

Detection of Malaria Parasite Based on Thick and Thin Blood Smear Images Using Local Binary Pattern



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Abstract Malaria is one of the dangerous diseases transmitted by a female *Anopheles* mosquito through parasites. Parasite is a type of microorganism. Microscopic examination of blood samples helps to diagnose malaria automatically and faster. It also reduces the time and human errors. This paper aims to experiment and analyze quickly the accurate number of malaria parasites using image processing techniques. Local binary pattern (LBP) technique is used to classify blood smear into thin and thick blood smears. Morphological operations and k-means clustering techniques along with intensity profiles within the cells are used to count infected cells. The experiments are performed over standard datasets using segmentation and morphological operations for thick and thin blood smear images. The performance of the proposed algorithm is evaluated using confusion matrix. The results are compared using sensitivity and specificity. This method proves to be much effective in terms of time considering large rural areas in India.

Keywords Red blood cells · Blood smear · Segmentation · Morphological operation · Malaria Parasite · k-means clustering · Local Binary Pattern

1 Introduction

Infections and spread of diseases due to mosquitoes are real challenges in rural as well as urban areas of the world. Malaria is the most common and dangerous disease caused by a female *Anopheles* mosquito with the help of parasites. It is a very infectious disease of humans and other animals. It remains one of the most widespread infectious diseases of mankind with 216 million cases worldwide in 91

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countries in 2016, according to the World Health Organization (WHO) [1]. It causes symptoms like fever, fatigue, vomiting, headaches, etc. In few cases, it can cause yellow skin, coma, or death. The symptoms usually begin 10–15 days after being bitten by mosquito. Improper treatment leads to recurrences of the disease after few months which lead to complications in treatment.

The microscopic examination of blood with blood films is used to diagnose malaria. Current state-of-the-art for medical diagnosis and research purposes involves drawing a blood sample from a patient or research subject. This blood sample is smeared onto a slide. It is stained in order to color cell nuclei. The mature red blood cell (RBC) does not possess nuclei. This helps the stain to find and mark malarial parasites. These slides are then examined under a microscope. The counting of the number of infected red blood cells is carried out during this examination.

1.1 Related Work

The proposed work is based on semi-automatic diagnosis methods using image processing techniques. This section deals with attempts made by researchers to diagnose malarial parasites using digital image processing (DIP) algorithms. These methods are complex, supervised and need manual intervention or calibration.

The implementation of KNN classifier for diagnosis and screening of malaria is given by Tek et al. [2]. It also suggests color-based features for detecting parasites and non-parasites. The shape-based features are also experimented to analyze the performance improvement. The color, size, and textural features are used to classify parasite infected areas with SVM [3]. Savkare et al. [4] used Otsu thresholding and watershed transform for segmentation followed by SVM classifier using color and statistical features to detect parasites.

Mandal et al. [5] discusses normalized cut algorithm for segmentation using various color spaces. RGB, HSI, and C-Y color spaces are experimented in [6] to detect malaria parasites. This discusses the mathematical model for classification of RBC as infected parasite and non-parasite. The method for counting RBC is also discussed. Comparative analysis of various classifiers for malaria detection along with stage identification is presented in [7]. Extensive literature survey is given in context with features and performance analysis for microscopic images to detect malarial parasites using thin blood smear (TBS) [8].

Tsai et al. [9] proposed technique of automated malaria parasite and infected erythrocytes segmentation (MPIE) which segments microscopic images to detect malaria parasites and infected erythrocytes. The automatic counting of number of malaria parasites using standard image processing algorithms like histogram equalization, thresholding, morphological operations, and connected components analysis is used in [10].

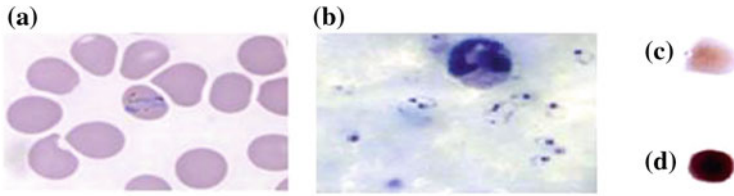


Fig. 1 Blood sample: **a** Infected red blood cell (RBC), **b** Infected RBCs and WBC, **c** Thin blood smear (TBS), **d** Concentrated thick blood smear (CBS)

The proposed research work is presented as: Sect. 2 explains about malaria parasite and diagnostic procedure. Section 3 details the proposed methodology. The experimental results and comparative analysis are given Sect. 4. The conclusion along with future directions is presented in Sect. 5.

2 Malaria Parasites

2.1 Red Blood Cells

The Red Blood Cells (RBC) with malaria infection is declared, if at least one parasite is detected within its interior. White blood cells and free-floating parasites are not considered. The current practice involves manual counting by an expert laboratory technician who can distinguish staining artifacts from actual nuclei, white blood cells, life cycle (depending on specific requirements), and species of malarial parasites. Although manual counting is relatively inexpensive to implement, adequate sensitivity requires proper training and supervision of technicians. This poses problems for both medical care providers in impoverished regions of the world as well as laboratory settings which may benefit from automation of a tedious and time-consuming task.

Automation of such task facilitates laboratory efficiency and also provides an alternative diagnostic tool. Also, expert pathologists are needed in parasite detection and their availability in rural areas is also a challenge. Obviously, automatic malaria parasite detection system is advantageous. The infection in RBC by malaria parasite and its effects are discussed in [11]. Figure 1a shows red blood cell with one infected cell and Fig. 1b shows infected RBCs and single WBC.

Two types of blood smears are preferred in malaria parasite detection and analysis as thin blood smear (TBS) and the concentrated thick blood smear (CBS). TBS drop spreads across a large area of the slide as shown in Fig. 1c. Within 10 min, thin blood smear (TBS) types of images get dried. So, the thin smear needs to be fixed in methanol once these images are dried. It helps to discover the type of species of malaria causing the infection. CBS has certain thickness as it is a drop of blood on

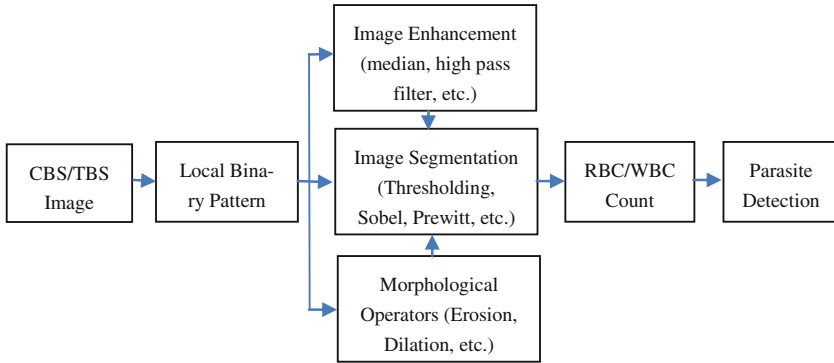


Fig. 2 The proposed methodology for malaria parasite detection

a glass slide as shown in Fig. 1d. These images are normally dried for 30 min. It is also not fixed with methanol. CBS images are useful in detecting infection along with the estimation of parasite concentration.

2.2 Diagnosis Procedure

The diagnosis processes can be manual or automatic. The manual diagnosis is done using microscope which is sensitive and specific. Human intervention is necessary and it takes more time as well as leads to erroneous diagnosis sometimes. Though the microscopy method has an advantage over automatic techniques, some of the problems of manual microscopy can be overcome by automatic process. Image processing techniques are effective in diagnosis of automatic detection of malaria parasites using CBS and TBS images. These automatic diagnosis procedures are unsupervised and highly sensitive. It helps to reduce the false negative cases. It is fast, accurate, and consistent in finding the true malaria cases.

3 Methodology to Detect Malaria Parasite

The proposed technique uses microscopic blood cell images (CBS/TBS) as an input. The source images are classified as CBS or TBS using Local Binary Patterns (LBPs) as a feature descriptor [12]. Various image enhancement techniques are used to improve the quality of image and to reduce noise. The image segmentation is applied followed by morphological operations. The next step is to count number of parasite identified within the image and RBC count of the respective image block as shown in Fig. 2.

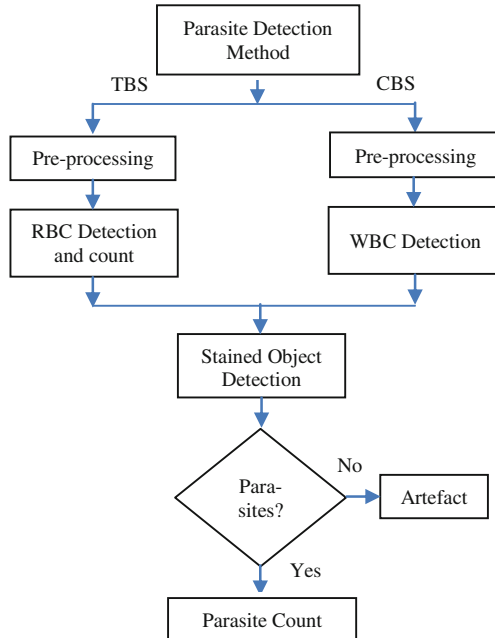


Fig. 3 Malaria parasite count process



Fig. 4 Operation on CBS image: a CBS image with malaria parasites and WBC, b Otsu thresholding to detect WBC nucleus, c Malaria parasites as white spots

The flowchart to enumerate malaria parasite using thick and thin blood smear images is as shown in Fig. 3. After images are classified as thick and thin smears, the counting of RBC/WBCs is required which will be useful for detecting stained cells. The total number of stained cells is the parasite count.

Figure 4a shows CBS image with one WBC and number of malaria parasites. The median filter is used for noise reduction. Otsu thresholding is used as a segmentation technique to separate WBC nucleus as a ROI as shown in Fig. 4b. To detect malaria parasites, k-means clustering is performed. Figure 4c shows the number of parasites in given input CBS image.

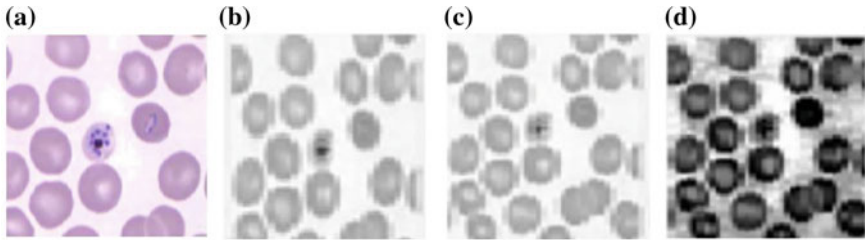


Fig. 5 Operation on TBS image: **a** Thin smear blood (TBS) with two infected cells, **b** RGB to grayscale, **c** filtered image, **d** histogram equalized image

TBS images are well identified, selected, filtered, and reformatted into the desired form. Figure 5a shows TBS image with two infected cells. TBS images sometimes have low brightness, low contrast, and noise. The preprocessing operation plays a significant role in operation on TBS images. The first image is converted into grayscale as shown in Fig. 5b followed by filtering (refer Fig. 5c). Histogram equalization is also preferred preprocessing to improve the contrast of source TBS image as shown in Fig. 5d.

Next step is highlighting ROI and locating objects within image boundaries. Otsu thresholding is used as segmentation tool. Sobel and Prewitt masks are used for edge detection. It detects high-frequency variations and abrupt changes can be highlighted. The morphological operations are used in shape identification based on the structuring elements. The RBC counting helps in detection of malaria parasites. Morphological operations are used for parasite count. The cell dimension is obtained from the step of RBC count. The contour plot helps to find the dimension and count of malarial parasites.

4 Result and Discussion

The dataset includes limited number of TBS and CBS image [13] for experimentation. The thin smear image contains parasites and is in the ring form. The thick smear consists of WBC and parasites. Few images only contain the malaria parasites. The WBC is also absent in few images.

Sensitivity and specificity are used to measure the performance of proposed algorithm. The values for sensitivity and specificity are calculated using four parameter namely true positive (TP), true negative (TN), false positive (FP), and false negative (FN). Sensitivity and specificity are calculated using Eq. 1 and Eq. 2, respectively.

$$\text{Sensitivity} = TP / (TP + FN) \quad (1)$$

$$\text{Specificity} = TN / (TN + FP) \quad (2)$$

Fig. 6 Performance comparison of malaria parasite detection over thin smear and thick smear

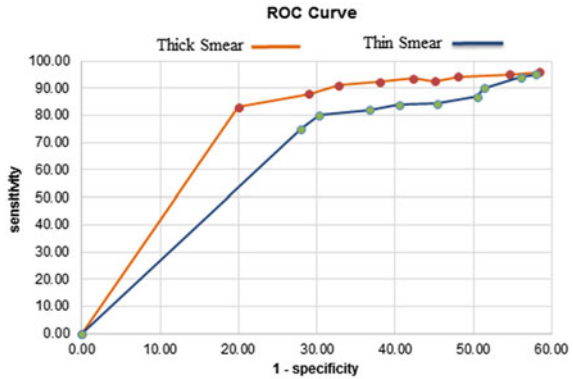


Table 1 Performance for thin blood smear (TBS) images

Metric	Thin smear								Average
	1	2	3	4	5	6	7	8	
TP	85	86	83	81	83	80	82	74	81.750
FP	4	6	6	6	5	5	3	2	4.625
FN	3	5	6	7	6	7	8	15	7.125
TN	3	6	6	7	7	10	7	11	7.125
Accuracy	92.6	88.3	88.1	87.1	88.1	85.3	90.0	87.3	88.362

Table 2 Performance for the concentrated thick blood smear (CBS) images

Metric	Thick smear								Average
	1	2	3	4	5	6	7	8	
TP	60	58	62	62	60	60	61	62	60.625
FP	4	6	7	6	7	8	6	5	6.125
FN	10	12	12	14	13	10	6	6	10.375
TN	3	6	7	8	10	10	10	10	8.000
Accuracy	90.9	85.4	84.1	84.4	81.1	79.5	80.7	81.9	83.515

The ROC curve is plotted using ten samples of thick smear and ten samples of thin smear in Fig. 6. It shows the performance of thick smear (CBS) and thin smear (TBS) images. There is average 91.98% sensitivity for thick smear and 85.51% sensitivity for thin smear.

Table 1 and Table 2 give the values of TP, FP, FN, and TN for eight sets of TBS and CBS images, respectively. It is revealed that average true positive rate (TPR) is 91.98% and 85.51% for thin and thick smears, respectively. However, average false positive rate (FPR) is 40.46% and 44.55% for thin and thick blood smears, respectively. The accuracy of the proposed algorithm for available limited dataset is 88.362% for TBS images and 83.515% for CBS images. Highest value of TPR, FPR, and accuracy are the measures of the better performance of algorithm. Thus, thin smear provides better performance compared to thick smear.

5 Conclusion

Thin blood smear (TBS) and Concentrated thick blood smear (CBS) images are classified using linear binary pattern (LBP). These images are used in the proposed automatic malaria parasite detection system. It helps to identify number of malaria parasites with the help of image processing algorithms like image segmentation, morphological operations, and edge detection techniques. These techniques together contribute for counting the RBCs, WBCs, and number of infected RBCs by malarial parasites. The performance of the proposed approach for thin blood smear is better as compared to thick blood smear. The system achieves acceptable values of sensitivity and specificity. The automatic detection of malaria parasites is helpful to the patients in rural areas. Further, it is useful to avoid complications due to delayed diagnosis and treatment. The proposed detection of malaria parasites is faster compared to manual process.

The proposed work is experimented with online data sets and using limited cases. It can be tested for its robustness and compared with manual process for large datasets. The work can be extended with other classifiers like Support Vector Machine (SVM), Artificial Neural Network (ANN), Neuro-Fuzzy approaches to analyze, classify, and verify the parasite species based on their size and shapes.

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