Analysis of Blood Cells of Malaria Patients using Artificial Neural Network

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Abstract— The global burden of malaria is enormous and the development of better laboratory diagnostic tools is a key step in malaria control recommended by the WHO. Our objective is to develop an automated tool for the recognition of intracellular malaria parasites in stained blood films. We used digital images of oil immersion views from microscopic slides captured though a capture card. They were preprocessed by segmentation and grayscale conversion to reduce their dimensionality and later fed into a feed forward back propagation neural network (NN) for training it. Then a user interface was developed incorporating this trained NN. In the final product, the tool allows a user to view the slide in a graphical user interface. When the user gives a command to analyze, a still image is captured and sent to the NN for recognition after preprocessing. Preliminary results show that the NN can identify carefully selected test data.

Key words: ANI, Neutral Network, Malaria

I. Introduction

Malaria is a public health problem in more than 90 countries, inhabited by a total of some 2.4 billion people, representing about 40% of the world's population. Best estimates currently describe the annual global burden of malaria as: 1.1 million deaths, 300-500 million cases and 44 million disability adjusted life years (DALYs). It has been estimated that the economic burden is also extremely high, accounting for a reduction of 1.3% in the annual economic growth rate of malaria endemic countries, and that the long-term impact in these countries is a reduction of GNP of more than half.

Malaria is caused by the single-celled protozoan parasites of the genus Plasmodium. Four species (P. falciparum, P. vivax, P. ovale, P. malariae) infect humans by entering the bloodstream. Major trends over the last few decades point to a worsening situation if effective action is not taken. In1999 WHO has put forward a control strategy for malaria, which focuses on early detection of cases, development of new tools, strategies and methodologies, and improvement of existing tools through research and development.

Feed forward back propagation Artificial Neural Networks (ANN's) have proven to be a promising paradigm for Intelligent Systems. Neural networks have been trained to perform complex functions in various fields of application including pattern recognition, identification, classification, speech, vision and control systems.

ANN's have the advantage of learning by example and the ability to generalize from their training data to other data. They are fault tolerant in the sense, they can produce correct outputs from noisy and incomplete data. ANN's are relatively inexpensive to build and train. These features of ANN's prompted us to look for a ANN based solution for the malaria parasite detection tool.

The project is planned to be completed in 2 stages. In the first stage it is decided to develop a suitable ANN and train it with a data set to find out the feasibility of using ANN for this project. The second stage is devoted to developing a suitable user interface incorporating the ANN and to create a real-time image acquisition system from the microscope.

II. Problem Statement

To develop an automated tool for the recognition of intracellular Malaria parasites in stained blood films.

III. Objectives

1) Acquisition of image.
2) Preprocessing and segmentation.
3) Feature extraction.
4) Back propagation ANN operation.
5) Detection and classification of the malaria parasite.

IV. Hardware Specifications

A. *Hardware Specifications:*

1) Digital Camera:

1) Effective pixels: 1240*1024
2) USB power suuply: 5V self supply from computer
3) Data transfer: 480 MB/sec
4) Image resolution: 1240*1024
5) Operating System: WINDOWS XP,VISTA

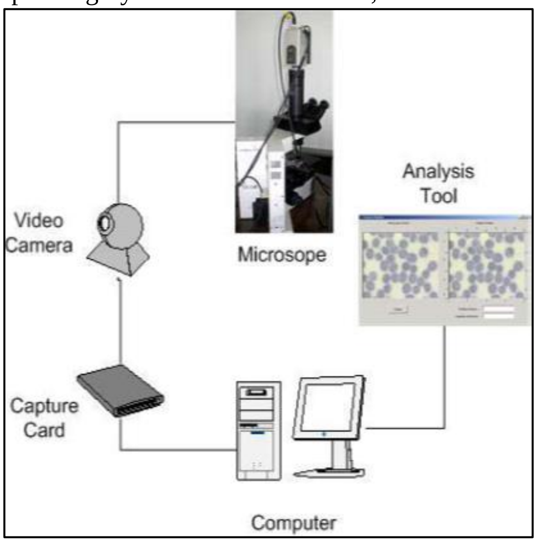

Fig. 1: Hardware Specification diagram

2) Computer:

- SDRAM: 6GB
- Processor: i3-2100
- Integrated HD graphics

B. Software Specifications:

1) Programming in MATLAB
2) Visual Basics (VB) for GUI

V. BLOCK DIAGRAM

A. Image Acquisition:

Images will be captured using a digital camera designed and built-in for the light microscope. However, in this project, we will generate images using relatively high resolution. The slides will be examined under oil immersion in order to adjust the refractory index. Images were saved in the JPEG format.

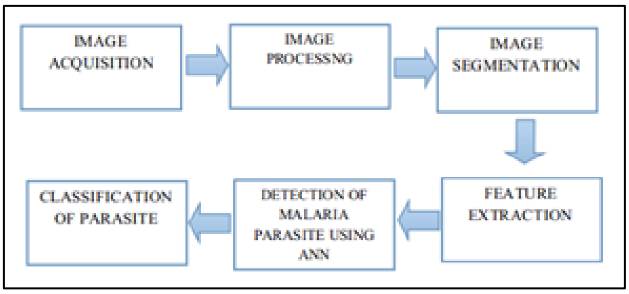

Fig. 2: Block Diagram Description

B. Image Pre-processing and Segmentation:

The pre-processing stage was designed to remove unwanted effects from the image and to adjust the image as necessary for further processing. This stage is comprised of converting the color image to gray-scale, filtering the obtained gray-scale image with median filter, and subjecting each image to contrast stretching.

Segmentation identifies and segments potential parasites and erythrocytes from the background. All foreground objects are separated to extract the infected erythrocytes and further identify the parasites components. To segment foreground from background Global threshold and Otsu threshold is used on grayscale enhanced image. For low contrast image segmentation is applied on enhanced green channel of the image. Result of thresholding on both images is added to get binary image of cells. Using morphological operation cells having larger area is identified which is overlapping of the cells.

C. Feature Extraction:

The features which give predominant difference between normal and infected cells are identified. The selected features are geometrical, color and statistical based. The mathematical morphology provides an approach to the processing of image based on shape. Mathematical morphological operations tend to extract their essential shape characteristics and to eliminate irrelevancies. Mathematical morphology represents the shapes which are manifested on binary or gray tone images. The set of parameters corresponds to the geometrical features are as radius, perimeter, compactness and Area.

D. Parasite detection and classification using ANN:

The images processed by above method are then fed into the feed forward Back Propagation method of ANN that has been trained to recognize the malaria parasites. The ANN will categorize images to two categories, i.e. images with parasites and without parasites. Image segments with malaria parasites are shown by highlighting them on the analysis window. The user is also presented with information such as how many image segments have parasites and their coordinates on the analysis window.

E. Classification of parasite:

As there are four different parasites which cause Malaria we need to classify them. The four parasites are P. falciparum, P. vivax, P. ovale, P. malariae. In this stage we will identify the parasite due to which the disease is caused.

VI. DIFFERENT PARASITES OF MALARIA:

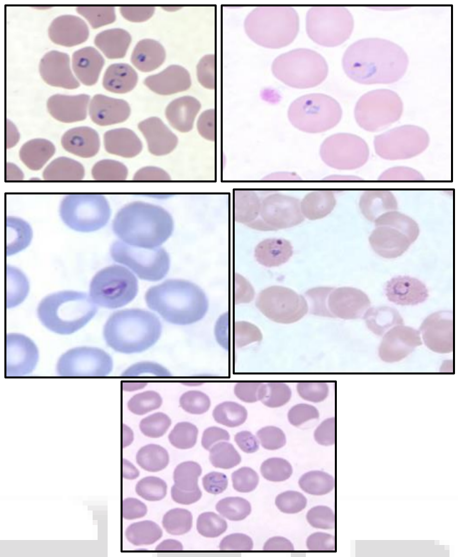

Fig. 3: Ring Forms of P. Falciparum, Ring Forms of P. vivax, Ring Forms of P. Malariae, Ring Forms of P.Ovale, Ring Forms of P. Knowlesi

VII. WORKING

1) Accept input image form the user.
2) Check whether the image is gray scale or RGB this can be do ne by checking the size of image.
3) We need Gray scale image for processing we don't use RGB image for processing since it will take three times more processing time and won't give that good result if sacrificed speed. If input image is gray scale then keep it like that only, if it is RGB then convert it into gray scale image.
4) RGB to Gray scale
   To convert image form RGB to Gray scale use the following formula Luminance = (0.3xRed) + (0.59xGreen) + (0.11xBlue)
5) Next step is to apply pre-processing on the image such as thresholding.

In Otsu's thresholding method we exhaustively search for the threshold that minimizes the intra-class variance, defined as a weighted sum of variances of the two classes:

$$\sigma_w^2(t) = \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t)$$

Weights ω_i are the probabilities of the two classes separated by a threshold t and σ_i^2 variances of these classes.

Otsu shows that minimizing the intra-class variance is the same as maximizing inter-class variance:[2]

$$\sigma_b^2(t) = \sigma^2 - \sigma_w^2(t) = \omega_1(t)\omega_2(t)\left[\mu_1(t) - \mu_2(t)\right]^2$$

which is expressed in terms of class probabilities ω_i and class means μ_i.

The class probability $\omega_1(t)$ is computed from the histogram as t:

$$\omega_1(t) = \Sigma_0^t p(i)$$

while the class mean $\mu_1(t)$ is:

$$\mu_1(t) = \Sigma_0^t p(i) * x(i)$$

Where x(i) is the value at the center of the ith histogram bin. Similarly, you can compute $\omega_2(t)$ and μ_t on the right-hand side of the histogram for bins greater than t.

The class probabilities and class means can be computed iteratively. This idea yields an effective algorithm.

6) Erosion is one of the two basic operators in the area of mathematical morphology, the other being dilation. The basic effect of the operator on a binary image is to erode away the boundaries of regions of foreground pixels (i.e. white pixels, typically).

The mathematical definition of erosion for binary images is as follows:

Suppose that X is the set of Euclidean coordinates corresponding to the input binary image, and that K is the set of coordinates for the structuring element.

Let Kx denote the translation of K so that its origin is at x.

Then the erosion of X by K is simply the set of all points x such that Kx is a subset of X.

7) The processed image is then given to the parasite detection so that the parasite can be detected. The training of the ANN is done using Feed Forward Back Propagation Algorithm.

When the user enters a test image, the trained network compares the sample images and test image and decides whether the test image is infected by Malaria or normal.

VIII. TEST PROCEDURES AND RESULTS

A. *Implementation*

1) *Image Acquisition:*

Images will be captured using a digital camera designed and built-in for the light microscope. However, in this project, we will generate images using relatively high resolution. The slides will be examined under oil immersion in order to adjust the refractory index.

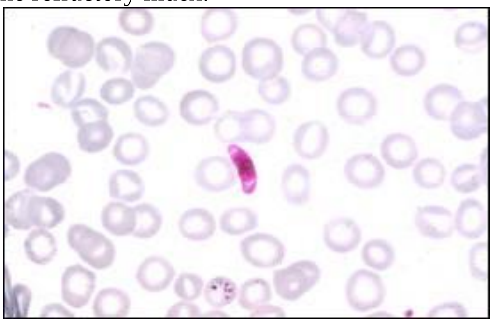

Fig. 4: Input Image

2) *Image Pre-processing:*

The pre-processing stage was designed to remove unwanted effects from the image and to adjust the image as necessary for further processing. This stage is comprised of converting the color image to gray-scale, filtering the obtained gray-scale image with median filter, and subjecting each image to contrast stretching.

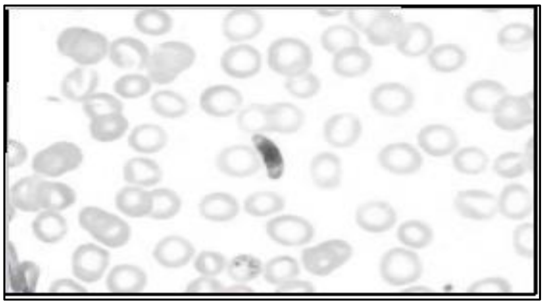

Fig. 5: Output of median filter

3) *Image segmentation:*

Segmentation identifies and segments potential parasites and erythrocytes from the background. All foreground objects are separated to extract the infected erythrocytes and further identify the parasites components. To segment foreground from background Global threshold and Otsu threshold is used on grayscale enhanced image. For low contrast image segmentation is applied on enhanced green channel of the image. Result of thresholding on both images is added to get binary image of cells. Using morphological operation, cells having larger area is identified which is overlapping of the cells.

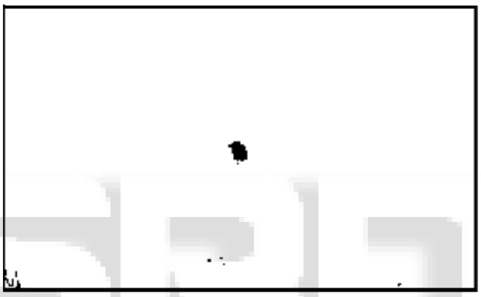

Fig. 6: Thresholded image

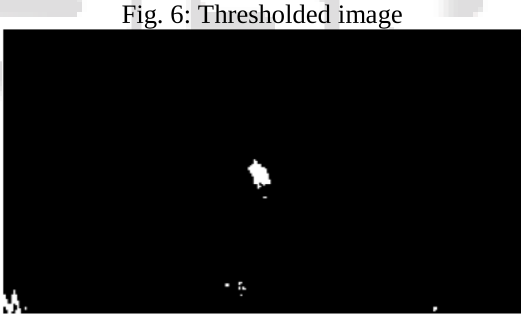

Fig. 7: Eroded image

4) *Feature Extraction:*

The features which give predominant difference between normal and infected cells are identified. The selected features are geometrical, color and statistical based. The mathematical morphology provides an approach to the processing of image based on shape. Mathematical morphological operations tend to extract their essential shape characteristics and to eliminate irrelevancies. Mathematical morphology represents the shapes which are manifested on binary or gray tone images. The set of parameters corresponds to the geometrical features are as radius, perimeter, compactness and Area.

B. *Parasite detection using ANN:*

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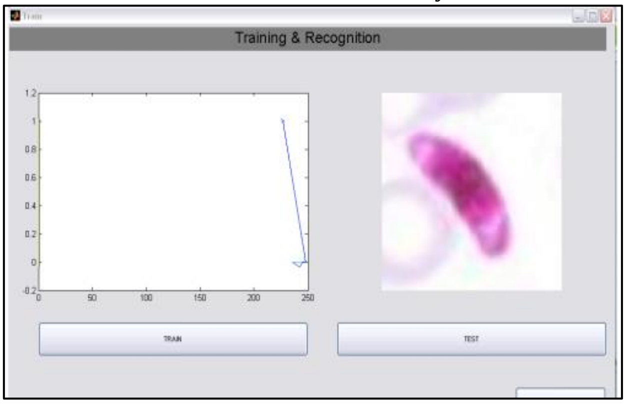

Fig. 8: GUI of infected image

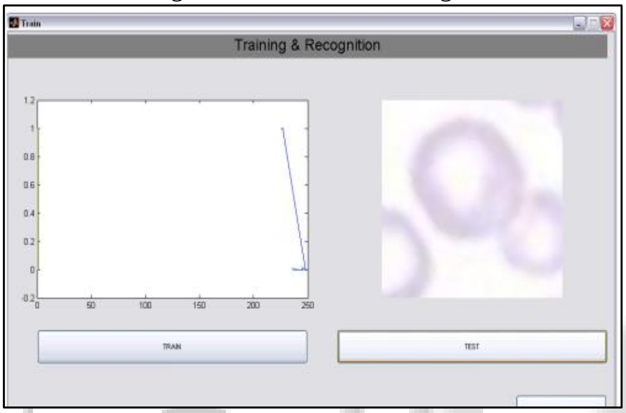

Fig. 9: GUI of uninfected image

1) *Classification of parasite:*

As there are four different parasites which cause Malaria we need to classify them. The four parasites are P. falciparum, P. vivax, P. ovale, P. malariae. In this stage we will identify the parasite due to which the disease is caused.

C. *Results and Conclusion*

Blood cell analysis can be easily done through image processing. Different diseases lead to different changes in blood. The cell images of the blood can lead to detect the illness. Though further analysis of the patient should be done manually for confirmation of the diseases, initial diagnosis can be performed using image processing.

When tested with a selected set of different images other than that used for training the ANN was able to categorize it accordingly.

1) *Results:*

Image type	Total	Malaria	Normal	% of accuracy
Malaria	25	-	5	80%
Normal	25	3	-	88%

Table 1: Number of incorrect recognitions

No.of training images	No. of testing images	Sample blood type	No. of correct recognition of testing	Percentage of accuracy
25	10	Malaria	9	90%
25	10	Normal	8	80%

Table 2: Number of correct recognitions

Thus from above table we conclude that the averag accuracy of the system is 85%.

Image type	TP	TN	FP	FN	Sensitivity	PPV	Accuracy
Malaria	-	21	4	-	88%	84.16 %	86%
Normal	22	-	-	3			

Table 3: Sensitivity, PPV and accuracy of algorithm

2) *Outputs:*

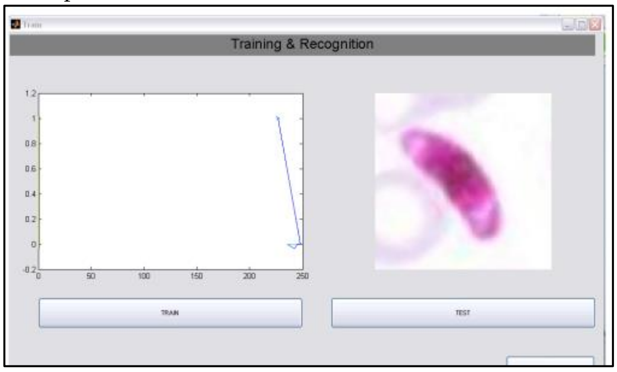

Fig. 10.4.1: GUI for infected image

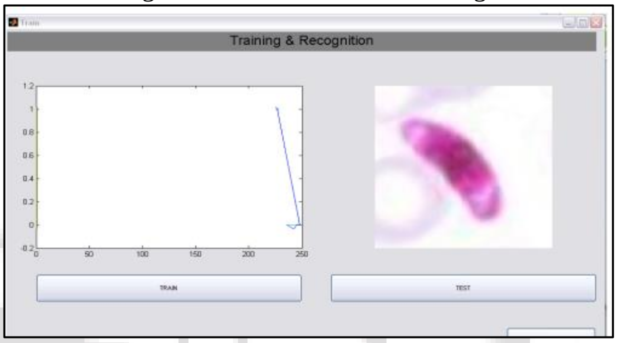

Fig. 10.4.2: GUI for uninfected image

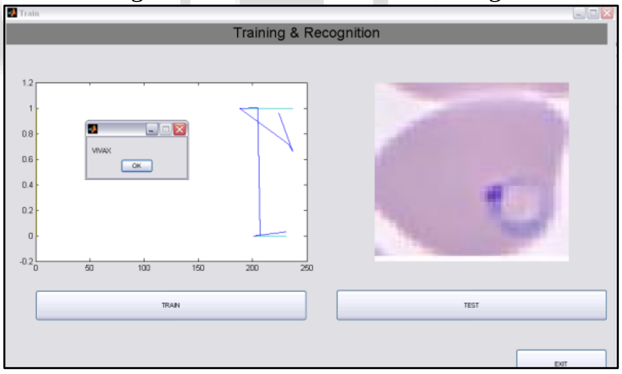

Fig. 10.4.3: GUI for P. vivax infected image

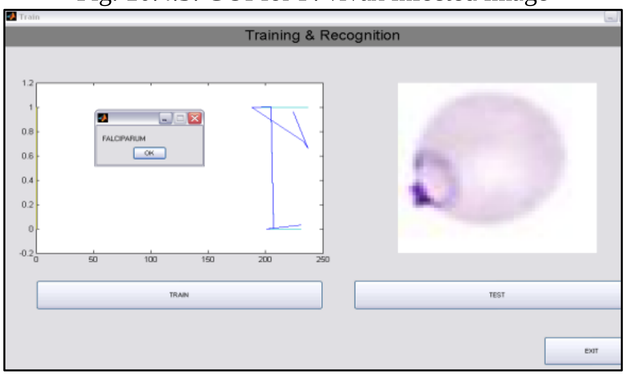

Fig. 10.4.4: GUI for P. falciparum infected image

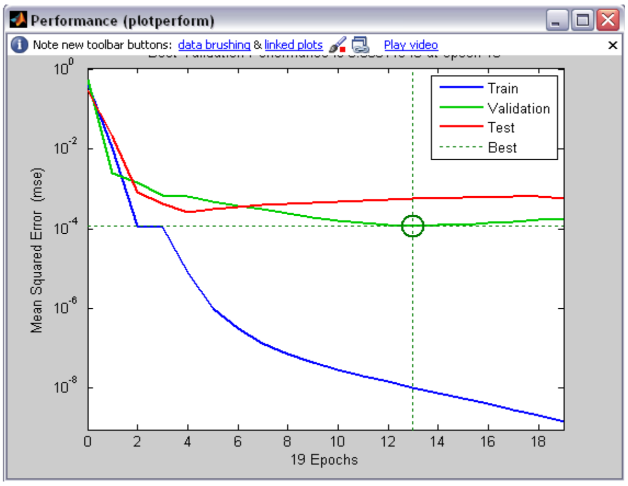

Fig. 10.4.5: Performance plot

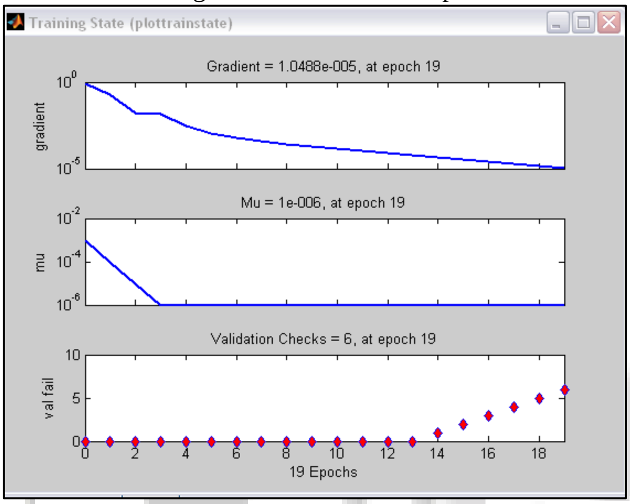

Fig. 10.4.6: Training state plot

IX. Advantages

1) Some situations where a Back Propagation Neural Network might be a good idea:
2) A large amount of input/output data is available, but you're not sure how to relate it to the output.
3) The problem appears to have overwhelming complexity, but there is clearly a solution.
4) It is easy to create a number of examples of the correct behavior.
5) The solution to the problem may change over time, within the bounds of the given input and output parameters (i.e., today 2+2=4, but in the future we may find that 2+2=3.8).
6) Outputs can be "fuzzy", or non-numeric.
7) Back Propagation ANN provides an analytical alternative to conventional techniques which are often limited by strict assumptions of normality, linearity, variable independence etc. Because an ANN can capture many kinds of relationships it allows the user to quickly and relatively easily model phenomena which otherwise may have been very difficult or impossible to explain.
8) When incorporated into the software tool the performance of the ANN is not satisfactory as there are substantial number of errors in categorizing.
9) When used with the software tool in a practical scenario the results aren't satisfactory.

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