Usage of ART for Automatic Malaria Parasite Identification Based on Fractal Features

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***Abstract*-- Malaria, a life threatening disease named in 1740, is largely a geographical disease, endemic to tropical climates. It is caused by the protozoans called plasmodium. The infected female Anopheles mosquitoes, also known as malaria vectors spread the parasites to people through their bites. Malaria diagnosis involves identifying malaria parasites in patient blood. Contemporary malaria diagnosis techniques basically depend on microscopic analysis of Giemsa-smeared thin and thick films of blood. However due to inherent technical limitations and the number of steps required in manual assessment, this diagnostic method is time consuming and prone to human error. This situation has prompted an increasing interest in finding technological solutions to carrying out the diagnosis automatically. This paper presents an efficient approach for automatic malaria detection with fuzzy based color segmentation, fractal feature extraction and ART neural network classification. The process starts with converting the input image to gray scale, LAB and HSV. L and B planes from LAB image and S plane from HSV image are extracted for identification of parasites. Fuzzy based segmentation technique is followed. Further color features and fractal features are extracted. Based on these features, malaria parasites in an image can be identified. Identification is done using four classifiers- Adaptive Resonance Theory (ART) based neural network, Support vector machine (SVM), Neural Network based Back propagation Feed Forward (NN-BPFF) and k-Nearest Neighbor (k-NN). These classifiers automatically classify the images as malaria and non-malaria. A Performance Evaluation toolbox has been designed and developed for the malaria parasite classification and comparative analysis has been done with all the four classifiers. Best performance of 98.52% has been recorded for ART classifier Receiver Operating Characteristic Curve (ROC).**

Index Term*-- *Fuzzy based segmentation, color features, fractal features, malaria parasite classification

I. INTRODUCTION

Malaria is a serious global disease and a leading cause of morbidity and mortality in tropical and sub-tropical countries. It affects between 350 and 500 million people and causes more than 1 million deaths every year. Yet, malaria is both preventable and curable. Rapid and accurate diagnosis which enables prompt treatment is an essential requirement to control the disease. It is caused by parasitic protozoa (a type of unicellular microorganism) of the genus Plasmodium. The Plasmodium organism is found in the blood of persons having malaria. The parasites are transferred from person to person through the bites of infected female Anopheles mosquitoes, also called "malaria vectors", which bite mainly between dusk and dawn. Female Anopheles introduces the parasites from its saliva into a person's circulatory system. The cycle repeats when the mosquitoes take a blood meal from a human who is contaminated with mature parasites. The intensity of transmission depends on factors related to the parasite, the vector, the human host, and the environment.

Current medical diagnosis and research involves drawing a blood sample from patient or research subject. This blood sample is smeared onto a slide and stained in order to color cell nuclei and microscopic examination is carried out. Next stage involves manual counting by a laboratory technician or other individual, who can distinguish staining artifacts from actual nuclei and white blood cells. Although manual counting is relatively inexpensive to implement, accurate diagnosis is difficult to achieve because of inherent technical limitations and human inconsistency. Considering this problem many researchers have found out devices based on digital image processing for automatic malaria detection. However these image processing tools, focusing on detection of parasites on thin blood films, may not detect the existence of parasites due to the parasite scarcity on the thin blood film. The problem is aggravated with low parasitemia condition.

Venturing the above limitation needs to be seriously advocated in bridging the work of the man power. Hence necessity of the technology has to be intervened in order to fulfil the compensation. In doing so, computer vision techniques has to be brought into consideration so that the diagnosis with computer vision methods, taking advantage of existing equipment and compensating for the shortage of human expertise is established in identify parasites in blood smear images captured through a standard microscope. Couple of works which researchers have proposed on automated malaria detection devices using digital image analysis is been covered in the post occurrences of the paper.

However, from the point of present inception this paper presents an efficient approach for automatic malaria detection. In doing so, we inaugurate the process with converting the input image to gray scale, LAB and HSV. L and B planes from LAB image and S plane from HSV image are extracted for identification of parasites. But for the correct detection of malarial parasites, segmentation process has to be carried out. For this purpose fuzzy based segmentation technique is followed. Further color features and fractal features are extracted. Based on these features, malaria parasites in an image can be identified. Identification is done using four

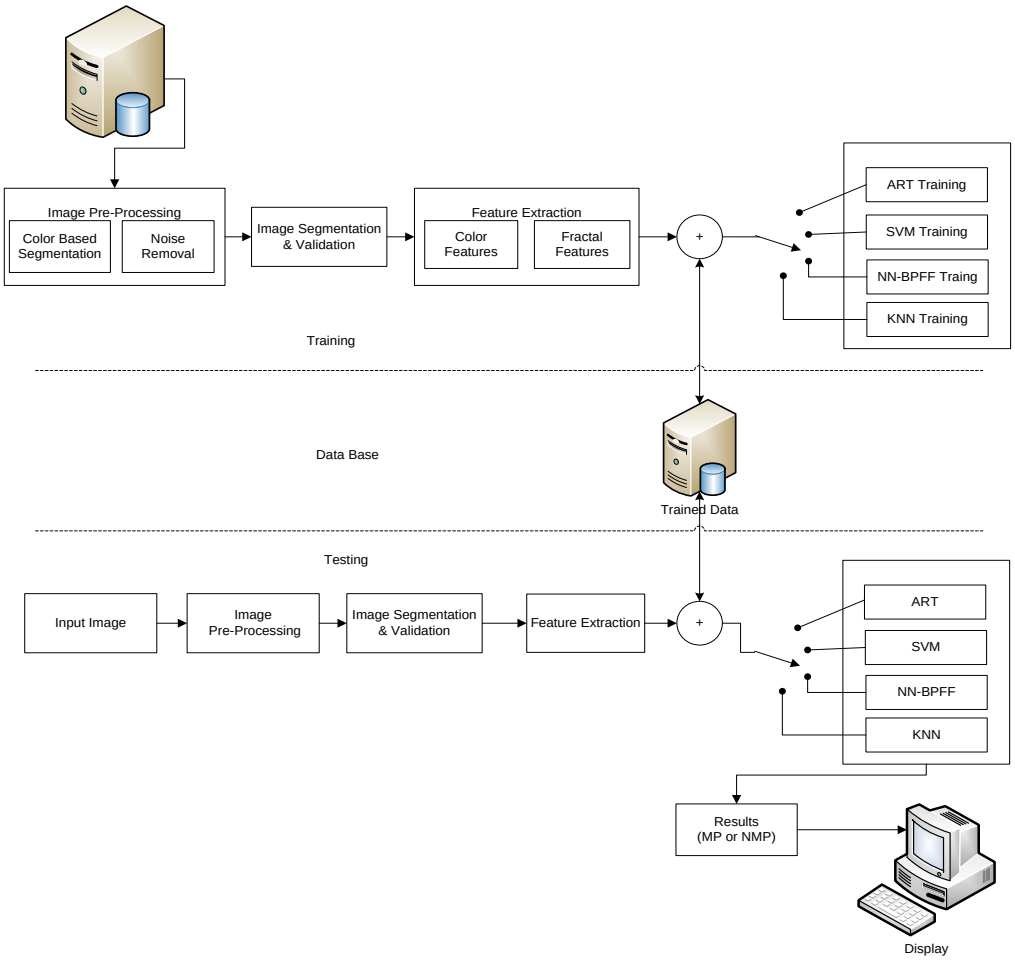

Fig. 1. Block Diagram of the Proposed Work

classifiers- SVM, KNN, NN-BPFF and ART. These classifiers automatically classify the images as malaria and non-malaria.

II. Methodology

The system consists of two stages-testing and training. The system is trained using the images in the dataset. In the testing phase the image is classified as malaria or non-malaria. Initially pre-processing is carried out where the image is converted to LAB color space and all the noise objects are removed. Then the fuzzy based segmentation is carried out, color and fractal features of malaria causing parasites are extracted. Further malaria is detected by the classifier, based on the information stored in the database during training. Figure 1 shows the block diagram of the proposed work.

A. Image Pre-processing

The input to this stage is a medical image on which the malaria detection procedure has to be carried out. This stage includes color conversion of the input image to gray scale, LAB and HSV. Figure 2 shows one of the test images. Once an RGB image is converted to gray scale all the colors are substituted with shades of gray.

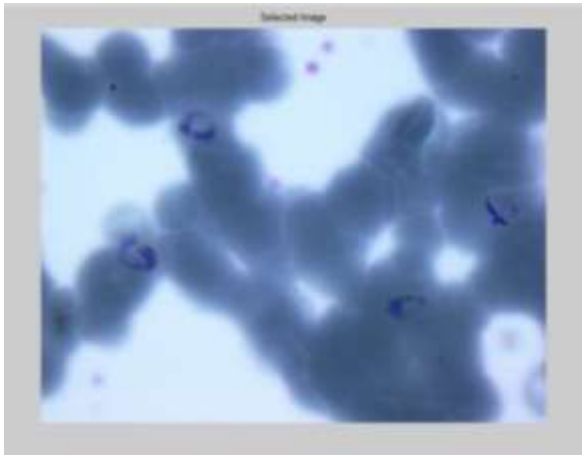

Fig. 2. Test Image

Recent formula that is being used in image processors for gray scale conversion is:

Gray = (Red * 0.299 + Green * 0.587 + Blue * 0.114)

A Lab color space also known as color opponent space is having L as dimension for lightness and a and b dimensions for the color-opponent. Figure 3 is the input image in LAB color space.

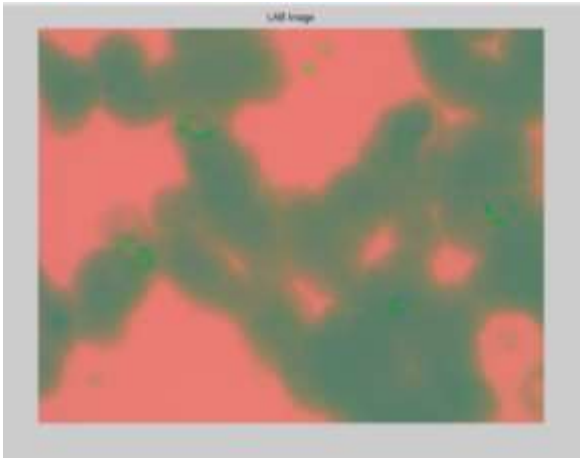

Fig. 3. RGB to LAB Converted Test Image

HSV relies on intuitive color characteristics such as shade, tone and tint (or family, purity and intensity). The hue value H spans from 0 to 360º. The saturation S is the level of strength or purity and ranges from 0 to 1. Brightness V also runs from 0 to 1, where 0 is the black.

B. Segmentation

Segmentation is generally the first stage in any attempt to analyze or interpret an image automatically. It is typically used to locate objects and boundaries in images. For medical image segmentation, fuzzy technique is considered one of the best methods.

In our work, we have incorporated fuzzy technique [1] for segmentation. The flow diagram of this stage is as shown in the Figure 4. The stages involved in the process are as follows:

1. Classify the pixels of an image into a desired number of regions using any appropriate clustering algorithm.
2. Derive the key weight and threshold value, and the membership function for each pixel distribution.
3. Initialise the centre of all regions required to define the membership function.
4. Sequentially select an unclassified pixel from the image and calculate each membership function value in each region for that pixel.
5. Classify the pixel into a region applying the fuzzy rule.
6. Return to step 4 until every pixel is classified.

The definition of the membership function lies at the heart of any fuzzy logic system and the capability of fuzzy rule based techniques significantly depend upon it. The eminent psychologist Gestalt discovered that visual elements may be perceptually grouped together based on the principles of: proximity, similarity, common fate, good continuation, surroundness, closure, relative size and symmetry [2].

Membership functions have been constructed using only feature values, i.e. gray level pixel intensities. Spatial relations between pixels within an identified region have not been considered, yet are vital since they characterise the geometric features of a region as any spatial object contains two descriptors: feature and geometric[3,4].

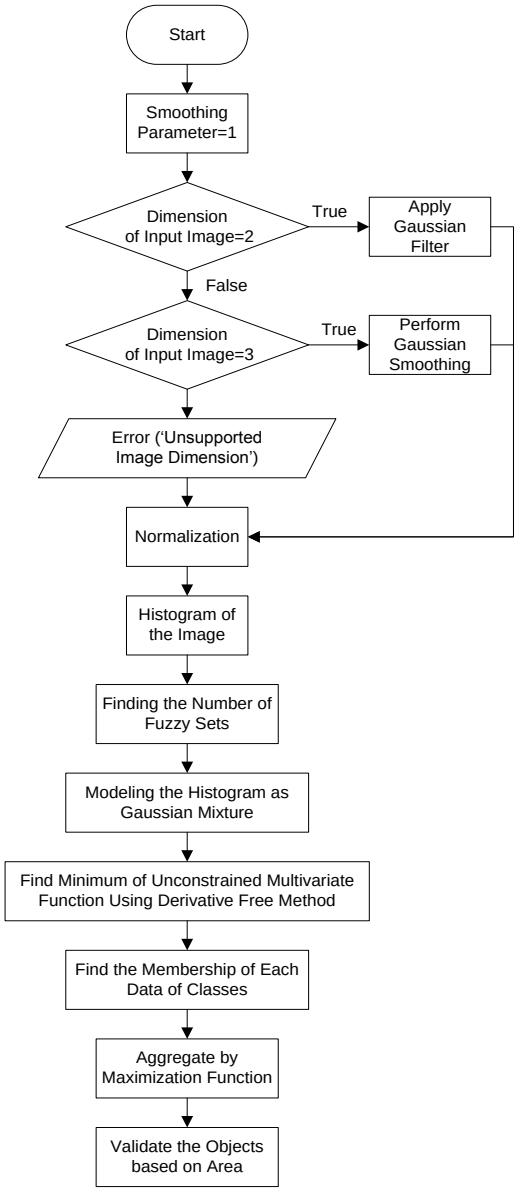

Fig. 4. Flow Diagram of the Segmentation Stage

To construct a membership function, the number of neighbourhood pixels and their distances from the candidate pixel must be considered. The membership function μ should possess the following properties:

1. $\mu \propto N$ where N is the number of neighbours.
2. $\mu \propto \left(1/d\left(P_{x,y}, P_{s,t}\right)\right)$,

where $d\left(P_{x,y}, P_{s,t}\right)$ is the distance between pixels $P_{x,y}$ and $P_{s,t}$ Key weighting factor and its threshold value is calculated [1]. Figure 5 is the result obtained after segmentation.

Fig. 5. Binarised Segmented Result

C. Feature Extraction

Color and fractal features are extracted from each segmented objects. Malaria parasite cannot be detected based on shape since there is no regular shape feature and it changes during growth phases. 32 color features (8 features for each four planes: L,B, S, gray) and 48 fractal features (16 features for each three planes: L, B & S). 80 features are extracted by the combination of color and fractal features.

a) Color Features

Color features is one of the most widely used visual features. Use of color histogram is the most common way for representing color feature. Color histogram does not consider color spatial distribution. This is a major disadvantage of the color histogram. One of disadvantage of the color histogram is that it does not take the color spatial distribution into consideration [5]. In this paper a different method for color feature extraction is proposed and the flow diagram color feature extraction method is as shown in the Figure 6.

Initially 1st (L plane) and 3rd (B plane) planes of LAB image and 2nd (S) plane of HSV image and gray image are considered. 3x3 non-overlapping matrices are extracted from each plane, and convolution is applied on each matrix. This generates 32 features in total; 8 features for each plane. All the features are concatenated and their mean is calculated.

a) Fractal features

Segmentation of objects and regions in medical images necessitates features which can provide unambiguous discrimination. Researchers have found that fractal features are quite effective for this purpose. For any fractal, its fractal dimension is an important characteristic, because it carries information about their geometric structure [6]. Considering all these factors, fractal technique is used for feature extraction. Here we consider four planes (1st and 3rd planes of LAB image and 2nd plane of HSV image along with the gray image) for feature extraction. Each plane is divided into 4x4 matrices. Feature extraction procedure includes determination of the histogram peak for the local fractality of the selected plane [7]. This procedure is carried out for all the four planes which results in 48 features, 16 features for each plane. The resulting features of all four planes are concatenated and their mean is calculated.

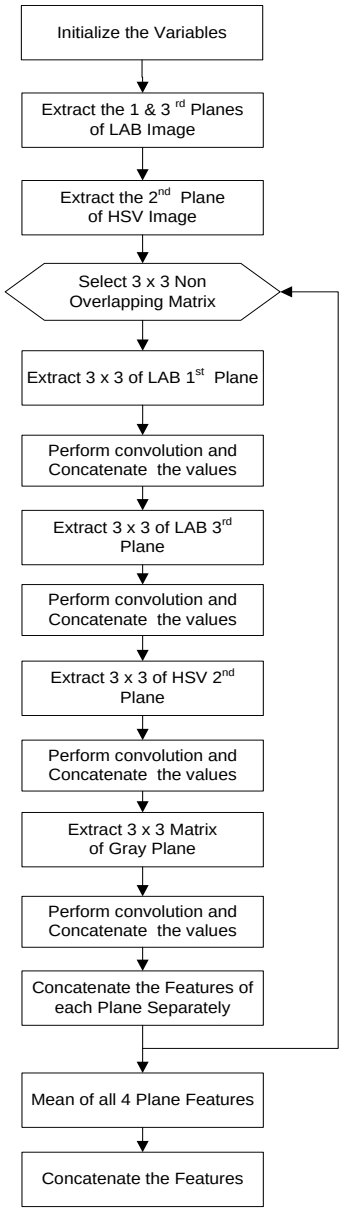

Fig. 6. Flow of Color Feature Extraction

D. Classification

a) ART

An ART system has four basic properties. The first is the self-scaling computational units. The attentional subsystem is based on competitive learning enhancing pattern features but suppressing noise. The second is self-adjusting memory search. The system can search memory in parallel and adaptively change its search order. Third, already learned patterns directly access their corresponding category. Finally, using the environment as a teacher, the system will be able to modulate attentional vigilance in a flexible way. If the environment disapproves the current identification of the system, it turns this parameter to be more vigilant. This makes

this classifier a more efficient one. The classification result of ART is shown in the Figure 7, MP represents malaria parasite, NMP represents non malaria parasites.

b) SVM

SVM belong to a family of generalized linear classification. A special property of SVM is, it synchronously increase the geometric margin and reduce the empirical classification error. The main concepts of SVM are to first modify input features into a higher dimensional space using a kernel function and later build an OSH (Optimal Separating Hyper Plane) between the two classes in the modified space.

c) NN-BPFF

This is a type of ANN. Artificial neural networks in general are machine learning models which are genuinely inspired by the animals' central nervous systems (in particular the brain) that are capable of machine learning and pattern recognition. There are three main learning paradigms: supervised, unsupervised, and hybrid [8]. Here we are using unsupervised learning procedure.

The input layer consists of n neurons that code for the n pieces of input signal (X1…Xn) of the network (independent variables). The user decides the number of neurons of the hidden layer. Finally, the output layer consists of k neurons for the k classes (dependent variables). Each connection between two neurons is associated with a weight factor (random value between _0.3 and _0.3 at first). Successive iterations during the training of the network modify the weight according to input and output data. In the input layer, the state of each neuron is determined by the input variable; the other neurons (hidden layer and output layer) evaluate the state of the signal from the previous layer as:

$$a_j = \sum_{i=1}^{I} X_i W_{ji}$$

where a_j is the net input of neuron j; X_i is the output value of neuron i of the previous layer; W_{ji} is the weight factor of the connection between neuron i and neuron j. The activity of neurons is usually determined via a sigmoid function:

$$f(a_j) = \frac{1}{1 + \exp^{-a_j}}$$

Thus, weight factors represent the response of the NN to the problem being faced.

d) KNN

In pattern recognition, the k-Nearest Neighbours algorithm (or k-NN for short) is a non-parametric method used for classification and regression. An object is classified by the "distance" from its neighbours, with the object being assigned to the class most common among its k distance-nearest neighbours. If k = 1, the algorithm becomes nearest neighbour algorithm and the object is classified to the class of its nearest neighbour.

Distance is a key word in this algorithm, each object in the space is represented by position vectors in a multidimensional feature space. It is usual to use the Euclidean distance to calculate distance between two vector positions in the multidimensional space.

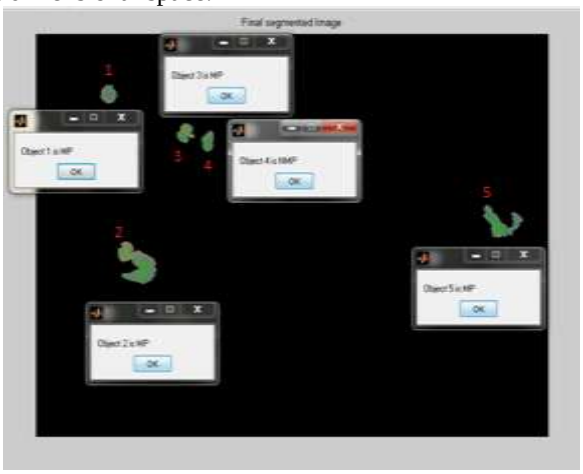

Fig. 7. ART classification of the segmented objects

Distance between two scenarios is computed using Euclidean distance function $d(x,y)$ where x,y are scenarios composed of N features, such that $x = \{x_1, \dots, x_N\}, y = \{y_1, \dots, y_N\}$.

Euclidean Distance Measuring:

$$d_E(x,y) = \sum_{i=1}^{N} \sqrt{x_i^2 - y_i^2}$$

The classification rules are generated by the training samples themselves without any additional data. The KNN classification algorithm predicts the test sample's category according to the K training samples which are the nearest neighbours to the test sample, and judge it to that category which has the largest category probability.

III. Results and Discussion

The methodology presented in this paper makes an efficient classification between malarial and non-malarial parasites. For forming the dataset 476 images were collected, which are Giemsa stained original blood smear of several malaria patients. CCD (Charge Coupled Device) camera mounted on Bright Field/Conventional microscope is used capture blood smear MP images. These images were collected from JSS medical college, Mysore. 1694 sample objects are used for implementation with Matlab. Classification is carried out using four different classifiers namely ART, SVM, NN-BPFF and KNN. The dataset was divided into three ratios: 50:50, 60:40, 70:30, as training: tesing. Performance analysis was carried out using 6 different parameters-accuracy, precision, sensitivity, specificity, recall and F-measure. From the results given in the tables' I-IV, which contains all 6 parameter values of ten different cases for four classifiers, performance of ART classifier is outperformed. Performance analysis is also represented in the form of plots as demonstrated in Figure 8. From the bar chart shown in the Figure 9, it is clear that the performance of ART is appreciable. The classification is obtained more accurately by

ART when compared to SVM, NN-BPFF and KNN. Figure 10 displays the ROC curve of the ART classifier for the dataset divided in the ratio 70:30.

TABLE I.
PERFORMANCE ANALYSIS RESULTS OF SVM FOR THE DATSET IN THE RATIO 70:30

SVM 70-30					
Accuracy	**Precision**	**Sensitivity**	**Specificity**	**Recall**	**F – Measure**
0.928571	0.945946	0.921053	0.9375	0.921053	0.933333
0.929078	0.946667	0.922078	0.9375	0.922078	0.934211
0.882629	0.941748	0.836207	0.938144	0.836207	0.885845
0.883392	0.923077	0.857143	0.914729	0.857143	0.888889
0.895775	0.928571	0.875648	0.919753	0.875648	0.901333
0.889671	0.922374	0.87069	0.912371	0.87069	0.895787
0.889336	0.931727	0.859259	0.92511	0.859259	0.894027
0.882042	0.926056	0.851133	0.918919	0.851133	0.887015
0.882813	0.922601	0.856322	0.914384	0.856322	0.888227
0.885915	0.924791	0.860104	0.916667	0.860104	0.891275

TABLE II.
PERFORMANCE ANALYSIS RESULTS OF NN-BPFF FOR THE DATSET IN THE RATIO 70:30

NN-BPFF 70-30					
Accuracy	**Precision**	**Sensitivity**	**Specificity**	**Recall**	**F – Measure**
0.842857	0.862069	0.78125	0.894737	0.78125	0.819672
0.865248	0.8	0.9375	0.805195	0.9375	0.863309
0.868545	0.848485	0.865979	0.87069	0.865979	0.857143
0.904594	0.859155	0.945736	0.87013	0.945736	0.900369
0.895775	0.869822	0.907407	0.88601	0.907407	0.888218
0.899061	0.841629	0.958763	0.849138	0.958763	0.896386
0.877264	0.837398	0.907489	0.851852	0.907489	0.871036
0.887324	0.846975	0.918919	0.860841	0.918919	0.881481
0.88125	0.8375	0.917808	0.850575	0.917808	0.875817
0.884507	0.84375	0.916667	0.857513	0.916667	0.878698

TABLE III.
PERFORMANCE ANALYSIS RESULTS OF KNN FOR THE DATSET IN THE RATIO 70:30

KNN 70-30					
Accuracy	**Precision**	**Sensitivity**	**Specificity**	**Recall**	**F – Measure**
0.828571	0.825	0.868421	0.78125	0.868421	0.846154
0.829787	0.844156	0.844156	0.8125	0.844156	0.844156
0.821596	0.814516	0.87069	0.762887	0.87069	0.841667
0.826855	0.830189	0.857143	0.790698	0.857143	0.84345
0.864789	0.879581	0.870466	0.858025	0.870466	0.875
0.852113	0.847737	0.887931	0.809278	0.887931	0.867368
0.84507	0.850909	0.866667	0.819383	0.866667	0.858716
0.829225	0.82716	0.867314	0.783784	0.867314	0.846761
0.83125	0.82967	0.867816	0.787671	0.867816	0.848315
0.840845	0.842105	0.870466	0.805556	0.870466	0.856051

TABLE IV.
PERFORMANCE ANALYSIS RESULTS OF ART FOR THE DATSET IN THE RATIO 70:30

ART 70-30					
Accuracy	**Precision**	**Sensitivity**	**Specificity**	**Recall**	**F – Measure**
0.942857	0.947368	0.947368	0.9375	0.947368	0.947368
0.971631	0.974026	0.974026	0.96875	0.974026	0.974026
0.971831	1	0.948276	1	0.948276	0.973451
0.943463	0.948052	0.948052	0.937984	0.948052	0.948052
0.949296	0.962963	0.943005	0.95679	0.943005	0.95288
0.957746	0.973451	0.948276	0.969072	0.948276	0.960699
0.959759	0.966418	0.959259	0.960352	0.959259	0.962825
0.950704	0.963696	0.944984	0.957529	0.944984	0.954248
0.957813	0.965217	0.956897	0.958904	0.956897	0.961039
0.95493	0.965789	0.950777	0.959877	0.950777	0.958225

IV. CONCLUSION

Development of accurate malaria diagnosis techniques is still a field of interest. Fuzzy based color image segmentation with fractal feature extraction using ARTNN classifier has been proposed in this paper to segment the stained malaria parasites from the blood smear background. Color and Fractal features are extracted from the segmented objects and feature vectors are given as input to classifiers. Comparative study has also been made with SVM, NN-BPFF and KNN. Performance Evaluation toolbox has been proposed to provide the complete range of training, testing and classification algorithm selection. ROC curve analysis is made and considerable improvement in the accuracy of 94.45%, precision 96.41%, specificity 94.68% and sensitivity 94.32% has been recorded over the malaria parasite image dataset. Complete dataset is evaluated to classify the objects as malaria & non-malaria parasites. Area under ROC curve is calculated with false positive rate versus true positive rate of the classifier and found to be 0.9847. The proposed low cost, automated detection methods with performance evaluation toolbox can assist doctors in malaria parasite image analysis and diagnosis for a better patient treatment. In future, work will be extended to identify different types of malaria parasites with more accuracy.

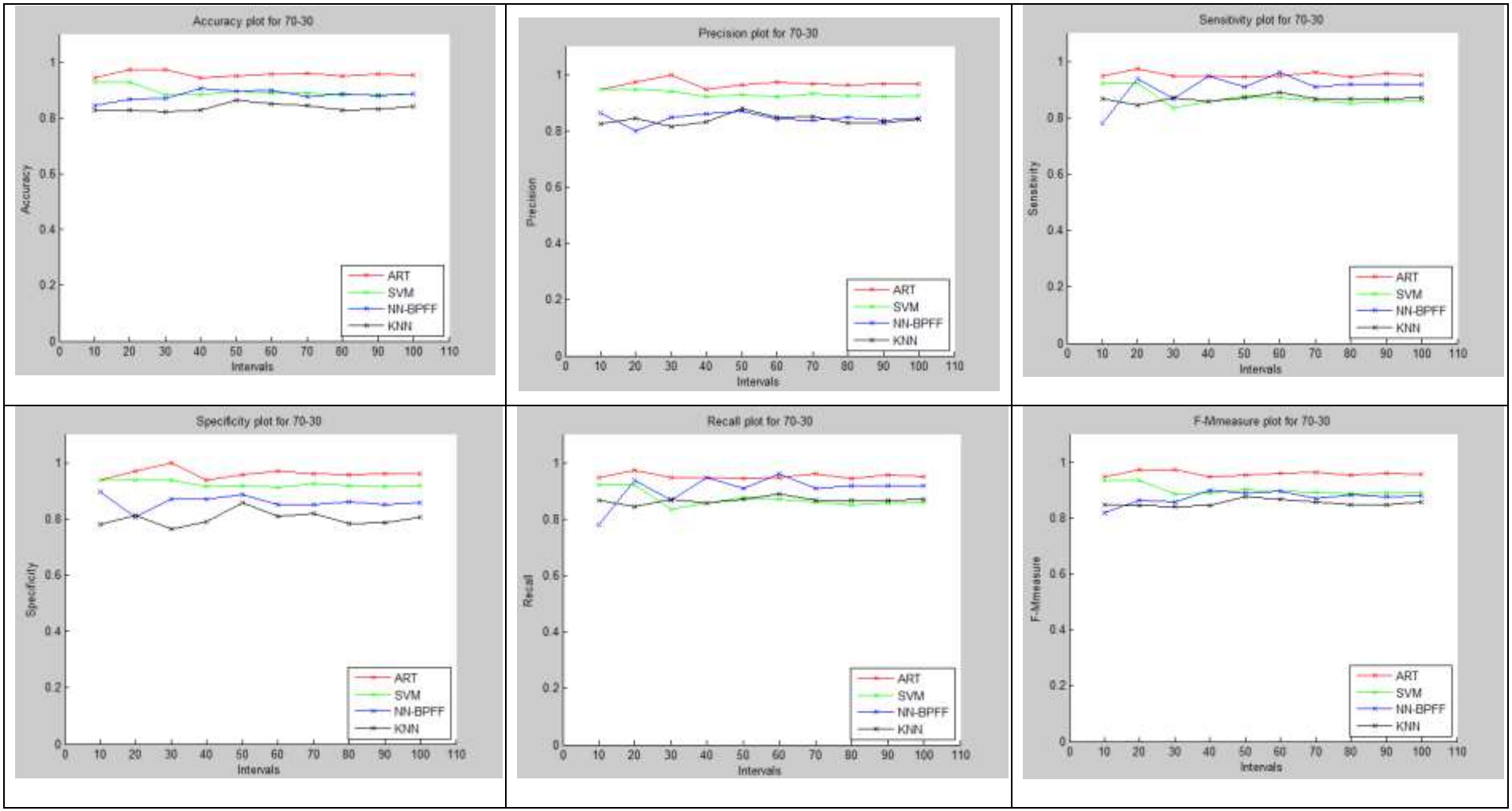

Fig. 8. Performance plots of all the Classifiers obtained for the dataset in the ratio 70-30

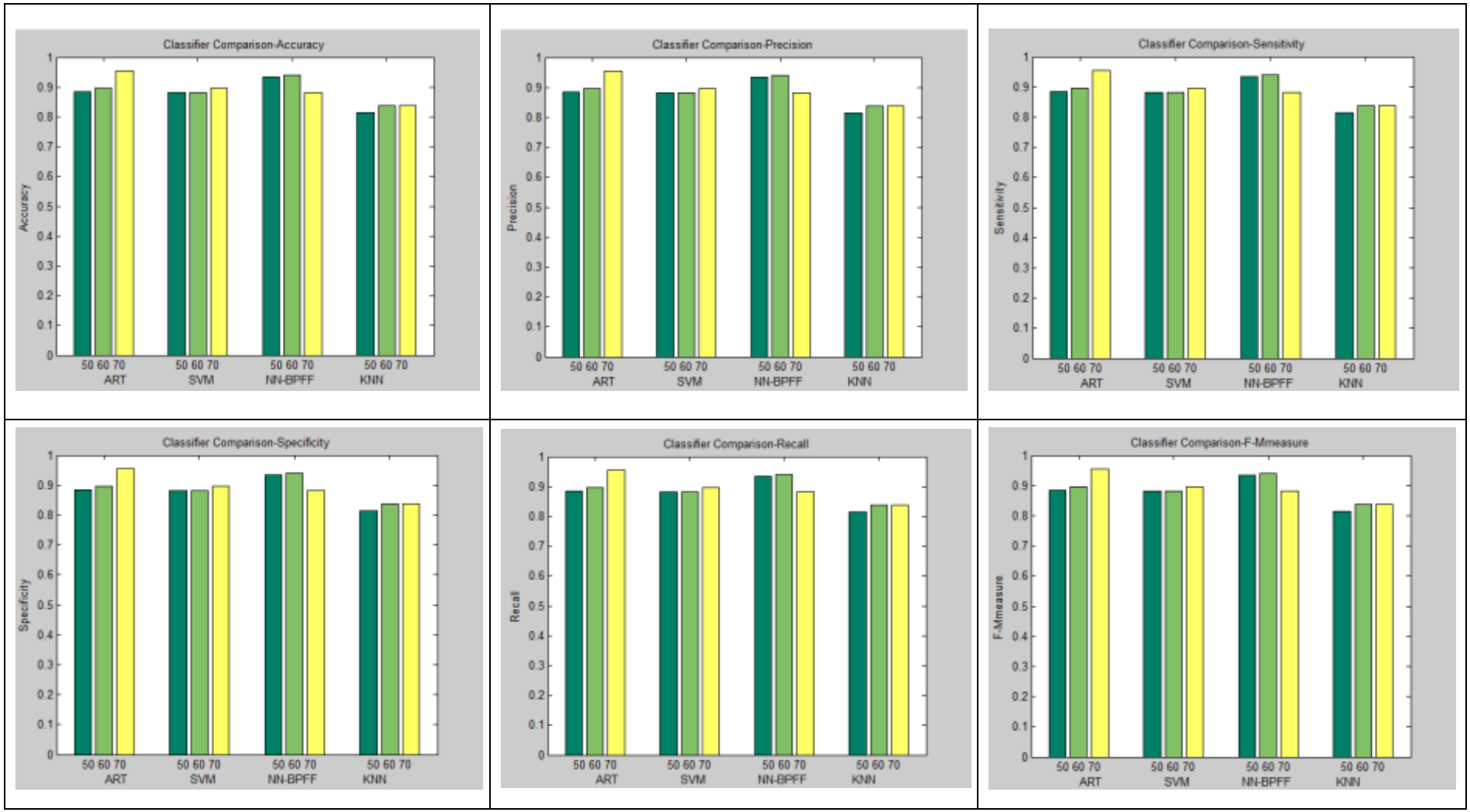

Fig. 9. Performance evaluation represented in the form of Bar Chart

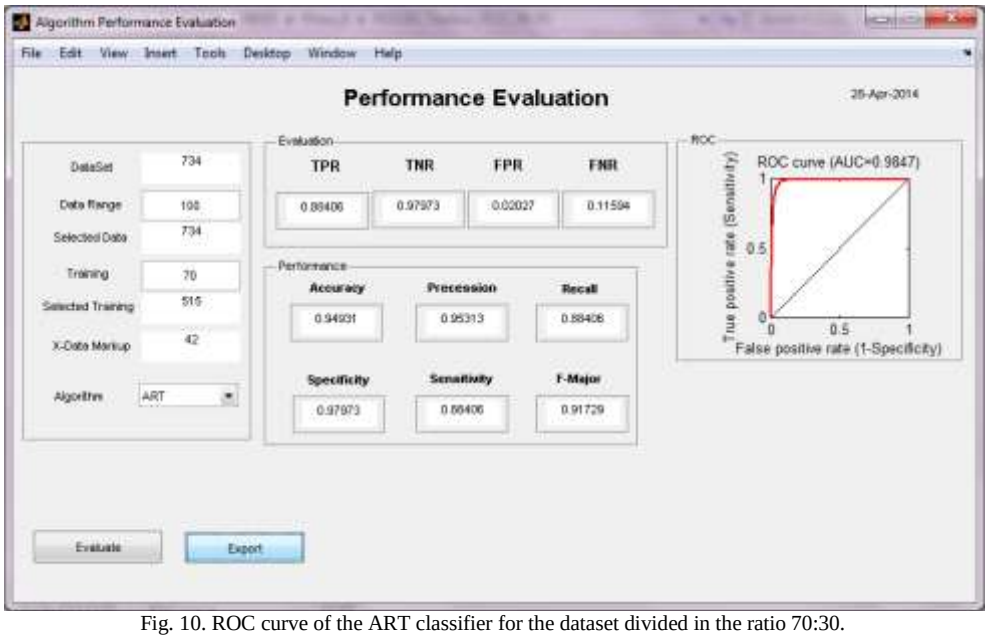

Fig. 10. ROC curve of the ART classifier for the dataset divided in the ratio 70:30.

REFERENCES

[1] Gour C. Karmakar , Laurence S. Dooley, "A generic fuzzy rule based image segmentation algorithm", *Pattern Recognition Letters* 23, 2002, pp.1215–1227.

[2] Wertheimer, M., "Laws of organization in perceptual forms", *Pshychol. Forsch*, 1923.

[3] Kellogg, C.B., Zhao, F., Yip, K., "Spatial aggregation: language and applications", *In: Proc. AAAI-96*, 1996.

[4] Yip, K., Zhao, F., "Spatial aggregation: theory and applications", *J. Artif. Intell. Res*, vol 5, 1996, pp.1-26.

[5] Fatemeh Alamdar and Mohammad Reza Keyvanpour, "A New Color Feature Extraction Method Based on Dynamic Color Distribution Entropy of Neighborhoods", *IJCSI International Journal of Computer Science Issues*, Vol. 8, Issue 5, September 2011.

[6] Yuan Y. Tang, Yu Tao, Ernest C.M. Lam, "New method for feature extraction based on fractal behavior", *Pattern Recognition*, 2002, pp. 1071–1081.

[7] Radu DOBRESCU, Florin, "Fractal Dimension Based Technique for Database Image Retrieval", *IONESCU*, 2003.

[8] Ani1 K. Jain, Jianchang Mao and K.M. Mohiuddin, IEEE, 1996.

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