Global Journal of Computer Science and Technology: F
Graphics & Vision
Volume 17 Issue 2 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Review of Microscopic Image Processing Techniques to wards Malaria Infected Erythrocyte Detection from Thin Blood Smears

By Md. Jaffar Sadiq & Dr. V.V.S.S.S. Balaram
Sreenidhi Institute of Science & Technology

Abstract- In order to diagnose malaria, the test that has traditionally been conducted is the gold standard test. The process mainly entails the preparation of a blood smear on glass slide, staining the blood and examining the blood through the use of a microscope so as to observe parasite genus plasmodium. Although these are several other kinds of diagnostic test solutions that are available and which can be adopted, there are numerous shortcomings which are always observed when microscopic analysis is carried out. Presently, the treatments are hugely conducted based on symptoms and upon the occurrence of false negatives, it might be fatal and may result into the creation of different kinds of implications. There have been a number of deaths which have been associated with malaria and as a result, there is the dire need to ensure that there is early detection of malarial infection among the people.

Keywords: *texture features, soft computing, morphological features, microscopic image processing, malaria parasite, malaria detection, machine learning, heuristic scale, feature selection, erythrocyte, disease diagnosis, classifiers, case based reasoning, blood samples.*

GJCST-F Classification: *J.3*

Strictly as per the compliance and regulations of:

Review of Microscopic Image Processing Techniques towards Malaria Infected Erythrocyte Detection from Thin Blood Smears

Md. Jaffar Sadiq [α] & Dr. V.V.S.S.S. Balaram [σ]

Abstract- In order to diagnose malaria, the test that has traditionally been conducted is the gold standard test. The process mainly entails the preparation of a blood smear on glass slide, staining the blood and examining the blood through the use of a microscope so as to observe parasite genus plasmodium. Although these are several other kinds of diagnostic test solutions that are available and which can be adopted, there are numerous shortcomings which are always observed when microscopic analysis is carried out. Presently, the treatments are hugely conducted based on symptoms and upon the occurrence of false negatives, it might be fatal and may result into the creation of different kinds of implications. There have been a number of deaths which have been associated with malaria and as a result, there is the dire need to ensure that there is early detection of malarial infection among the people. This manuscript mainly provides a review of the current contributions regarding computer aided strategies, as well as microscopic image processing strategies for the detection of malaria. They are discussed based on the contemporary literature.

Keywords: texture features, soft computing, morphological features, microscopic image processing, malaria parasite, malaria detection, machine learning, heuristic scale, feature selection, erythrocyte, disease diagnosis, classifiers, case based reasoning, blood samples.

I. Introduction

It is worth pointing out that Malaria is one of the epidemic health disease which is having huge implications on peoples' health. In a number of nations globally, individuals faces the risk of malaria and based on the World Health Organization reports, annually, millions of individuals die as a result of malaria. The reports also indicate that about 250 million infections takes place every year as a result of the parasites of genus plasmodium, with over 98 percent of deaths being brought about by plasmodium falciparum. The different kinds of techniques which are currently being used in order to diagnose infections from Falciparum include various manual process.

Author α: Associate Professor, Dept., of IT, Sreenidhi Institute of Science & Technology, Ghatkeser, Hyderabad, Telangana State, India. e-mail: jaffer_610@yahoo.com

Author σ: Professor& HOD, Dept., of IT, Sreenidhi Institute of Science & Technology, Ghatkeser, Hyderabad, Telangana State, India.

This takes place even in the developing nations. Despite the fact that there are a number of highly advanced techniques which can be adopted, the process of manual microscopy of blood films over the slides is still considered as the golden standard solution. The manual microscopy has more advantages in comparison to the other kinds of techniques due to sensitivity, as well as because of specifics. Among the disadvantages associated with the use of manual microscopy techniques, the need for human intervention in the process is very high, and at the same time, there is the possibility that it may result into late diagnosis and at the same time, there may also be erroneous diagnosis.

The use of the microscope requires extensive training to gain sufficient expertise in diagnosis. In addition, the huge volume of samples which are supposed to be analyzed may result into various kinds of inconsistencies in the reports which are generated. In addition, the other impacting factors include blood smear, the quality of the stain, as well as the quality of microscope which is used during the process of analysis. The expertise of pathology professionals is also one of the leading factors which have to be taken into consideration.

The use of microscope requires quality training to ensure that expertise is gained in the process of diagnosis. Considering the quantum of samples which have to be analyzed, this microscopic method may be inconsistent. In addition, factors such as stain quality, blood smear, microscopic quality, as well as the domain expertise of the professionals play a huge role in ensuring that the diagnosis is done effectively. When computer aided diagnostic techniques such as image-based diagnosis technique are employed, the different kinds of limitations which are associated with the manual process can be adequately looked into.

The main aim of this report is to study the semi-automatic diagnosis technique based on image processing, as well as the ones which offer highly effective and highly reliable solution. In the past, a number of studies have been carried out which have proposed different kinds of computer vision or image based algorithms. However, a number of the algorithms are supervised and complex solutions, which needs manual intervention, as well as calibration. Taking into

consideration the rate at which the given disease is impacting, as well as the volume of the samples which are supposed to be analyzed, there is the integral need for a highly effective and a robust solution that requires minimal human intervention.

In conditions like that, computer aided solutions are capable of ensuring that there is a highly accurate and a highly consistent diagnosis of the true causes of malaria. It can also make sure that highly appropriate diagnosis of the symptoms of malaria in the case samples are carried out. Process of Manual microscopy is aimed at investigating under the microscope, the thin blood films on the slides for assessing the ratio of the infected red blood cells (iRBCs) which are referred to as Parasitemia over about 100 microscopic fields. At the same time, the pathologists should also study parasite morphology by different life cycle stages for specification advocated by World Health Organization practical microscopy guide.

In most cases, Giemsa staining technique is always used in order to highlight the parasites. There are a number of disadvantages which are brought as a result of the use of Giemsa method. These include the fact that it always stains the other blood film features such as the WBC, platelets, as well as the slide artifacts. The other stained objects may result into various kinds of implications during the process of analysis of the results through the use of the manual microscope.

In the whole world, with the ever increasing population, even the risk of individuals who are prone to malaria is also increasing at an alarming rate and every year, there is an increase indeaths which are linked to malaria.

Malaria Parasitemia is always used as the parameter to affirm the quantum of parasites in the blood of the patients and besides, it is also considered to be one of the main indicators of the levels of infection of malariain the body of the human beings. Manual process of assessing thin blood smears through the use of the microscope is highly tedious and at the same time, it generally consumes a lot of time. Besides, it is associated with so many errors. Although the automated assessments are capable of effectively addressing some of these limitations, the in ability in terms of assessing cases which are different from the standard model have turned out to be a huge challenge.

Althougha microscope malaria parasite is always detected in the blood slides, detection, as well as the recognition of plasmodium is always possible by the staining method (Giemsa), and this is a chemical process. It highlights the life treating plasmodium parasites, WBC, and the RBCs.

a) Microscopic Image Processing

Microscopic images are always employed in molecular biology, as well as in medical domain. Because the image modalities are diverse, several issues always arise after the first data acquisition stage. In this report, numerous algorithms have been reviewed so as to observe the existing solutions besides proposing highly essential pipeline of microscopic image storage or compression and the ones which may be assessed in a manner that is highly efficient.

II. Nomenclature of the Erythrocyte Features

Erythrocyte refers to the cell which is always observed in the blood, which is having a life of approximately 120 days. Analysis of the microscopic image of the blood cells are carried out in order to diagnose different diseases such as cancer and malaria among others [1]. Using the size, texture, as well as the color, the various differences between the abnormal and the normal erythrocyte can easily be noted. During the normal conditions, the mature erythrocytes are always round, biconcave disc-shaped and at the same time, the diameter of the nuclear cell is about 7-8 microns. In addition, it is worth pointing out that the erythrocytes which are normal are always termed as normocytic while the ones which comprises malarial infection have changes in their features as indicated in Fig.1

(a) The normal Erythrocyte

(b) The infected Erythrocyte

Figure 1: Infected and Normal Erythrocytes

a) Feature extraction from Microscopic Blood Smear Images

Feature extraction refers to the approach that entails the evaluation of the different kinds of images for the identification of objects or the regions of interest and analyzing tissues in pathology slides for structure as well as for other kinds of features. In order to make sure that the right features are used in the process of analysis, highly appropriate selection of subgroup is vital for improving the levels of accuracy of classification as well as for the minimization of any type of complexities. In order to distinguish the non-infected and the infected erythrocytes, different features can be adopted from a

wide array, and computation of fresh variables can be conducted.

Feature sets as indicated above are comprising factors that are aimed at distinguishing variance for class and in class of feature vector space, i.e. differentiating the classes by various features. Texture features, morphological features, as well as intensity features are some example of the set of features that are highly resourceful in distinguishing between the non-infected and the infected erythrocytes.

The morphological features are signifying the shape and the size of erythrocyte without considering the density, and strongly in the case of P.Ovaleand P.Vivaxinfections, the erythrocytes are enlarged. However, erythrocyte generally remains the same in the case of the P.falciparum. several factors such as the perimeter, area, compactness ratio, eccentricity, minor axis of best fit ellipse, major axis of best fit ellipse, bending energy, as well as roundness ratio [2] some of the features which are highly significant with the Morphological features. It is also worth pointing out that spatial distribution of intensity within a given range is offered by texture features exploration. Gray level co-occurrence matrix (GLCM) is an integral element of intensity, as well as texture features, saturation histogram, local binary pattern, laplacian and the gradient textures [3] [4] [5].

It is also worth pointing out that researchers have laid much emphasis on several features for the classification of the non-infected and the infected erythrocyte. F.BorayTek et.al has employed the feature set which comprises are agranuometry, color histogram, relative shape measurements, and auto-correlogram for the diagnosis of malaria parasite infection in the erythrocyte [4]. As [5] indicates, in order to detect erythrocyte observation, the technique of automated image processing have been proposed.

[6] Proposessemi-automated technique for the quantification, as well as for the classification of the malaria infected erythrocytes. Some of the main features which have been used in the model include gray scale histogram, sobel histogram, saturation level histogram, as well as the gray scale histogram.

Spirngl et.al proposes the mode of automatic malaria diagnosis through the use of microscopic imaging process. The main key features which have been chosen in the model include Hu set of invariant moment, flat texture, intensity histogram, gradient features, run-length matrix, and co-occurrence matrix for the classification of theerythrocytes [7].

In [8] Perimeter area, as well as the form factor are employed in digital analysis of the changes by the plasmodium vivax. They are followed by [9] content based retrieval technique which depends on features such as Hu moment and intensity histogram as the major features have been proposed.

Color and the statistical features are comprising the perimeter, the area, the grey scale histogram, metric and saturation histogram are majorly employed in [10] for the detection of malaria. In [11] the researchers employed various feature sets such as the nuclear density and Nucleon cytoplasmic ratio in detecting the stages of malaria parasite in a manner that is automated. In [12], the quantum of pixels which comprises of chromatin dot stain and standard deviation linked to value channel of the HSV representation for every ROI, are chosen as the main features during the classification of the erythrocytes which are infected by malaria. In [13], researchers have laid much emphasis on the development of web based frame work for classification on the basis of texture, as well as automated storage of the malaria parasite images through the use of some features such as run length matrix, fractal dimension, local binary pattern, as well as gray level co-occurrence matrix.

Features such as color auto-correlogram, color histogram, Hu moment, and relative shape measurement which depends on Mobile support for the Diagnosis of Communicable Diseases within the Remote Locations have been proposed by [14]. [15] Proposesimage analysis system which is dependent on feature sets such as color attributes, gray level texture, as well as geometric features to ensure the automatic detection and automatic classification.

[16] Proposes multi-scale laplacian of Gaussian and Gabor filter based technique. At the same time, the process of quantitative characterization for plasmodium vivax in infected erythrocytes has generally been proposed in [17].

[18] Proposes automatic screening of the malaria parasite based on machine learning which comprises 96 features which generally includes gray level run length matrix, fractal dimension, entropy, heraldic texture, histogram based features, and several other such features sets.

Malaria Parasite Detection in the Giemsa-Stained Blood Cell images which rely on features have been proposed by [19]. [20] proposes morphological features based diagnosis of malaria infections while in [21], the researchers proposed a highly effective technique for ensuring automatic classification of vivid blood diseases through the use of the digital image processing methods. In it, histogram based features for different color channels such as the intensity, hue, as well as saturation are employed in the identification of the erythrocytes, which are normal and the ones which have been infected. [22] Proposes that automatic detection of the malaria parasite can be carried out through the usage of histogram of color channel, as well as fractal dimension. Symptom analysis of malaria disease can be done through the use of histogram, as well as through the use of image processing features as [23] proposes. [24] Proposed morphological feature, as

well as textural features based solution for ensuring rapid diagnosis of malaria.

At the same time, it is worth pointing out that diagnosis of malaria over the thin blood smears was proposed where features such as energy, standard deviation, phase of image, skewness, and energy among others are employed. [25].

[26] Also proposed the technique of computer vision screening of the plasmodium falciparum candidate areas in blood smears. Feature sets such as scale invariant feature transformation and local binary pattern rotation invariant local contrast are employed during the process of analysis. Automatic characterization based analysis of the microscopic images of the thin blood smears have also been proposed which comprises about 16 morphological features, as well as 80 texture feature sets.

III. Review of Learning Based Malaria Detection Strategies

Makkapati and Rao [27] supports segmentation of HSV color space in which Red Blood Cells, WBCs, as well as Parasites are color space segmented besides the estimation of the optimal saturation thresholds. The process is associated with 83 percent sensitivity, and at the same time, it always operates in HSV space. However, it has a challenge which generally includes the fact that it is only capable of detecting the optimal threshold but is not capable of determining any type of global or local threshold. At the same time, it is worth pointing out that the solution generally reflects on color image processing methods.

Ravi raja and et.al [28] proposed the techniques of blood image processing for the detection of malarial parasites which comprises infected erythrocytes after the use of statistical based approach for classification. A wide array of information such as the color of the infected blood, shape and size are always used in the process of the analysis. When the images are compared to infected images, the process of image transformation is conducted through the use of shaping and scaling, for the reconstruction of the image.

Ruberto et.al [29] introduced the Morphological approach technique where segmentation of the cell images are highly accurate in comparison to the traditional watershed based algorithm. The non-flat disk-shape structuring components are adapted so as to enhance the level of accuracy of the normal watershed oriented algorithm and this has made the performance to be highly effective. The use of such kind of methods has brought about better understanding of the structure of the RBC structure, in the existing watershed based algorithm.

Sadeghian et.al [30] has generally illustrated a framework, where digital image processing is employed in the segmentation of the white blood cells. The gray level image processing is employed in order to classify it into two parts: one as morphological analysis based nucleus segmentation while the other one as cytoplasm segmentation depending on thresholding of pixel intensity. [27] Offers a discussion of the various kinds of processes which depends on RGB color space which segments the RBC's, as well as malarial parasites. In this solution's experiments, images are taken from Leishman-stained blood smears. 83 percent of sensitivity has also been observed in this model.

[28] Proposes automated image analysis based solution. This process is founded on detection of parasite boundaries, as well as edge detection for representing cell. Stages such as pre-processing, edge linking, edge detection, as well as clump split are employed in order to ensure effective processing of the proposed solution.

[31]Proposes the use of solution of digital images through the use of microscopic slides. For training sets, feed forward back propagation neural network has been employed. 64 X 64 pixel images are employed in order to train the data set, as well as segmentation into digital image.

Chen Pan et.al [32] proposed Image retrieval based solution. Its classifying cell of image is comprising high image databases. Two kinds of histogram are employed during the process. Kernel Principal Component Analysis (KPCA) is employed in order to extract highly effective features from feature vector.

In [33], the researcher proposes techniques of automatic detection, as well as classification of the MCCs. The technique of block region growing, as well as that of k-means clustering is used for the extraction of the region. Accordingly, the blanket technique is employed during the identification of the MMCs clusters. The solution has gained 95 percent high classification and about 93 percent detection rate.

Amit and P U [34] introduced the segmentation of the infected cells in blood smear images which comprises adoptive threshold that is carried out through the application of Otsu algorithm, and it is capable of generating better result in comparison to the averaging technique.

Rapid Diagnostic Tests (RDTs)as [35] points out are employed in immune chromatographic techniques for the detection of the antigens which are derived from malaria in the lyses blood. Tests like that are presently used in detecting Histidinerich protein II, as well as Parasite lactate dehydrogenizes (pLDH). [36] Points out that Histidinerich protein II is always produced by the trophozoites, as well as by the young gametocytes of P.

Quantitative Buffy Coat (QBC) speed was proposed by [35] for the detection of malarial parasites and it is having definitive advantage in laboratories. It is comprising several samples. It is often noted that there

is barely any loss of the parasites as a result of the usage of the procedure. [36] Lays much focus on the advantage of the QBC model. Technicians are capable of carrying out QBC test besides detecting malaria parasite in a less than one day. On the contrary, the constraints include the comparatively higher costs of carrying out the given model, as well as the scope of leak or the breakage of the blood filled QBC tubes. In addition, the lack of scope for the management of the permanent record of the test is the other major disadvantage which is associated with the given model [37].

In addition, it is worth pointing out that QBC techniques generally reflect very high levels of sensitivity and specificity during the tests which are being carried out in the laboratory in comparison to the field level tests when compared to the blood smears technique. Otsu algorithm approach is highly effective in comparison to the other kinds of models, and the main advantage of this algorithm is the fact that despite the numerous evaluations, less time is always consumed when it is employed. Among every data science strategy which is considered for carrying out the feature sets, computer vision of the microscopic images provides better quality outcome. This reviews points out that there is huge scope for enhancing the feature optimization strategies for the diagnosis of the disease through the application of data science strategies on computer vision of the microscopic images.

IV. Conclusion

This report has mainly reviewed various data science strategies such as mining, machine learning, heuristic, as well as statistical approaches which are used over microscopic image features such as the local binary patterns, texture, as well as morphological features, for the achievement of disease prediction during the early stages. Focus has been more on comprehending the scope, as well as the implications envisaged in the computer vision of the microscopic image analysis which ought to be capable of observing the Parasitemia counts within sub-standard smears. The review has provided some of the main limitations such as the lack of optimal feature set optimization techniques. The report also notes that accuracy of the search strategies are often observed in the existing techniques which are provided by the contemporary literature. The report has also reviewed some of the highly suitable description features which constitutes discriminative properties for the classification of blood smears as erythrocytes, as well as parasite infected erythrocytes. According to the report, highly efficient features have to be used for the analysis aimed at improving the process outcome. The key areas such as the feature extracting techniques, image research, as well as classification strategies are highly significant and should be taken into consideration when carrying out future research.

References Références Referencias

1. Castellot, Jaime García, and Jaime Lazcano Bello. "ADT-3D Tumor Detection Assistant in 3D." International Journal of Interactive Multimedia and Artificial Intelligence 1, no. 1 (2008).
2. Di Ruberto, Cecilia, Andrew Dempster, Shahid Khan, and Bill Jarra. "Morphological image processing for evaluating malaria disease." In Visual Form 2001, pp. 739-748. Springer, Berlin, Heidelberg, 2001.
3. Tek, F. Boray, Andrew G. Dempster, and Izzet Kale. "Malaria Parasite Detection in Peripheral Blood Images." In BMVC, pp. 347-356. 2006.
4. Tek, F. Boray, Andrew G. Dempster, and Izzet Kale. "Parasite detection and identification for automated thin blood film malaria diagnosis." Computer vision and image understanding 114, no. 1 (2010): 21-32.
5. Ross, Nicholas E., Charles J. Pritchard, David M. Rubin, and Adriano G. Duse. "Automated image processing method for the diagnosis and classification of malaria on thin blood smears." Medical and Biological Engineering and Computing 44, no. 5 (2006): 427-436.
6. Díaz, Gloria, Fabio A. González, and Eduardo Romero. "A semi-automatic method for quantification and classification of erythrocytes infected with malaria parasites in microscopic images." Journal of Biomedical Informatics 42, no. 2 (2009): 296-307.
7. Špringl, Vít. "Automatic malaria diagnosis through microscopy imaging." FACULTY OF ELECTRICAL ENGINEERING (2009): 128.
8. Edison, Maombi, J. B. Jeeva, and Megha Singh. "Digital analysis of changes by Plasmodium vivax malaria in erythrocytes." (2011).
9. Khan, Mohammad Imroze, Bhibhudendra Acharya, Bikesh Kumar Singh, and Jigyasa Soni. "Content based image retrieval approaches for detection of malarial parasite in blood images." International Journal of Biometrics and Bioinformatics (IJBB) 5, no. 2 (2011): 97.
10. Savkare, S. S., and S. P. Narote. "Automatic detection of malaria parasites for estimating parasitemia." International Journal of Computer Science and Security (IJCSS) 5, no. 3 (2011): 310.
11. Kumarasamy, Saravana Kumar, S. H. Ong, and Kevin SW Tan. "Robust contour reconstruction of red blood cells and parasites in the automated identification of the stages of malarial infection." Machine Vision and Applications 22, no. 3 (2011): 461-469.

12. Prasad, Keerthana, Jan Winter, Udayakrishna M. Bhat, Raviraja V. Acharya, and Gopalakrishna K. Prabhu. "Image analysis approach for development of a decision support system for detection of malaria parasites in thin blood smear images." Journal of digital imaging 25, no. 4 (2012): 542-549.
13. Maity, Maitreya, Ashok K. Maity, Pranab K. Dutta, and Chandan Chakraborty. "A web-accessible framework for automated storage with compression and textural classification of malaria parasite images." International Journal of Computer Applications 52, no. 15 (2012).
14. Cesario, Manuel, Michael Lundon, Saturnino Luz, Masood Masoodian, and Bill Rogers. "Mobile support for diagnosis of communicable diseases in remote locations." In Proceedings of the 13th International Conference of the NZ Chapter of the ACM's Special Interest Group on Human-Computer Interaction, pp. 25-28. ACM, 2012.
15. Ahirwar, Neetu, Sapnojit Pattnaik, and Bibhudendra Acharya. "Advanced image analysis based system for automatic detection and classification of malarial parasite in blood images." International Journal of Information Technology and Knowledge Management 5, no. 1 (2012): 59-64.
16. Suryawanshi, Ms Snehal, and V. V. Dixit. "Improved technique for detection of malaria parasites within the blood cell images." Int. J. Scientific & EnggResrch 4, no. 7 (2013).
17. Ghosh, Madhumala, Devkumar Das, Chandan Chakraborty, and Ajoy Kumar Ray. "Quantitative characterisation of Plasmodium vivax in infected erythrocytes: a textural approach." International Journal of Artificial Intelligence and Soft Computing 3, no. 3 (2013): 203-221.
18. Das, Dev Kumar, Madhumala Ghosh, Mallika Pal, Asok K. Maiti, and ChandanChakraborty. "Machine learning approach for automated screening of malaria parasite using light microscopic images." Micron 45 (2013): 97-106.
19. Malihi, Leila, Karim Ansari-Asl, and AbdolamirBehbahani. "Malaria parasite detection in giemsa-stained blood cell images." In Machine Vision and Image Processing (MVIP), 2013 8th Iranian Conference on, pp. 360-365. IEEE, 2013.
20. Vink, J. P., M. Laubscher, R. Vlutters, KamolratSilamut, R. J. Maude, M. U. Hasan, and G. Haan. "An automatic vision-based malaria diagnosis system." Journal of microscopy 250, no. 3 (2013): 166-178.
21. Nithyaa, A. N., R. Premkumar, D. Kanchana, and Nalini A. Krishnan. "Automated detection and classification of blood diseases." In Recent Advancements in System Modelling Applications, pp. 393-404. Springer, India, 2013.
22. Chayadevi, M. L., and G. T. Raju. "Usage of art for automatic malaria parasite identification based on fractal features." (2014).
23. Chavan, Sneha Narayan, and Ashok Manikchand Sutkar. "Malaria disease identification and analysis using image processing." Int. J. Latest Trends Eng. Technol 3 (2014): 218-223.
24. Memeu, Daniel Maitethia. "A rapid malaria diagnostic method based on automatic detection and classification of plasmodium parasites in stained thin blood smear images." Dep. Physics, University of Nairobi (2014).
25. Annaldas, S., S. S. Shirgan, and V. R. Marathe. "Automatic identification of malaria parasites using image processing." International Journal of Emerging Engineering Research and Technology 2, no. 4 (2014): 107-12.
26. Linder, Nina, RikuTurkki, Margarita Walliander, Andreas Mårtensson, Vinod Diwan, Esa Rahtu, MattiPietikäinen, Mikael Lundin, and Johan Lundin. "A malaria diagnostic tool based on computer vision screening and visualization of Plasmodium falciparum candidate areas in digitized blood smears." PLoS One 9, no. 8 (2014): e104855.
27. Makkapati, Vishnu V., and Raghuveer M. Rao. "Segmentation of malaria parasites in peripheral blood smear images." In Acoustics, Speech and Signal Processing, 2009. ICASSP 2009. IEEE International Conference on, pp. 1361-1364. IEEE, 2009.
28. Raviraja, S., Gaurav Bajpai, and Sudhir Kumar Sharma. "Analysis of detecting the malarial parasite infected blood images using statistical based approach." In 3rd Kuala Lumpur International Conference on Biomedical Engineering 2006, pp. 502-505. Springer Berlin Heidelberg, 2007.
29. Di Rubeto, C., Andrew Dempster, Shahid Khan, and Bill Jarra. "Segmentation of blood images using morphological operators." In Pattern Recognition, 2000. Proceedings. 15th International Conference on, vol. 3, pp. 397-400. IEEE, 2000.
30. Sadeghian, Farnoosh, ZaininaSeman, Abdul Rahman Ramli, BadrulHisham Abdul Kahar, and M-Iqbal Saripan. "A framework for white blood cell segmentation in microscopic blood images using digital image processing." Biological procedures online 11, no. 1 (2009): 196.
31. Premaratne, Sobath Pradeepa, Nadira Dharshani Karunaweera, Shyam Fernando, W. Supun R. Perera, and R. P. A. Rajapaksha. "A neural network architecture for automated recognition of intracellular malaria parasites in stained blood films." In Proceedings of APAMI & CJKMI-KOSMI Conference. 2003.
32. Pan, Chen, Xiangguo Yan, and Chongxun Zheng. "Recognition of blood and bone marrow cells

using kernel-based image retrieval." International Journal of computer Science and Network security 6 (2006): 29-35.

33. Lee, San-Kan, Chien-Shun Lo, Chuin-Mu Wang, Pau-Choo Chung, Chein-I. Chang, Ching-Wen Yang, and Pi-Chang Hsu. "A computer-aided design mammography screening system for detection and classification of microcalcifications." International journal of medical informatics 60, no. 1 (2000): 29-57.
34. Kumar, Amit, A. Choudhary, P. U. Tembhare, and C. R. Pote. "Enhanced identification of malarial infected objects using otsu algorithm from thin smear digital images." International Journal of Latest Research in Science and Technology ISSN (Online) (2012): 2278-5299.
35. Howard, Russell J., ShigehikoUni, Masamichi Aikawa, Stephen B. Aley, James H. Leech, Andrew M. Lew, Thomas E. Wellems, Joan Rener, and Diane W. Taylor. "Secretion of a malarial histidine-rich protein (Pf HRP II) from Plasmodium falciparum-infected erythrocytes." The Journal of cell biology 103, no. 4 (1986): 1269-1277.
36. Malmberg, Vetle Nilsen, Marte Langsrud, and Stine Haram. "Malaria in Malawi. The current status of diagnosis, prophylaxis and treatment of malaria in Malawi, how international and national guidelines can improve the situation, and how research can change these guidelines for the future." Master's thesis, UniversitetetiTromsø, 2013.
37. Salmani, Manjunath P., Preeti B. Mindolli, and Basavaraj V. Peerapur. "Comparative study of peripheral blood smear, QBC and antigen detection in malaria diagnosis." Journal of clinical and diagnostic research 5, no. 5 (2011): 967-969.

This page is intentionally left blank