A Novel Approach for the Detection of Malaria Parasites and Measure its Severity Using Image Processing and Fuzzy Logic

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ABSTRACT:This paper investigates automated detection and measurement of degree of severity of malaria parasites in microscopic images of Giemsa stained thin blood film specimens. The focused of this study mainly about detection of malaria parasites which is present in Human RBCs and determine the several stages of parasites according to their severity. An efficient algorithm has been proposed which can extract the affected RBC cells from the microscopic image of stained blood and also could count the number of parasites present in that image. This algorithm deals with two important fields, first, one is image processing followed by fuzzy inference system (FIS). This segmentation based method finds the area of the affected cell which used as one of the fuzzy input to the fuzzy inference system. The other two inputs to the fuzzy inference system are corner points and no. of detected parasites which are obtained from connected component analysis and Corner detection algorithm respectively. Using these three inputs, FIS can determine the several stages of malaria parasite according to their degree of severity.

KEYWORDS: Malaria Parasites, RBC cell, Fuzzy Inference System, Segmentation, Connected Component Analysis, Corner Detection.

I.INTRODUCTION

Malaria can be a severe disease if not detected in proper time.Sometimes it becomes an epidemic in Middle East, Africa and some part of Asia also. A child dies of malaria in every 30sec in somewhere around the world [1]. Although in recent years medical science has been advanced a lot but still when it comes to malaria, pathologists use same old blood staining process that eventually requires skillful lab technician. But due to lack of efficient analyst diagnosis of malaria often leads to false positive cases. There is mainly four types of malaria parasites- (a*) Plasmodium viva*x, (b) *Plasmodium falciparum, (c) Plasmodium ovale, (d) Plasmodium malariae.*This paper deals with only first two types of malaria parasites as *P.falciparum* and *P.vivax* are the most common types.Diagnosis of malaria requires two essential tasks:

    1. Determine the presence (or absence) of malarial parasite in the examined blood specimen.
2.Identify the life-cycle-stages of the detected parasites.

Positive detection of malaria parasites from stained blood film is the most important task. Giemsa staining process changes the color of affected RBC cells from red to blue but sometimes it also changes the color of WBC cells and turned them into blue one [2]. So for the lab technician, it's become quite difficult to correctly identify the real affected cells. Hence, the prime objective of this paper is to avoid false diagnosis and determine the only parasite affected RBC cells.Identification of life-cycle-stages is important for correctly evaluating theparasitemia (degree of infection, i.e. infected/uninfected cell ratio)and also for clinical research where the malarial parasite developmentor response with respect to a treatment/-drug must be observedor quantified.In this digital microscopic image analysis system an algorithm has been proposed where we can just feed the image of affected RBC cells into the system and detect the parasites. As this method is fully run by software (Matlab), so it can avoid human error due to stress and could also save time.

II.METHODOLOGY

This paper isthe most comprehensive work up-to-date from a computer visionperspective addressing all the required essential tasks for thediagnosis. Two main contributions of this study must be highlighted:

1. This algorithm uses a novel method to differentiate parasites from non-parasites. We use adaptive thresholding technique to extract affected RBC cells from the healthy one. This adaptive thresholding method adjusts its threshold level according to the variation of the intensity level of different microscopic images.

2. We compare three different classification schemes for identification and then conclude that the detection, species and lifecycle-stage identification tasks can be performed successfullyby a single multi-class classification. This particular work of ours uses Fuzzy Inference System (FIS) to classify the several stages of malaria parasites according to their severity.

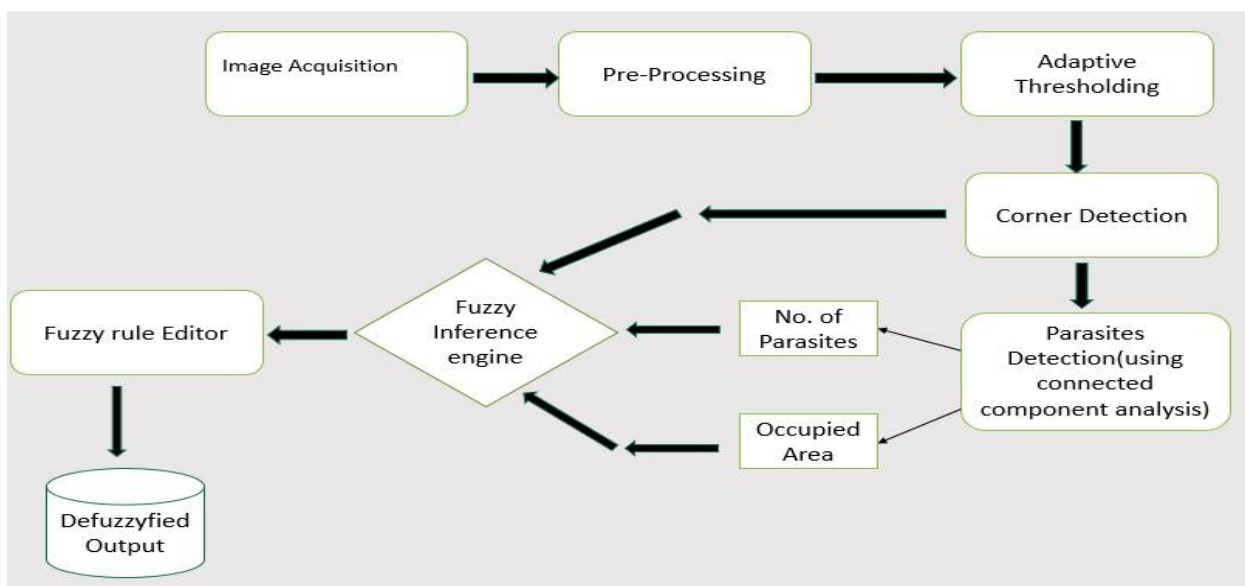The block diagram representation of this entire scheme is shown below-

Fig. 1 Block Diagram representation of the proposed method

The above block diagram indicates that first we have to collect data i.e. microscopic images of malaria affected blood cell. Then it converts that 3-D image (RGB) into 2-D (Gray level) image for pre-processing. In pre-processing the noise present in the gray scale image has to be removed with the help of Gaussian filter, after that the contrast of the image has been enhanced using adaptive histogram equalization. Later the segmentation of the image has been done by applying adaptive thresholding [3]. This process extracts the affected cell from the background of the image. Then Harris corner detection algorithm is applied to determine the corner points present in detected parasites. Finally, the connected component [4] present in the image is determined by using region selection method to count the parasites.

III.STEPS OF PROPOSED ALGORITHM

This algorithm involves four major fields of digital image processing, namely they are (a) Pre Processing (b) Segmentation (c) Corner Detection (d) Region selection. Apart from image processing this algorithm also involves Fuzzy Inference System. The detailing of these fields is described below.

A. Image acquisition

Any system needs input, and so does ours. We have collected the images of malaria parasites of the type *P.falciparum* and P.vivax from the website of Public health library, USA [5].These images only contain ring trophozoites and schizonts stages.

B. *Pre Processing*

Pre-processing is the necessary criteria to process an image. The collected images have different contrasts and sizes. So to process all these several images under the same operating condition it must be equalized. Conversion of the RGB or color image to gray scale image takes place first for further processing.

Filtering is done to remove the noise from the image. Here Gaussian low pass filter is used to mitigate the unwanted frequency present in the image. It is one kind of spatial filter which works on the frequency domain and directly operates on the intensity values of the image. A Gaussian filter with a mask of size $m \times n$, acting upon an image f of size $M \times N$ can be given by -

$$g(x,y) = \sum_{s=-p}^{p} \sum_{t=-q}^{q} w(s,t) f(x + s, y + t) \qquad (1)$$

Where w is the masking coefficient. To developed a fully filtered image, the above equation must be applied to $x = 0,1,\ldots,M-1$ and $y = 0,1,\ldots,N-1$, where $p = (m-1)/2$ and $q = (n-1)/2$ [6].

After convolving the Gaussian mask with an original image we obtain a brighter and smooth image. So, the intensity values of the objects (parasites) become higher compared to the background. Hence, the segmentation becomes easier. The final step of preprocessing is histogram equalization. This operation is done to achieve higher contrast. It distributes the pixels values over the entire range. This method is very useful when the difference between the intensity values of background and object is very close. Sometime the use of histogram equalization increases the noise within the image. Hence, to discard this problem a process known as adaptive histogram equalization is used [7]. This method computes various histogram and each corresponds to a particular segment of the image which eventually redistributed those histogram values over the entire image.

C. *Segmentation*

Segmentation is the most vital step in this algorithm. In this part, the system differentiates the parasite affected RBC cells from others healthy RBC cells. Thresholding is the most common tool for segmentation procedure. By selecting a suitable threshold value T, we can convert a gray scale image to binary form. Typically the threshold can be defined as-

$$T = [x, y, p(x, y), f(x, y)] \qquad (2)$$

Where, T is the threshold function.
x, y are the coordinates of threshold value point.
$p(x, y)$ are some local property of pixel (x, y).
$f(x, y)$ is the gray level pixel of the image.

Very common way to segment an image is to select a single threshold value T, then all the gray level pixels having the value greater than T will be treated as white (1) or object pixel and rest of the pixels classified as black (0) or belongs to background [7]. It can be shown as-

$$g(x,y) = 1 \quad if \ f(x,y) > T \qquad (3)$$
$$= 0 \quad if \ f(x,y) \leq T$$

An effective way to select a threshold value is by analyzing the histogram of the image. In this algorithm choosing the threshold value is tough by observing the histogram plot as it does not contain any certain valley. Global thresholding [8] is also not helpful as these microscopic images show very less margin between the object pixel and background pixel. So, the system applied adaptive thresholding method where it finds the mean and standard deviation of the image and combined them into a single formula and then compare this with each pixel value of the image. If the pixel value of the image is greater than this particular value then the pixel belongs to the object otherwise it treated as background. So, the value of threshold changes with image intensities and adapts to the local characteristics of each image. This proposed method works well on all input images.

D. Corner Detection

Corner points are interesting as they are formed from two or more edges and edges usually define the boundary between two different objects or parts of the same object.The use of interest points (and thus corner detectors) to find corresponding points acrossmultiple images is a key step in many image processing and computer visionapplications. There are some corner detectors available which have been proposed by several researchers. These detectors are mainly divided into two main category: Contour based and Intensity based. This particular work of ours used an intensity based corner detector known as Harris corner detector. This Harris corner detection method calculates the gradient at each pixel [9]. If the gradient values in two different directions are maximum then we denote that pixel as a corner. Harris corner detection algorithm follows as:

$$R = \det(P) - k\,tr^2(P) \tag{4}$$

$$P(x,y) = \begin{bmatrix} I_u^2(x,y) & I_{uv}(x,y) \\ I_{uv}(x,y) & I_v^2(x,y) \end{bmatrix} \tag{5}$$

$$I_u^2(x,y) = X^2 \otimes g(x,y) \tag{6}$$

$$I_v^2(x,y) = Y^2 \otimes g(x,y) \tag{7}$$

$$I_{uv}(x,y) = XY \otimes g(x,y) \tag{8}$$

$$g(x,y) = \frac{1}{2\pi} * e^{-(x^2+y^2)/2} \tag{9}$$

Where $Iu(x,y)$ and $Iv(x,y)$ are the partial derivatives ofthe gray values in direction u and v at point (x,y), and$Iuv(x,y)$ is the second-order mixed partial derivative; k isan empirical value; $g(x,y)$ is a Gaussian function; X and $Y$are the first-order directional differentials, which can beapproximately calculated by convolving the gray valuesand difference operators in direction u and v. Gaussianfunction is used to reduce the impact of noise, becausefirst-order directional differentials are sensitive to noise.If R exceeds a certain threshold, then take the point as acorner. Here, the Harris corner points are used as one of the major input to fuzzy inference engine in order to determine the correct stage of malaria parasites.

E. Region Selection

Region selection is the method by which the system chose some portion of the image on the basis of some common property [10]. The use of predefined Matlab function 'Regionprops' to determine the properties of connected component turns out very fruitful. This calculates Area, Centroid, Bounding box, ConvexHull, ConvexArea etc. of the binary image. Sometime, by applying regionprops upon grayscale image, we can measure Max Intensity or Min Intensity value pixel [10]. In this piece of work area of each connected segment has been calculated to count the number of parasites present in blood. Furthermore, this calculated area of parasites and the no. of detected parasites is fed to the FIS as other two inputs.

F. Fuzzy logic controller

Fuzzy Logic (*FL)* is a method of reasoning that resembles human reasoning. Fuzzy Logic Systems (*FLS)*produce some definite output in response to ambiguous, distorted, or inaccurate fuzzy input. Fuzzy Logic System contain four main parts: 1) Fuzzyfied input variables, 2) Knowledge Base, 3) Inference Module and 4) Defuzzyfied output variables [11][12].
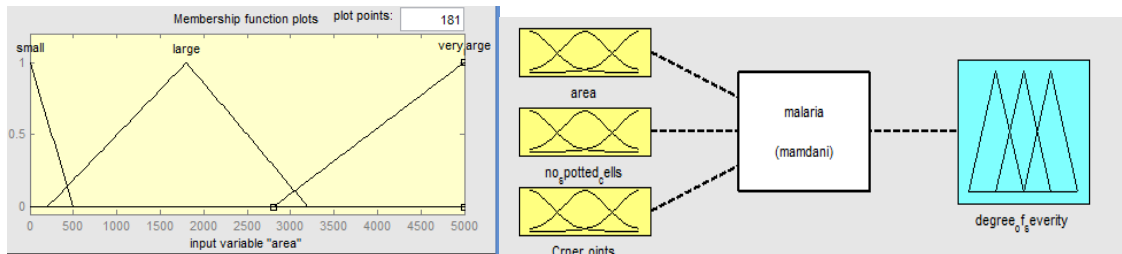
Fig. 2 Membership function plot for input Area   Fig. 3 I/p and O/P variable for FIS

Another important factor of FIS is membership function. It's work upon fuzzy variables. Membership function allows us to quantify linguistic term and projects a fuzzy variable set graphically. The range of the membership function lies between 0 to 1.
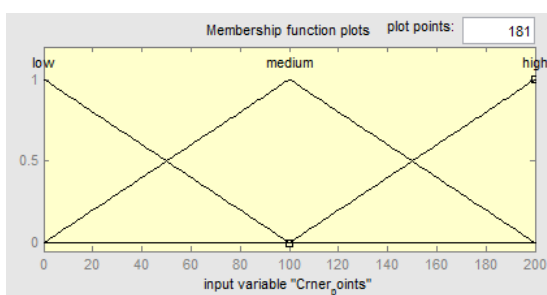

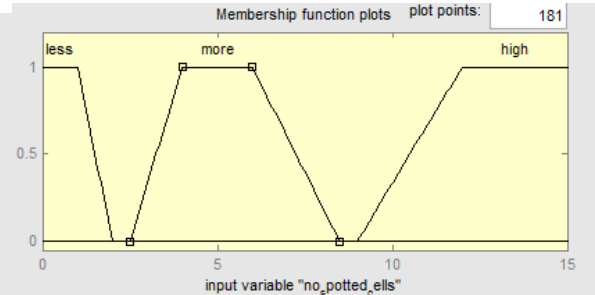Fig. 4 Membership function plot for Detected corner   Fig. 5 Membership function plot for spotted no. of Parasites
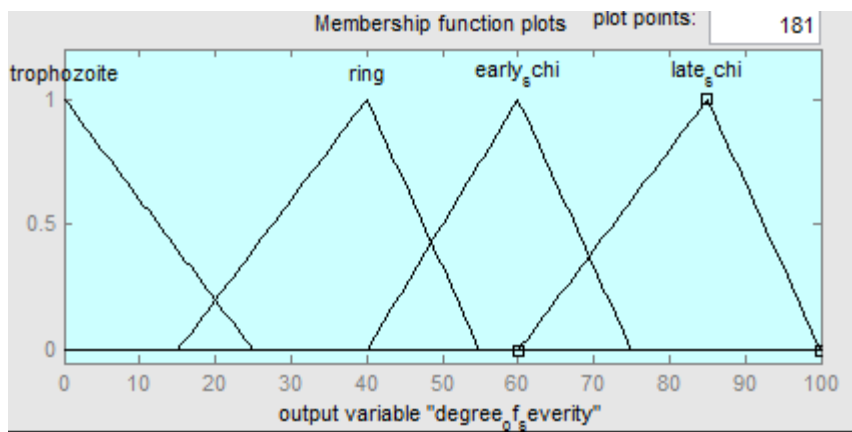

Fig. 6 Membership function plot for Degree of severity of malaria parasites

Fig. 2, Fig. 4 and Fig. 5 represents the membership function for the input variables fed to the FIS system Area occupied by the parasites lies within infected RBC cells, no. of Corner points and No. of detected parasites respectively while Fig. 6 represents the same for the output variable degree of severity of malaria parasites defined to FIS.

III.RESULT AND DISCUSSION

In this study of work an extensive use of MATLAB has been done. All of these results has been obtained by this software. The microscopic images of ring trophozoites and schizonts oftwo different plasmodium parasites *(P.falciparum and P.vivax)* are used as input to the system and by running the proposed algorithm the following results has achieved.

Results set for P.falcipaarum Ring trophozoites
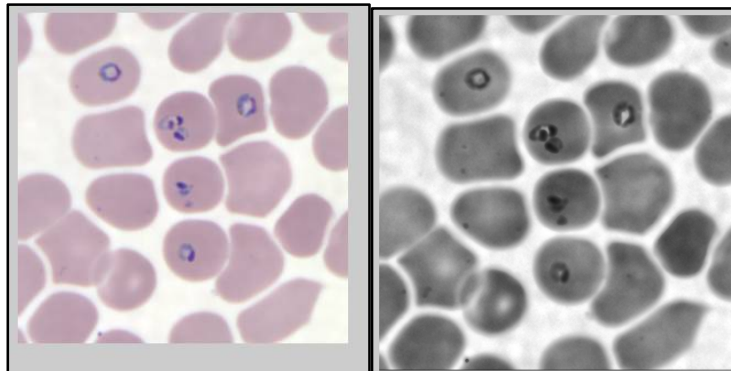

Fig. 7 Original input image   Fig. 8 Histogram equalized image

Fig.7 represents original malaria affected thin blood film microscopic image which is taken from our database as an input to our proposed algorithm. It represent *P.falciparum* ring stage parasites.Fig. 8 is obtained after the final stage of pre- processing i.e. histogram equalization. Histogram equalization has smoothened the gray scale image for the sake of segmentation.
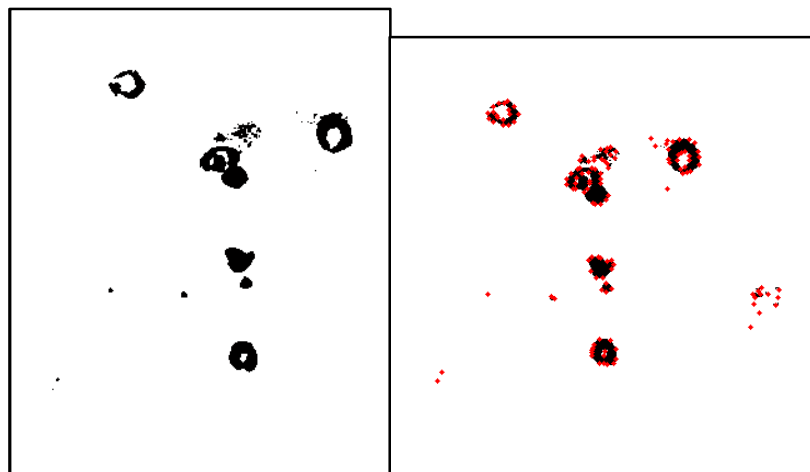

Fig. 9 Image after thresholding operation   Fig. 10 Image after applying corner detection algorithm

After applying the adaptive thresholding technique to the histogram equalized image Fig.9 is obtained which extract the parasites from infected blood cells. Here, adaptive thresholding is used instead of global thresholding to provide a better result.After that the corner detection algorithm is applied to pin point each parasite. Fig.10 and Fig.14 are the corner detected images.

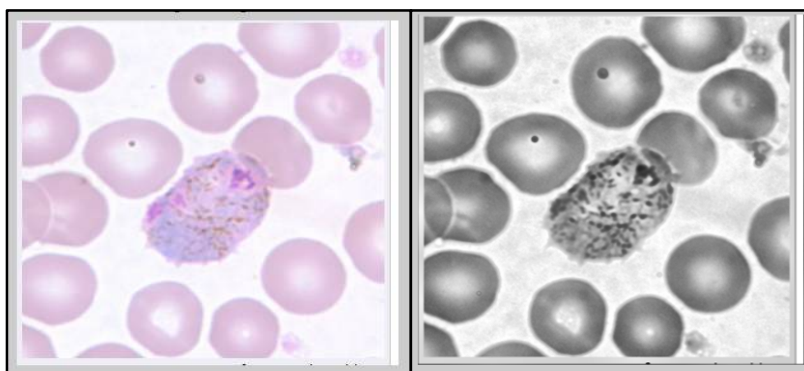**Results set forP.vivaxschizonts stage**

| Fig. 11 Original input image | Fig. 12 Histogram equalized image |

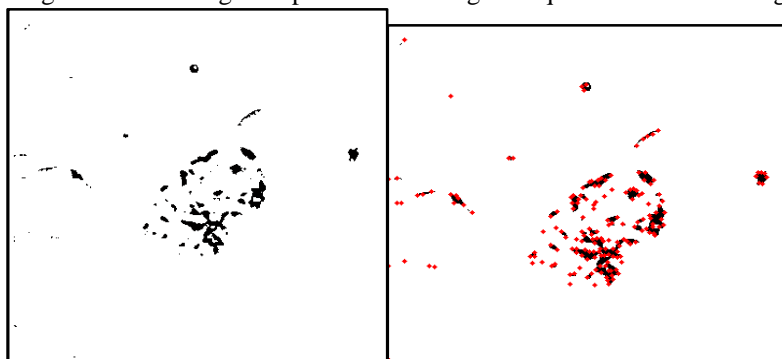Fig.11 shows schizonts stage of P.vivax. Fig.12 represent the histogram equalized version of Fig.11.

Fig. 13 Image after thresholding operationFig. 14 Image after applying corner detection algorithm

In Fig.13 it can be clearly seen that there are plenty of parasites present but segmentation cannot precisely detect that hence we use corner detection. But after corner detection the gametocytes present inside the schizont is clearly countable.

Table 1: Experimental database of some processed images

SL No.	Sample Type	Number of detected Parasites	Total Occupied Area	Number of detected corner points
1.	P.FalciparumTrophozoite Stage	2	471	98
2.	P.Falciparum Ring Stage	7	2869	132
3.	P.Falciparum Ring Stage	4	2648	128
4.	P.Falciparum early Schizont stage	3	3889	167
5.	P.Falciparum mature Schizont stage	12	4476	189

Table 1 shows a part of our experimental data records. It is quite evident from the above table that though early schizont stage is more severe than ring stage but shows less no. of detected parasites. But when we do apply corner detection it detects more corner points in case of schizont than ring stage. Finally fuzzy logic is applied to determine the stages of malaria parasites. We trained FIS with our database then we take some test data which is unfamiliar to FIS to find its accuracy. No. of counted parasites, Area occupied by parasites and corner points are taken as input to FIS. The ranges of input variables are set by observing the results obtained from trained data. After that we fed some test data to FIS and it determines the stage of that parasite with 92% accuracy. Below we have given some of the test results which is obtained from FIS.
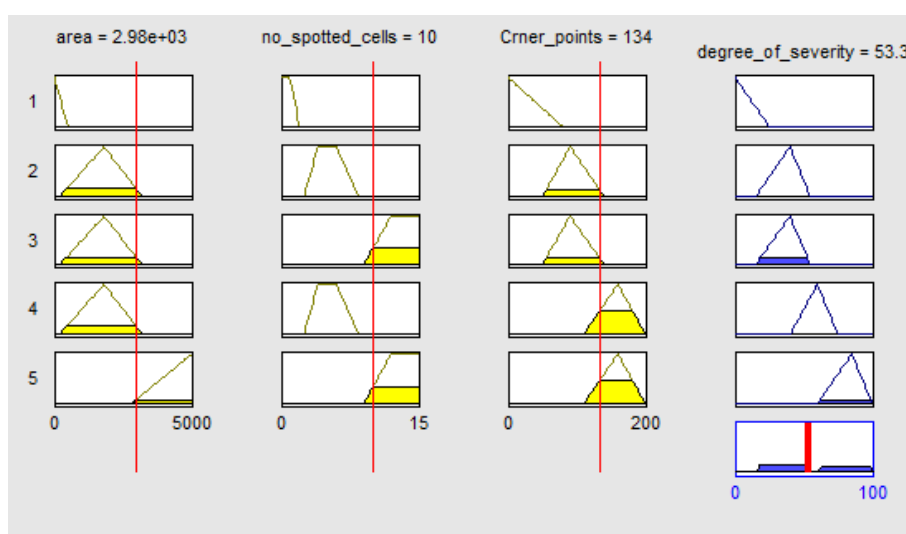

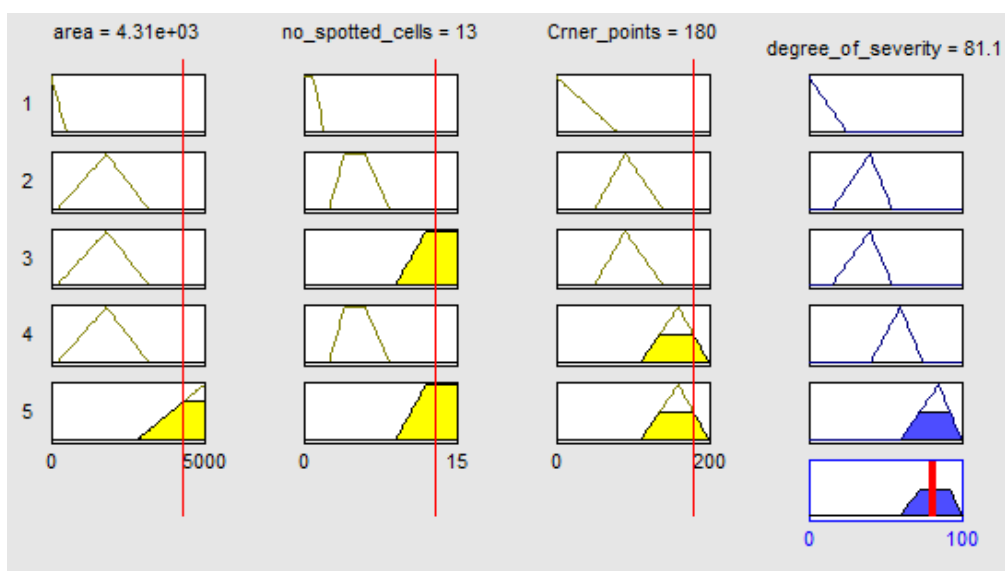Fig. 15 Severity measurement by FIS for Ring trophozoite test sample

Fig. 16 Severity measurement by FIS for Mature Schizont test sample

By observing above two results we can say that Ring trophozoite is less dangerous than mature schizont stage of malaria parasites as the percentage of the severity of ring trophozoite is 53% and that of mature schizont is 81%. So, the results obtained by our proposed FIS model is very much effective in the case of diagnosing malaria.

IV.CONCLUSION

The aim of this work was the development of a semi-automated image analysis system for enumeration of malaria parasite and it has been broadly achieved. The proposed method has been applied to more than 110 test images of two different stages of malaria parasites one of them is trophozoite ring stage and the other is schizont as these two stages are the most deadly. In both the cases, the proposed algorithm delivered a promising result.

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