Automatic Detection of Malaria Parasite from Blood Images: A Review

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Abstract— Malaria is a serious disease for which the immediate diagnosis is required in order to control it. Microscopes are used to detect the disease and pathologists use the manual method due to which there is a lot of possibility of false detection being made about the disease. If the wrong detection is done then the disease can turn into more severe state. So the study about the computerized diagnosis is done in this paper, which will help in developing automatic malaria detection system in a robust manner so that it is unaffected by the exceptional conditions and will achieve high percentages of sensitivity, specificity, positive prediction and negative prediction values.

Key words: Immediate Diagnosis, Pathologists, False Detection, Computerized Diagnosis, Automatic Malaria Detection, Robust, Sensitivity

I. INTRODUCTION

Malaria is a life-threatening parasitic disease, caused by the protozoan parasites of the genus Plasmodium and is transmitted through the bite of a female Anopheles mosquito. Inside the human body, the parasite undergoes a complex life cycle in which it grows and reproduces. During this process, the red blood cells (RBCs) are used as hosts and are destroyed afterwards. Hence, the ratio of parasite-infected cells to the total number of red blood cells called parasitaemia can be used as a measure of infection severity and is an important determinant in selecting the appropriate treatment and drug dose. Malaria is a serious global disease and a leading cause of morbidity and mortality in tropical and sub-tropical countries.

Approximately, 40% of the world's population, mostly those living in the world's poorest countries, is at risk of malaria. A child dies of malaria every 30 seconds. Every year, more than 500 million people become severely ill with malaria. Between 300 million and 500 million people in Africa, India, Southeast Asia, the Middle East, the South Pacific, and Central and South America have the disease. The worldwide annual economic burden of malaria, calculated to include spending on prevention and treatment as well as loss of productivity due to illness, was estimated at US$ 500 million in 2005.

It becomes the fifth cause of death from infectious diseases worldwide in low income countries. Yet, malaria is both preventable and curable. Rapid and accurate diagnosis which enables prompt treatment is an essential requirement to control the disease. Currently, clinical diagnosis primarily utilizes microscopy to study the prepared blood smears. However, evaluation of smears is arduous and time consuming, especially in situations where large numbers of samples require reliable analysis. Hence, it is important to develop an automated image analysis that is able to identify the uninfected and infected RBCs in a blood smear image.

II. DIAGNOSIS OF MALARIA

The definitive diagnosis of malaria infection is done by searching for parasites in blood slides (films) through a microscope. In peripheral blood sample visual detection and recognition of plasmodium is possible and efficient via a chemical process called (Giemsa) staining. The staining process slightly colorizes the red blood cells (RBCs) but highlights plasmodium parasites, white blood cells (WBC), and platelets or artefacts. The detection of Plasmodium parasites requires detection of the stained objects. However, to prevent false diagnosis the stained objects have to be analyzed further to determine if they are parasites or not. In the figure's 1, 2, 3, and 4,there are four types of human malaria – Plasmodium falciparum, P. vivax, P. malaria, and P. ovale. P. falciparum and P. vivax are the most common. P. falciparum is by far the most deadly type of malaria infection.

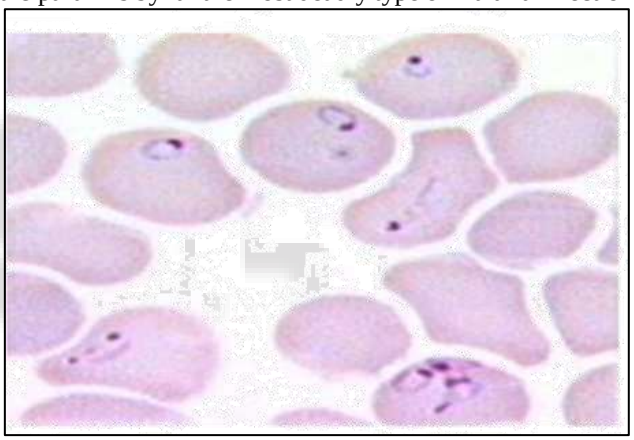

Fig. 1: Plasmodium Falciparum

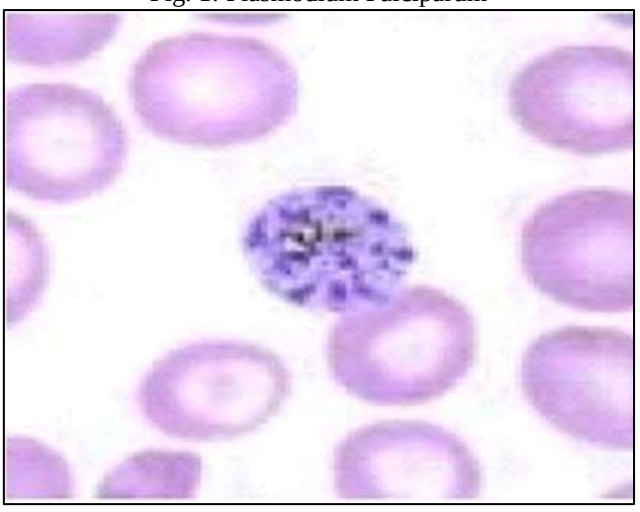

Fig. 2: P. Vivax

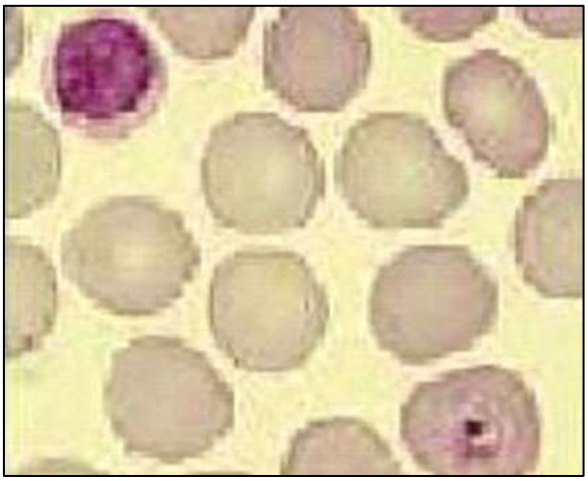

Fig. 3: P. Malaria

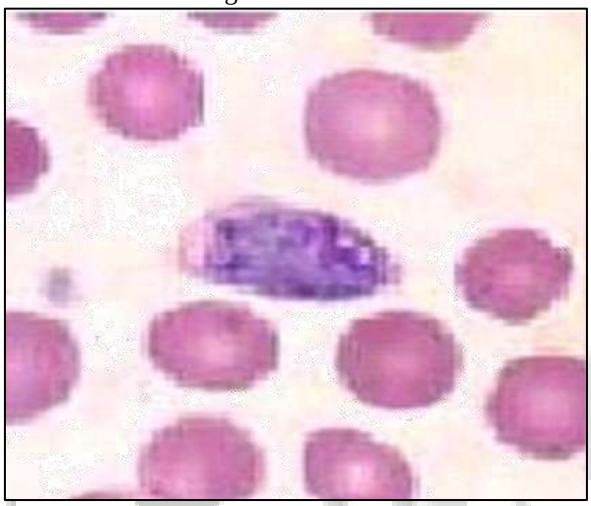

Fig. 4: P. Ovale

III. OVERVIEW OF RELATED WORK

In the paper Estimating Malaria Parasitaemia from Blood Smear Images the author Silvia Halim, Timo R., Bret Schneider, Yikun Li used pattern matching and template extraction. Malaria Parasite Detection in Peripheral Blood Images F. Boray Tek, Andrew G., Dempster used the method of Baysian Pixel classifier, k-nearest neighbor classifier. In Segmentation of Malaria Parasites in Peripheral Blood Smear Images Vishnu V., Makkapatti, Raghuveer M. Rao used image segmentation and chromatin dot selection. Malaria is caused by protozoan parasites of the genus Plasmodium. There are four species of Plasmodium that infect man and result in four kinds of malarial fever: P. falciparum, P. vivax, P.ovale, and P. malaria. P. vivax shows the widest distribution and is characterized by reappearances of symptoms after a latent period of up to five years. With the similar characteristics, P. ovale appears mainly in tropical Africa. P. falciparum is most common in tropical and subtropical areas. It causes the most dangerous and malignant form of malaria without relapses and contributes to the majority of deaths associated with the disease. P. malaria is also widely distributed but much less than P. vivax or P. falciparum.

There are three phases of development in the life cycle of most species of plasmodia: exoerythrocytic stages in the tissues, usually the liver; erythrocytic schizogony (i.e. protozoan asexual reproduction) in the erythrocytes; and the sexual process, beginning with the development of gametocytes in the host and continuing with the development in the mosquito.

When an infected mosquito bites humans, several hundreds sporozoites (the protozoan cells that develop in the mosquito's salivary gland and infect new hosts) may be injected directly into the blood stream, where they remain for about 30 minutes and then disappear. Many are destroyed by the immune system cells, but some enter the cells in the liver. Here they multiply rapidly by a process referred to as exoerythrocytic schizogony. When schizogony is completed, the cells produced by asexual reproduction in the liver termed merozoites are released and invade the erythrocytes. In Plasmodium vivax and P. ovale, some injected sporozoites may dierentiate into stages termed hypnozoites which may remain dormant in the liver cells for some time before undergoing schizogony causing relapse of the disease.

When the released merozoites enter erythrocytes, the erythrocytic cycle begins. This process is referred to as erythrocytic schizogony. Within an erythrocyte, the parasite is first seen microscopically as a minute speck of chromatin surrounded by scanty protoplasm. The plasmodium gradually becomes ring shaped and is known as ring or immature trophozoite (Fig.5). It grows at the expense of the erythrocyte and assumes a form differing widely with the species but usually exhibiting active pseudopodia (i.e. projections of the nuclei). Pigment granules appear early in the growth phase and the parasite is known as a mature trophozoite. As the nucleus begins to divide, the parasite is known as a schizont. Dividing nucleus tends to take up peripheral positions and a small portion of cytoplasm gathers around each. The infected erythrocyte ruptures and releases a number of merozoites which attack new corpuscles and the cycle of erythrocytic schizogony is repeated. The infection about this time enters the phase in which parasites can be detected in blood smears. Some merozoites on entering red blood cells become sexual gametocytes, instead of asexual schizonts. When gametes are ingested by a mosquito, the cells rapidly undergo gamete production. This is the third phase of development in the life of plasmodium, the sexual process of reproduction in a mosquito. The figure for the development of plasmodium parasite is shown in figure 5, 6, 7, 8, 9, and 10.

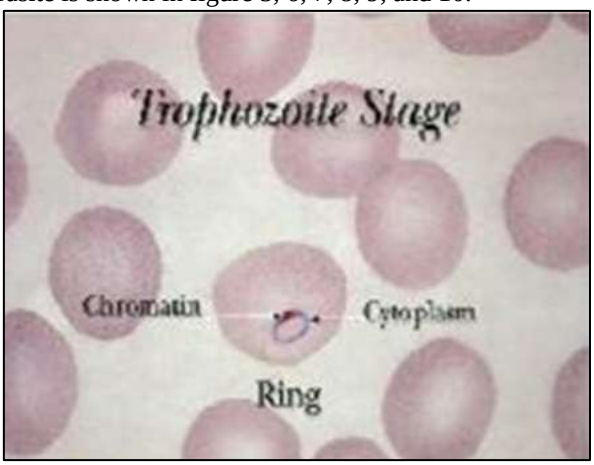

Fig. 5: Ring Trophozoite Stage

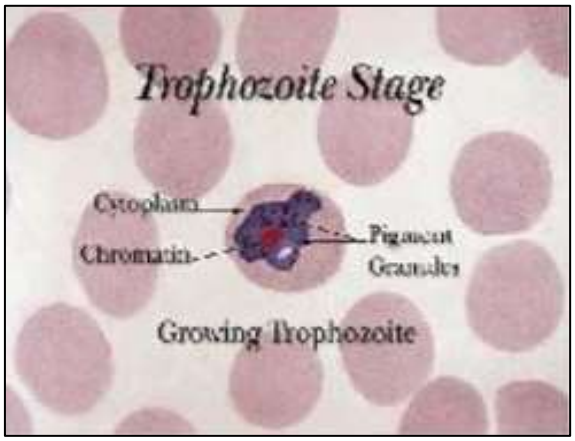

Fig. 6: Growingtrophozoite Stage 1

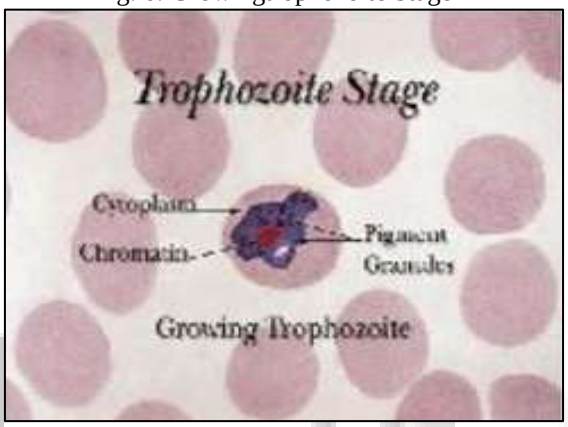

Fig. 7: Growing Trophozoile Stage 2

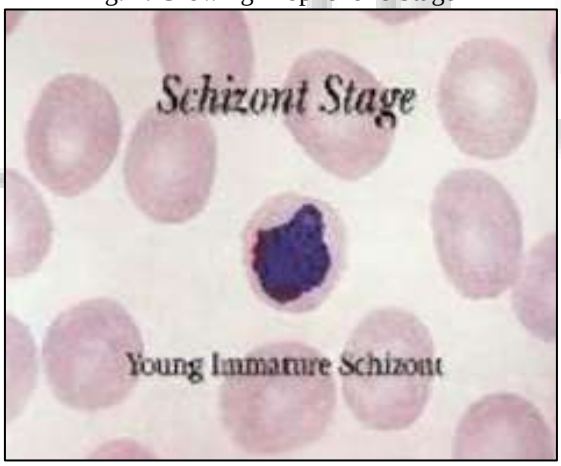

Fig. 8: Schizont Stage

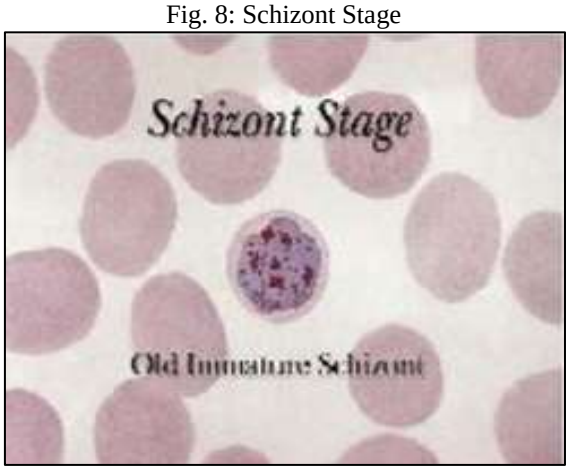

Fig. 9: Old Immature Schizont Stage

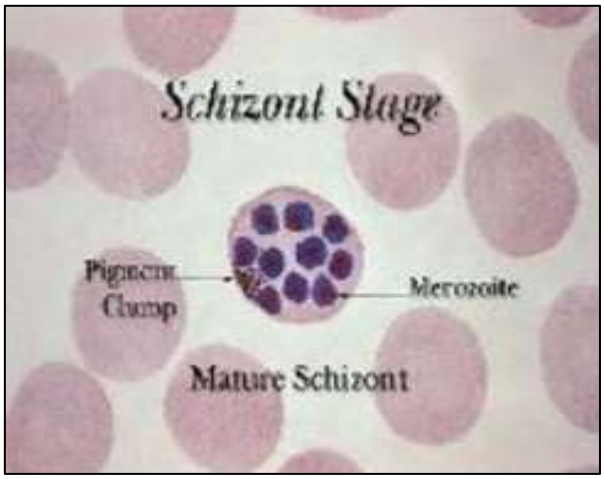

Fig. 10: Mature Schizont Stage

Deepa. A. Kurer et. al. 2013 developed an image processing algorithm to automate the diagnosis of malaria in blood images. The image classification system is designed to positively identify malaria parasites present in thin blood smears, and differentiate the species of malaria. They tried to implement a new approach to low-level image processing - SUSAN (Smallest Univalue segment assimilating nucleus) Principle, which performs edge and corner detection. Images are acquired using a charge coupled device camera connected to a light microscope. Morphological and novel threshold selection techniques are used to identify erythrocytes (red blood cells) and possible parasites present on microscopic slides. Image features based on colour, texture and the geometry of the cells and parasites are generated, as well as features that make use of a priori knowledge of the classification problem and mimic features used by human technicians. The first order features provides the basic mathematical ranges for different types of parasites. A two-stage tree classifier distinguishes between true and false positives, and then diagnoses the species.[1]

Pallavi et al. 2013 reviews image analysis studies aiming at automated diagnosis or screening of malaria infection in microscope images of thin blood film smears. Malaria is a mosquito-borne infectious disease of humans and other animals caused by parasites (a type of microorganism) of the genus Plasmodium. Infection is initiated by a bite from an infected female mosquito, which introduces the parasites via its saliva into the circulatory system, and ultimately to the liver where they mature and reproduce. The disease causes symptoms that typically include fever and headache, which in severe cases can progress to coma or death. Malaria is widespread in tropical and subtropical regions in a broad band around the equator, including much of Sub-Saharan Africa, Asia, and the Americas.[2]

Ms. Deepali Ghate et al. 2013 described in their paper malaria is a serious disease for which the immediate diagnosis is required in order to control it. Microscopes are used to detect the disease and pathologists use the manual method due to which there is a lot of possibility of false detection being made about the disease. If the wrong detection is done then the disease can turn into more severe state. So the study about the computerized diagnosis is done in this paper, which will help in immediate detection of the disease to some extent, So that the proper treatment can be

provided to the malaria patient. Also the image processing algorithm is used which will reliably detect the presence of malaria parasite from Plasmodium falciparum species in thin smears of Giemsa stained peripheral blood sample. Some image processing algorithms to automate the diagnosis of malaria on thin blood smears are developed, but the percentage of parasitaemia is often not as precise as manual count. One reason resulting in this error is ignoring the cells at the bor-ders of images. This paper removes the human error while detecting the presence of malaria parasites in the blood sample by using image processing and automation. This is achieved by using Image Segmentation techniques to detect malaria parasites in images acquired from Giemsa stained peripheral blood samples. This is comparative study of two methods for detecting malaria parasites, first method is based on segmentation and second uses feature extraction using minimum distance classifiers. We built the malaria detection system in a robust manner so that it is unaffected by the exceptional conditions and achieved high percentages of sensitivity, specificity, positive prediction and negative prediction values.[3]

K. M. Khatria, et al. 2013 described in their paper, Malaria is one of the serious infectious disease which is because of mosquito bites. Diagnosis of malaria is done by microscopic examination of blood. But this diagnosis method is time consuming and requires pathologists. This paper aims to introducing fast and accurate method based on image processing for malaria parasite identification. The database was generated by taking the microscopic images of blood of 30 malarial patients. Based on morphological operations total number of cells are counted. Infected cells are analyzed based on intensity profiles within the cells. The result is validated by comparing with manual analysis. This approach can be used in rural areas where less experts are available and the delayed diagnosis may lead to complications in patients health.[4]

Anuja Vane et al. 2016 described in their paper one of the most serious infectious mosquito-borne disease spread worldwide is none other than malaria. The diagnosis of this threatening disease is done by microscopic examination of blood. But the diagnosis method requires efficient pathologists and lot of time. In this paper, we aim at introducing a fast and accurate method for RBC's classification which is based on image processing for parasites of malaria in particular. The generation of the database is done with the help of microscopic images of blood of 30 malarial patients. The total number of cells is counted on the basis of morphological operations. Based on the intensity profiles within the cells the infected cells are analyzed. The manual analysis is compared to validate the results. This approach will prove a boon to the rural areas where there is unavailability of experts and improper diagnosis can take a toll on the patients' health.[5]

Sneha Narayan Chavan et al. 2014 described in his paper, Malaria is a serious infectious disease. The focus of this study is to develop a robust, unsupervised and sensitive malaria screening technique with low material cost and one that has an advantage over other techniques in that it minimizes human reliance and is, therefore, more consistent in applying diagnostic criteria.[6]

C Berin Jones1 et al. 2018 described, clinical trials have started focusing on other plasmodium species too, contrasting to the emphasis on Plasmodium falciparum so far. This review article lists out certain major techniques in detection and classification of malarial parasites. Although the world has succeeded in finding out the devices that detect and classify the malaria parasites well in thin blood films, technology still lacks sufficient innovation in identifying and classifying these infectious parasites in thick blood films. In order to fill the gap, it is aimed to provide a brief study of a collection of methods and systems especially via image processing in which these concepts are prioritized. Thick blood smear is primarily focused that would let in knowing the percentage of infected red blood cells by identifying the malarial parasites. Real time in vivo optical imaging of infected cells based on automated computer vision provides possible insights about the plasmodium species that could be applied to treat and prevent malaria.[7]

Kishor Roy et al. 2016 described in their paper Malaria is one of the deadliest diseases ever exists in this planet. Automated evaluation process can notably decrease the time needed for diagnosis of the disease. This will result in early onset of treatment saving many lives. As it poses a serious global health problem, they approached to develop a model to detect malaria parasite accurately from giemsa blood sample with the hope of reducing death rate because of malaria. In this work, they developed a model by using color based pixel discrimination technique and segmentation operation to identify malaria parasites from thin smear blood images. Various segmentation techniques like watershed segmentation, HSV segmentation have been used in this method to decrease the false result in the area of malaria detection. They believe that, their malaria parasite detection method will be helpful wherever it is difficult to find the expert in microscopic analysis of blood report and also limits the human error while detecting the presence of parasites in the blood sample.[9]

Leila Malihi et al. 2015 used MATLAB software for the implementation of computation procedures. Using five extracted features (flat texture, saturation channel histogram, color histogram, gradient, and granulometry) and six classifiers (k-Nearest Neighbors (k-NN), 1-Nearest Neighbor (1-NN), decision tree (DT), Fisher, linear discriminant analysis (LDA), and quadratic discriminant analysis (QDA)), images were classified into two classes: parasitic and nonparasitic. Then, classifier fusion was done using several algorithms: mean, min, max, stack, median, Adaboost, and bagging.[10]

S. S. Savkare, et al. 2011 described in their paper, Malaria, Thalassaema and Babesia are serious global health problem and rapid, precise diagnosis and determination of parasitemia is necessary for accurate medication. Visual quantification of parasitemia in thin blood films is a very tedious, subjective and time-consuming task. Manual counting by light microscopy is the most widely used technique for parasitemia determination but it is a time-consuming and laborious process and requires expertise. This work resents an automatic method for quantification and classification of erythrocytes in Giemsa stained thin blood films infected with Plasmodium Falciparum or Protozoan Parasite. The features are extracted using statistical

parameters and SVM classifier used for classification of normal or infected blood cells.[11]

Neetu Ahirwar et al. 2012 investigates the possibility of rapid and accurate automated diagnosis of red blood cell disorders and describes a method to detect and classify malarial parasites in blood sample images acquired from light microscopes. As malaria is an infectious disease which is mainly diagnosed by visual microscopical evaluation of Giemsa stained blood smears. As it poses a serious global health problem, automation of the evaluation process is of high importance. The image classification system is designed to positively identify malaria parasite in thin blood smears. Morphological and novel threshold selection techniques are used to identify erythrocytes (red blood cell) and possible parasites present on microscopic slides. Image features based on colour, texture and the geometry of the cells and parasites are generated, as well as features that make use of a priori knowledge of the classification problem and mimic features used by human technicians. Classifier using back propagation feed forward neural network distinguishes between parasite infected and non-infected blood images.[12]

IV. CONCLUSIONS

The detection of Malaria parasites is generally done by pathologists manually using microscopes. So, the chances of false detection due to human error are high, which in turn can result into fatal condition. To curb the human error in detecting the presence of malaria parasites in the blood sample two different methods, image segmentation and feature extraction using minimum distance classifier are used. In image segmentation one gets the accurate and required results in the short period of time whereas in case of feature extraction more time is required i.e. more CPU utilization is there. The system works in a robust manner so that it is unaffected by the exceptional conditions and achieves high percentages of sensitivity, specificity, positive prediction and negative prediction values. The extraction of red blood cells achieves a reliable performance and the actual classification of infected cells.

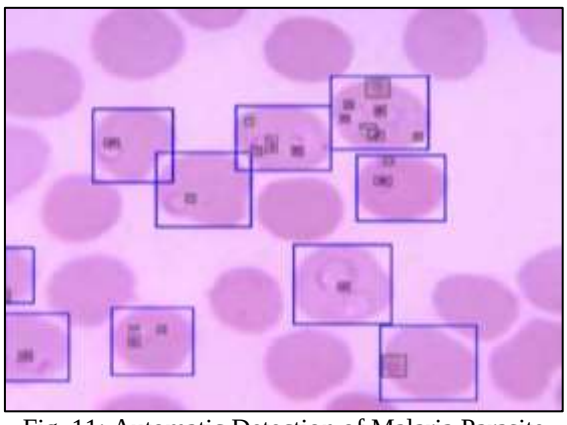

Fig. 11: Automatic Detection of Malaria Parasite

Automatic malaria parasite detection involves following steps: Threasholding, gray scale image conversion, binary image, edge detection algorithm, thinning of binary image, labeling algorithm. There exists a ring shape malaria parasite on RBCs. These parasites are having shape like a ring and the ring is generally of blue color. Extraction of color intensity range for malarial parasite expression technique is described best as compare to other technique.

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