Erythrocyte Features for Malaria Parasite Detection in Microscopic Images of Thin Blood Smear: A Review

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***Abstract* — Microscopic image analysis of blood smear plays a very important role in characterization of erythrocytes in screening of malaria parasites. The characteristics feature of erythrocyte changes due to malaria parasite infection. The microscopic features of the erythrocyte include morphology, intensity and texture. In this paper, the different features used to differentiate the non-infected and malaria infected erythrocyte have been reviewed.**

***Keywords* — Medical imaging, erythrocyte, malaria parasite, erythrocyte features.**

I. Introduction

Malaria is an infectious disease due to Plasmodia parasites. There are different parasite species causing human malaria i.e *Plasmodium falciparum, Plasmodium vivax, Plasmodium malariae, Plasmodium knowlesi and Plasmodium ovale.* Malaria is the priority tropical disease of the World Health Organization [1]. In 2013 malaria report from World Health Organization, it has been reported that there are 97 countries and territories with ongoing malaria transmission. Globally, total 3.4 billion people are in risk of malaria. The present scenario of malaria in India is best described as malaria endemic country with more than 95% of population at risk and north-eastern state of India contributes about 10%. *In India,* both *Plasmodium falciparum* and *Plasmodium vivax* are commonly reported. To diagnose the presence of malaria parasite in erythrocyte, the microscopic examination of the blood smear is done by the clinical expert. The blood smears are of two different type i.e. thick smear and thin smear. In thin smear, the changes in characteristic of the erythrocyte due to malaria parasite infection can be studied but in thick smears, the appearance of the parasite is much more distorted [2]. The erythrocyte is mainly used to diagnose the different diseases such as malaria, cancer, etc. The medical image processing is becoming very important to diagnose the diseases such as cancer, malaria, tumour detection, etc [3-4].

However, the microscopic analysis of blood smear by clinical expert is very tedious process and depends on the skill of the clinical expert. To avoid such a problem, different image analysis techniques are being explored to timely diagnose the malaria parasite infection in human being. The image analysis approach used different features to differentiate the infected and non-infected erythrocyte. The microscopic feature used for the analysis of the characteristic erythrocytes to detect the infected erythrocyte includes morphology, intensity and texture. Structural changes in erythrocyte take place due to malaria parasite infection. The features usually specific to morphology, intensity and texture. In some of the malaria species, the morphological feature does not affect but the textural changes occur. The morphological feature of different malaria parasites is shown in Table 1.

TABLE I. Morphological Feature of Malaria Parasites

Species	Stages	Size	Stippling
P. falciparum	Trophozoites Gametocytes	Normal	Maurer's dot
P. vivax	Schizonts Trophozoites Gametocytes	Enlarged	Schuffner's dots
P.ovale	Schizonts Trophozoites Gametocytes	Enlarged	Schuffner's dots
P. malariae	Schizonts Trophozoites Gametocytes	Normal	Ziemann's dots

Several researchers have used different feature set to classify the infected and non-infected erythrocytes [5-19]. The microscopic image of the thin blood smear is shown in Figure 1. The image contains both the infected and non-infected erythrocyte. It can be seen that there is variation in morphological features infected and non-infected erythrocyte.

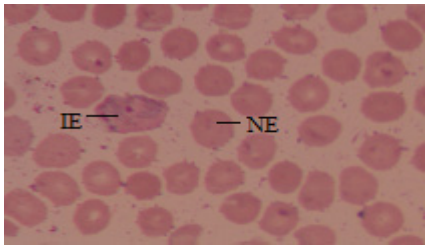

Fig. 1. Microscopic thin blood smear image
IE-Infected Erythrocyte, NE- Normal Erythrocyte

The contained of the paper is organised as follows. In section II, Morphological features of the erythrocyte are discussed. Microscopic feature of erythrocyte used for detection of malaria infected erythrocyte is studied in Section III. Conclusion is presented in the section IV of the paper.

II. Erythrocyte Morphology

Erythrocyte is a cell found in blood which carry oxygen and collect carbon dioxide through the use of haemoglobin. It has a life of about 120 days. For the diagnosis of several diseases such as malaria, cancer, etc, the microscopic image analysis of the blood cell is done [4]. The differentiation of the abnormal and normal erythrocyte can be done by using the features such as texture, color, size. Under normal conditions,

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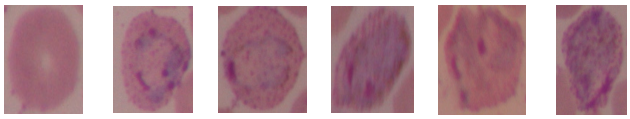
mature erythrocytes are round, biconcave disc-shaped, a nuclear cells with size of around 7-8 microns in diameter. The term normocytic is used to express normality of erythrocyte. Due to the malaria infection, the morphological features of the erythrocyte changes as shown in Fig. 2.



(a) (b) (c) (d) (e) (f)

Fig. 2. Erythrocyte image (a)- normal (b-f)-infected

III. Microscopic feature extraction

Feature extraction is the quantitative measurements of images typically used for identifying objects or region of interest and/or analyzes the pathology of a structure or tissues in the pathology slides. Once the features have been computed, appropriate selection of a subgroup of the significant and robust features is necessary to improve the classification accuracy and minimizing the overall complexity. In order to distinguish between infected and non-infected erythrocytes, different features have been used from the image array and compute new variables that concentrate information to separate classes. Such feature set consist of features leading to large between-class distance and small within-class variance in the feature vector space, i.e. the set of features can discriminate between different classes as well as possible. Some set of features that can distinguish between infected and non-infected erythrocytes are morphological features, intensity features and textures features.

Morphological features characterize the overall shape and size of the erythrocyte without taking the density into account. It is also reported that the size of the erythrocyte enlarged in *P.vivax and P.ovale* infection. In case of *P.falciparum*, the size of the erythrocyte remains same. Morphological features include shape features such as area, perimeter, compactness ratio, eccentricity, bending energy, minor axis of the bestfit ellipse, major axis of the best fit ellipse, Hu's moment, area granulometry, roundness ratio [5]. The texture feature gives the spatial distribution of the intensity in a particular region. An intensity and texture features includes gray level co occurrence matrix (GLCM), Gray level run length matrix, histogram, local binary pattern, color histogram, entropy, laplacian texture, gradient texture, color channel histogram such as saturation histogram [6] [7][8]. There are several feature set used by researchers in order to classify the infected and non-infected erythrocyte. F. Boray Tek et. al. used a set of feature which consist of colour histogram, colour auto-correlogram, area granuometry, relative shape measurements, Hu moments, scale invariance and number of colours to diagnose the malaria parasite infection in erythrocyte [7]. Automated image processing method for the diagnosis and classification of malaria infected erythrocyte using relative size and eccentricity features on thin blood smears had been proposed [8]. G.Diaz et. al. proposed a semi-automatic method for quantification and classification of malaria infected erythrocytes. Here, erythrocyte feature is described by a set of histogram features such as color histogram, saturation level histogram, gray scale histogram, tamura texture histogram, and sobel histogram [9]. Springl et. al. proposed an automatic malaria diagnosis through microscopic imaging. In this paper, the features such as Hu set of invariant moment, relative shape measurement, intensity histogram, gradient features, laplacian features, flat texture, co-occurrence matrix, run-length matrix are used to classify the erythrocytes [10]. Digital analysis of changes by *Plasmodium vivax* had been analysed using perimeter, area and form factor [11]. M.I.Khan et.at.[12] proposed a content based image retrieval approaches for detection of malarial parasite in blood images using intensity histogram and Hu moment as feature.

The color as well as statistical features which include area, perimeter, compactness ratio, metric, saturation histogram, gray scale histogram are used for automatic malaria detection [13]. Kumarasamy et. al. extract a set of feature such as Nuclear density, Nucleo-cytoplasmic ratio, Euler numberare used for automatic identification of malaria parasite stages [14]. The percentage of chromatin dot stained pixels, ring part stained pixels and the standard deviation of the value channel of the HSV representation of each ROI are used as features to classify the malaria infected erythrocytes [15]. A web accessible framework for automated storage with compression and textural classification of malaria parasite images using textural features such as fractal dimension, gray level co-occurrence matrix, run length matrix, local binary pattern [16]. Features such as colour histogram, Hu moment, relative shape measurement, colour auto-correlogram based Mobile Support for Diagnosis of Communicable Diseases in Remote Locations has also been proposed [17]. N. Ahirwar et. al.[18] proposed an image analysis based system for automatic detection and classification of malarial parasite in blood images using gray level texture, geometric features and colour attributes. Multiscale laplacian of Gaussian filter and gabor filter based malaria parasite detection has also been proposed [19]. M.Gosh et. al proposed a textural approach quantitative characterisation of Plasmodium vivax in infected erythrocytes [20]. Automatic screening of malaria parasite based on machine learning with a total 96 features which include entropy, haralick texture, fractal dimension, local binary pattern, histogram based features, gray level run length matrix, gray level co occurrence matrix, shape features, Hu's moment [21]. Malaria Parasite Detection in Giemsa–Stained Blood Cell Images based on features i.e. gradient, flat texture, colour histogram, area granulometry had been studied [22]. Malaria diagnostic system using morphological features has also been proposed [23]. A. N. Nithyaa et.al.[24] proposed a powerful diagnostic tool for automatic classification of various blood diseases using digital image processing technique. Here, histogram based features of various colour channels such as hue, saturation and intensity are used to identify the normal and infected erythrocytes. Fractal dimension and colour channel histogram are used for automatic malaria parasite identification [25]. Malaria disease identification and analysis using image processing based on histogram features had been proposed [26]. Memeu et. al. used the morphological feature as well as textural features for rapid malaria diagnosis. It includes the features such as form factor, roundness, aspect ratio, solidity, extent, compactness, convexity and statistical moment [27]. The diagnosis of malaria on thin blood smears had been proposed. To detect the presence of malaria parasite and to classify the malaria species, image features based on texture, color and geometry of the erythrocyte have been extracted. Features include phase of the image, skewness, kurtosis, standard deviation, energy [28]. N.Linder et. al. [29] proposed a malaria diagnostic tool based on computer vision screening and visualization of plasmodium falciparum candidate areas in digitized blood smears. The method achieved a diagnostic system using a feature set of local binary pattern-rotation invariant local contrast, scale invariant feature transform. Automatic characterization and classification of malaria-infected stages using light microscopic images of thin blood smears had been proposed with total 80 textures features and 16 morphological features [30]. The microscopic features of malaria classification are listed in table 2.

TABLE II. Microscopic Features of Malaria Classification

Authors	Features		Performance statistics (%)
	Morphological	Texture and Intensity	
C.Di. Ruberto (2001)	Granulometry, Regional Extrema		----
F. Boray Tek (2006)	Hu's moment, Relative shape measurements	Colour histogram	Sensitivity-74 Specificity-98 Positive prediction value-95 Negative prediction value-95
F. Boray Tek (2010)	Area granuometry, Relative shape measurements, Hu moments, Scale invariance	Colour auto-correlogram, Colour histogram	Sensitivity-72.4 Specificity-97.6
N. E. Ross (2006)	Relative size, Eccentricity		Sensitivity- 85 Positive prediction value-81
G. Diaz (2009)		Color histogram, Saturation level histogram, Gray scale histogram, Tamura texture histogram, Sobel histogram	Sensitivity-94 Specificity-98.7
V. Springl (2009)	Hu invariant moment, Relative shape measurement	Intensity histogram, Gradient features, Laplacian features, Flat texture, Co-occurrence matrix, Run-length matrix	----
M. Edison (2011)	Perimeter, Area, Form factor		----
M. I. Khan (2011)	Hu moments	Intensity histogram	Sensitivity-85.5 Positive prediction value-81
S. S. Savkare (2011)	Area, Perimeter, Compactness ratio, Metric	Saturation histogram, Gray scale histogram	Sensitivity-93.12 Specificity-93.17
S. K. Kumarasamy (2011)	Nuclear density, Nucleo-cytoplasmic ratio, Euler number		Accuracy Eythrocyte-97 Infected erythrocyte-85.3 Parasitaemia-85.3
K.Prasad (2012)	Percentage, Standard Deviation		
M.Maity (2012)		Fractal dimension, Gray level co-occurrence matrix, Run length matrix, Local binary pattern	Sensitivity-99 Specificity-99.8 Precision-99.1
M.Cesario (2012)	Hu moments, Relative shape measurement	Colour auto-correlogram, Colour histogram	----
N.Ahirwar (2012)	Geometric (shape, size)	Gray level texture, Colour histogram	----
S.Suryawanshi (2013)		Multiscale Laplacian of Gaussian, Gabor	----
M. Ghosh (2013)		Fractal dimension, Gray level co-occurrence matrix	Accuracy-98
D. K. Das (2013)	Shape features, Hu moment	Entropy, Haralick texture, Fractal dimension, Local binary pattern, Histogram based features, Gray level run length matrix, Gray level co occurrence matrix	Accuracy-84
L.Malihi(2013)	Area granuometry, Hu moment	Gradient, Flat texture, Colour histogram,	Accuracy-91

Authors	Features		Performance statistics (%)
	Morphological	Texture and Intensity	
V.P.Vink (2013)		Histogram based features (mean, Variance, kurtosis, skewness, energy, entropy)	Sensitivity-75 Specificity-99.99
A. N. Nithyaa (2013)		Hue histogram, Saturation histogram, Intensity histogram (mean, Variance, kurtosis, skewness, energy, entropy)	-----
M.Chayadevi (2014)		Fractal dimension, Colour channel intensity	Accuracy-94.45, Specificity-94.68, Sensitivity-94.32, Precision-96.41
S.N.Chavan (2014)		Histogram based features (mean, Variance, kurtosis, skewness, energy, entropy)	Accuracy-98.25
D.M. Memeu (2014)	Form factor, Roundness, Aspect ratio, Solidity, Extent, Compactness, Convexity and Statistical moment		Accuracy-79
S. Annaldas (2014)		Histogram based features (phase of the image, skewness, kurtosis, standard deviation, energy)	Accuracy-98.25
N. Linder (2014)		Local binary pattern-rotation invariant local contrast, Scale invariant feature transform	Sensitivity-92.5 Specificity-100
D. K Das (2015)	Shape features, Hu moment	Entropy, Haralick texture, Fractal dimension, Local binary pattern, Histogram based features, Gray level run length matrix,	Accuracy-96.84

IV. Conclusion

This paper gives an outline of different feature sets used for malaria infected erythrocyte classification. Different set of features can be developed to effectively classify the infected and non-infected erythrocytes. The main goal of the erythrocyte feature extraction is to effectively diagnose the presence of the malaria parasite host inside the erythrocyte. In malaria parasite infection, the structural features of the erythrocyte changes for every parasite life-cycle stages. From the analysis of the different set of features, it may be concluded that there is no individual features which can be considered good for the classification of infected, non-infected erythrocyte and malaria infection stages classification. Further analysis can be done to improve the classification accuracy of the system by introducing strong and efficient features.

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