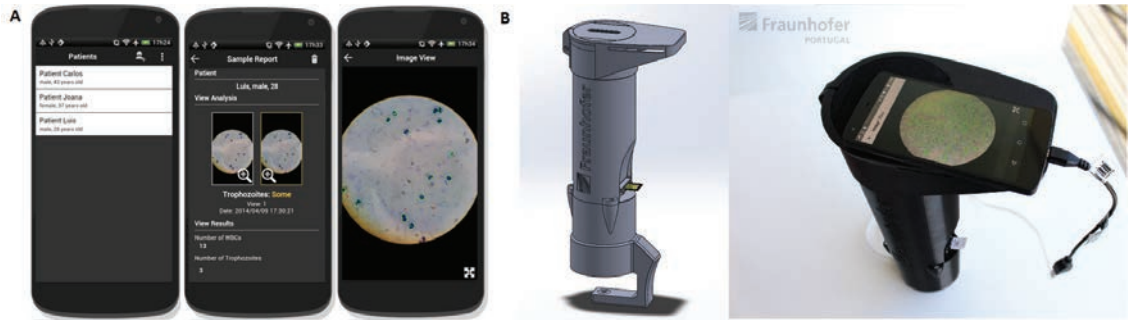

Fig. 2. Mobile-based Framework for Malaria Parasites Detection: (a) Smartphone Application; (b) Optical Magnification Prototype.