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Automated Approach for the Identification and Classification of Red Blood Cells Using LDA

Satish R. Suryawanshi[1], Shaikh Aamer[2]
[1]*M.Tech Student,* [2]*Assistant Professor, Electronics & Telecommunication Department, Shreeyash College of Engineering and Technology, Chhatrapati Sambhaji Nagar, Maharashtra, India.*

Abstract: ***this study presents an automated approach for the identification and classification of red blood cells (RBC) in microscopic blood smear images. The primary goal of this research is to develop an efficient and accurate method for identifying and classifying red blood cells using a combination of Discrete Wavelet Transform (DWT) feature extraction technique and Linear Discriminant Algorithm (LDA) classifier to improve the accuracy and efficiency of traditional image processing techniques used for diagnosing various hematological disorders. The methodology involves preprocessing microscopic blood smear images, segmenting RBCs, and applying discrete wavelet transform feature extraction technique to acquire important morphological properties such as diameter, shape geometric factor, central pallor, and target flag for classification purposes. The extracted DWT features are then fed as input to LDA which employs a linear decision boundary to classify RBCs into normal (Normocytic) and abnormal (Microcytic) categories. The proposed method achieved a notable 85% accuracy with the LDA classifier.***

Keywords: Discrete Wavelet Transform, Linear Discriminant Algorithm classifier, Red Blood Cells, Normocytic, Microcytic.

I. INTRODUCTION

Blood analysis plays a crucial role in medical diagnostics, providing valuable insights into a patient's overall health. Among the different components of blood, red blood cells (RBCs) are particularly significant, as their size, shape, and concentration are key indicators of various hematological disorders. Red Blood Cell (RBC) is the most important component of human blood. Most of the part in human blood is composed by RBCs. Function of Erythrocytes, also known as RBCs, is to transmit oxygen in the body. Red Blood Cells are biconcave disks having diameter of 7 to 8 in one cubic millimeter of human blood, 4-6 million Red blood corpuscles circulate. Healthy Red blood cells in human body are classified into four groups based on gender and age. The typical range of RBCs for newborn is approximately 4.8-7.2, for children 3.8- 5.5, for women 4.2-5.0 and for men 4.6-6.0 x 10^6 million per cubic millimeter. Due to oxygen deficiency, people may suffer from heart and lung disorders as well as difficulty in breathing. The size, shape and number of RBCs can affect person's health. In laboratories the analysis of blood cells is carried out by human observations. The classical manual methods are time consuming and not precise [1][2][3].

This studies gives an algorithm for automatic classification of microscopic blood smear images as normal (normocytic) or abnormal (Microcytic) based on Red blood cells. Normocytic and microcytic RBCs are two important classifications used in diagnosing conditions such as anemia, infections, and blood disorders. Normocytic RBCs have a normal size and shape, typically ranging between 80-100 femtoliters (fL) in volume, while microcytic RBCs are smaller than normal, often associated with conditions like iron deficiency anemia and thalassemia [2][3].

The accurate identification and classification of these RBCs are essential for early disease detection and effective treatment planning. Pattern recognition techniques, integrated with image processing algorithms, have emerged as powerful tools in medical imaging and hematology. These techniques enable automated segmentation, feature extraction, and classification of RBCs based on their morphological characteristics. By leveraging methods such as thresholding, edge detection, and machine learning algorithms, pattern recognition enhances the precision and efficiency of blood cell analysis. This study explores various methodologies for detecting and classifying normocytic and microcytic RBCs using pattern recognition. By reviewing advanced computational techniques, this research aims to improve diagnostic accuracy, reduce manual effort, and support clinical decision-making in red blood cell analysis[1][2][3].

The architecture of proposed automated approach for the identification and classification of Red Blood Cells using LDA system shown in figure 1. The Accuracy of the proposed system is based on the sharpness of input RBC smear images.

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II. SYSTEM ARCHITECTURE

The architecture of identification and classification of red blood cells using linear discriminant classifier system shown in figure 1. The proposed system is constructed using five components: input image, pre-processing, feature extraction and selection, classification and finally recognition result [4]. Each block of proposed system details given below.

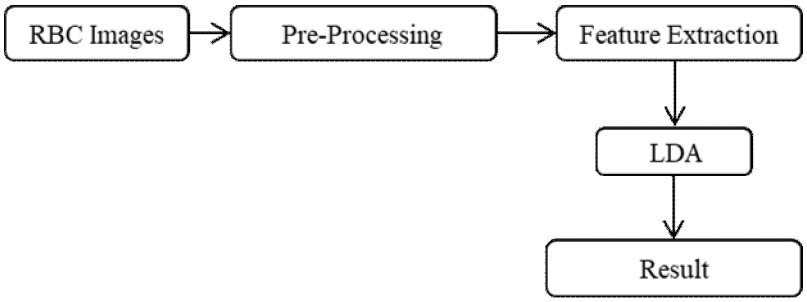

Fig. 1 Architecture of Identification and Classification of RBC System

A. Database Collection

The image acquisition is the initial and essential step of proposed system. In the image acquisition process, the first step involves preparing slides by an expert for manual examination. After staining, the slides are rinsed under tap water and allowed to dry. Lab specialists then use a BX53 Olympus microscope to determine the parasitemia count. High-resolution digital images are captured by attaching a numerical camera to the microscope. For this study, a 1024x1360 resolution camera was used with medium contrast and 400X magnification to acquire sample images. The dataset consists of 40 samples each from both normal and abnormal individuals. Microscopic images are captured for both normocytic and microcytic blood cells. Fig 2(a) and Fig 2(b) display color images of abnormal (microcytic) and normal (normocytic) red blood cells, respectively.

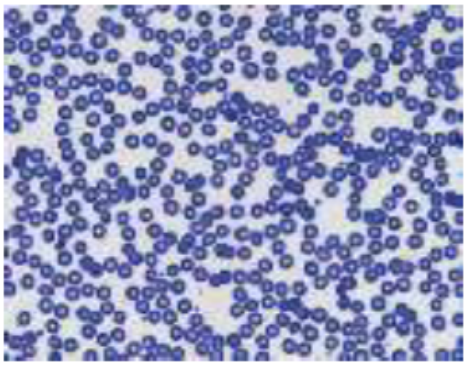

Fig. 2(a) Original RGB image (normocyte)

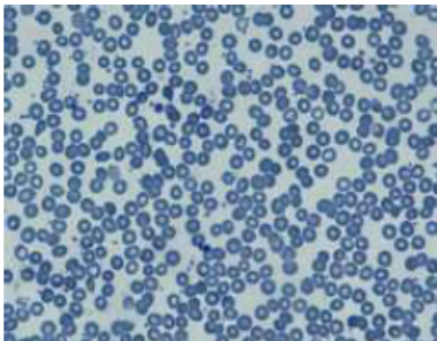

Fig. 2(b) Original RGB image (microcyte)

B. Image Pre-processing

The Initially captured database images are non-uniform illumination, with noise & poor contrast. The presence of these drawbacks are reduced by pre-processing and make suitable image to extract features. Original color images are converted into binary images. RGB color image, it is improved into binary image with thresholding. The binary image contains holes and small objects. Morphological operations are performed for segmentation and Label matrix is created. Binary image for a microcytic sample is shown in figure 3 [5].

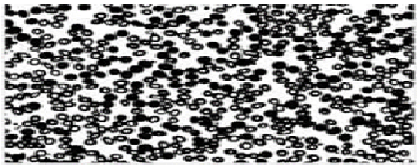

Fig. 3 Binary Image (microcyte)

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C. Feature Extraction

The next step of pre-processing is feature extraction. In this process overlapping cells are eliminated from the binary image using a label matrix and area thresholding. A new label matrix is then generated for the image containing only non-overlapping cells. Various cell properties, including area, major axis, minor axis, centroid and diameter, are computed. Figure 4 displays non-overlapping cells, highlighting the image centroid in blue and the 10 nearest cells in red from the image centre.

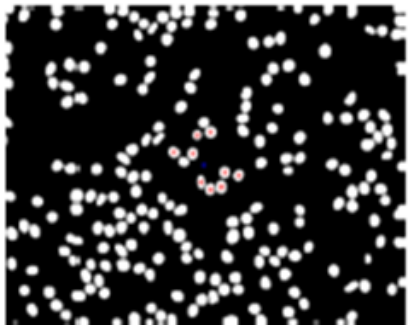

Fig. 4 Non-overlapped microcytic cells

Each isolated cell is then mapped onto the original image, and 10 cells are cropped. The cropped cells for microcytic and normocytic categories are shown in figure 5(a) and figure 5(b) respectively [5][6][7].

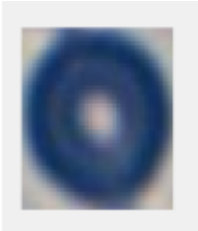

Fig. 5(a) Cropped RGB Cell (Normocytic)

Fig. 5(b) Cropped RGB Cell (Microcytic)

D. Wavelet Transform

Wavelet transform is used to discriminate central pallor of normal and abnormal blood cell. Four features are extracted by applying wavelet transform on each cell. Mean of features is calculated to create [1x4] feature vector for one image. Similarly, feature vectors are extracted for all the images of normal and abnormal red blood cells. The processed images undergo Wavelet Transform operations, with the Two-Dimensional Discrete Wavelet Transform (2D-DWT) being utilized in this work due to its fast computational efficiency for image decomposition and its suitability for discrete pixel-based images [2]. Wavelets from the Daubechies, Symlet, Coiflet, and Biorthogonal families are selected for their orthogonality or biorthogonality properties, which enable efficient data compression and rapid execution. Wavelet transforms refers to the decomposition of an image with a family of real orthonormal bases $\Psi_{(m,n)}(x)$ obtained through translation and dilation of kernel function $\Psi(x)$. For each integer r, the orthonormal basis $L^2(R)$ is defined as

$$\phi_{r,i,k}(x) = 2^{\left(\frac{i}{2}\right)}\phi_r(2^i x - k), \quad j,k \subset Z \tag{1}$$

Where the function $\Phi_{(r)}(x)$ in $L^2(R)$ has the property that $\{\Phi_r(x-k)/k\}, \in Z$ is an orthonormal sequence in $L^2(R)$ Here j is the scaling index, k is the shifting index and r is the filter index then the trend f_j, at scale 2^j of a function $f \in L^2(R)$ is defined as

$$f_j(x) = \sum_k (f, \phi_{r,i,k})\phi_{r,i,k}(x) \tag{2}$$

The details of r fluctuations are defined by

$$d_j(x) = f_{j+1}(x) - f_j(x) \tag{3}$$

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Daubechies' orthonormal basis has the following properties, $\Psi(x)$ has the compact support interval (0, 2r + 1), $\Psi(x)$ has about r/5 continuous derivatives

$$\int_{-\infty}^{\infty} \Psi(x)\,dx - \int_{-\infty}^{\infty} x^r \Psi(x)\,dx = 0 \tag{4}$$

The Wavelet function decomposes the input aggregate image and their statistical evaluation result. In this way feature vectors are extracted for all images from database. Feature vectors are stored in .mat file which is further used for classification [7][8].

E. LDA Classifier

From feature vectors, cell images are classified as normal and abnormal. .mat file containing features is imported for classification. It is done in PR Toolbox using LDA classifiers. Pattern Recognition (PR) toolbox can be implemented in MATLAB for classification. It gives accuracy of classification from feature matrix. The dataset from feature matrix is divided for training and testing. In dataset, rows represent samples and columns represent features. The percentage of dataset used for training is also given by user. In the proposed system, PR Toolbox version 5.0 is implemented with LDA classifier and results are analysed [5].

Linear Discriminant Analysis classifier is a simple statistical binary classifier. Classification is done using linear decision boundary. Discriminant function is evaluated from mean of features and covariance matrix of each class which are calculated from feature matrix. Decision boundary is decided from discriminant function. LDA assumes that covariance matrices of two classes are equal. It also considers that the conditional probability of features in feature space is a Gaussian function [5]. The features are divided in classes by calculating Maximum a Posteriori. The linear discriminant function g(x) can be written as,

$$g(x) = \omega_0 + \sum_{i=1}^{d} \omega_i x_i \tag{5}$$

Where, ω_i= components of the weight vector w

III. PERFORMANCE ANALYSIS

Feature vectors of 5 images out of 40 are shown in table1 for normocytic and microcytic respectively. In the feature table, first four features are of DWT and last one is of ratio thresholding. For classification, 66 % data from feature vectors of complete dataset (40 images) is considered for training and remaining for testing. Accuracy and error obtained using LDA classifiers for DWT along with thresholding is shown graphically in figure 6. LDA classifier gives better results with 85%.

Table1. Feature vectors of normocytic and microcytic

	Feature 1	Feature 2	Feature 3	Feature 4	Feature 5
Sample features for 5 normocytic cells	1308.392	1.062217	1.702513	-0.02872	0.159087
	911.2841	0.687386	0.481296	-0.34298	0.167035
	1462.196	-0.19089	0.408419	0.636231	0.153946
	1270.016	-0.72689	1.003075	-0.00801	0.094883
	1302.149	-0.22361	2.355821	-0.14962	0.245285
Sample features for 5 microcytic cells	1184.14	-0.83507	0.522412	-0.58708	0.347437
	1569.549	0.203232	0.09997	0.174431	0.507506
	1361.907	-2.56932	2.421977	-0.05496	0.262204
	1228.649	-1.05551	2.568563	-0.11925	0.474277
	1277.614	-0.67776	3.03327	0.002146	0.38142

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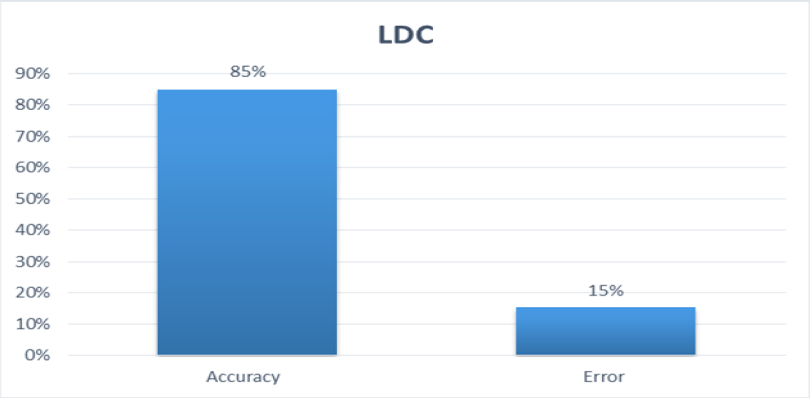

Fig. 6 Result Analysis of LDA Classifier

IV. CONCLUSION

This proposed system successfully demonstrates an automated approach for identifying and classifying red blood cells in microscopic blood smear images using Discrete Wavelet Transform (DWT) for feature extraction and the Linear Discriminant Algorithm (LDA) for classification. By leveraging important morphological properties such as diameter, shape geometric factor, central pallor, and target flag, the proposed method achieves an accuracy of 85%. The results indicate that the integration of DWT and LDA enhances classification efficiency compared to traditional image processing techniques.

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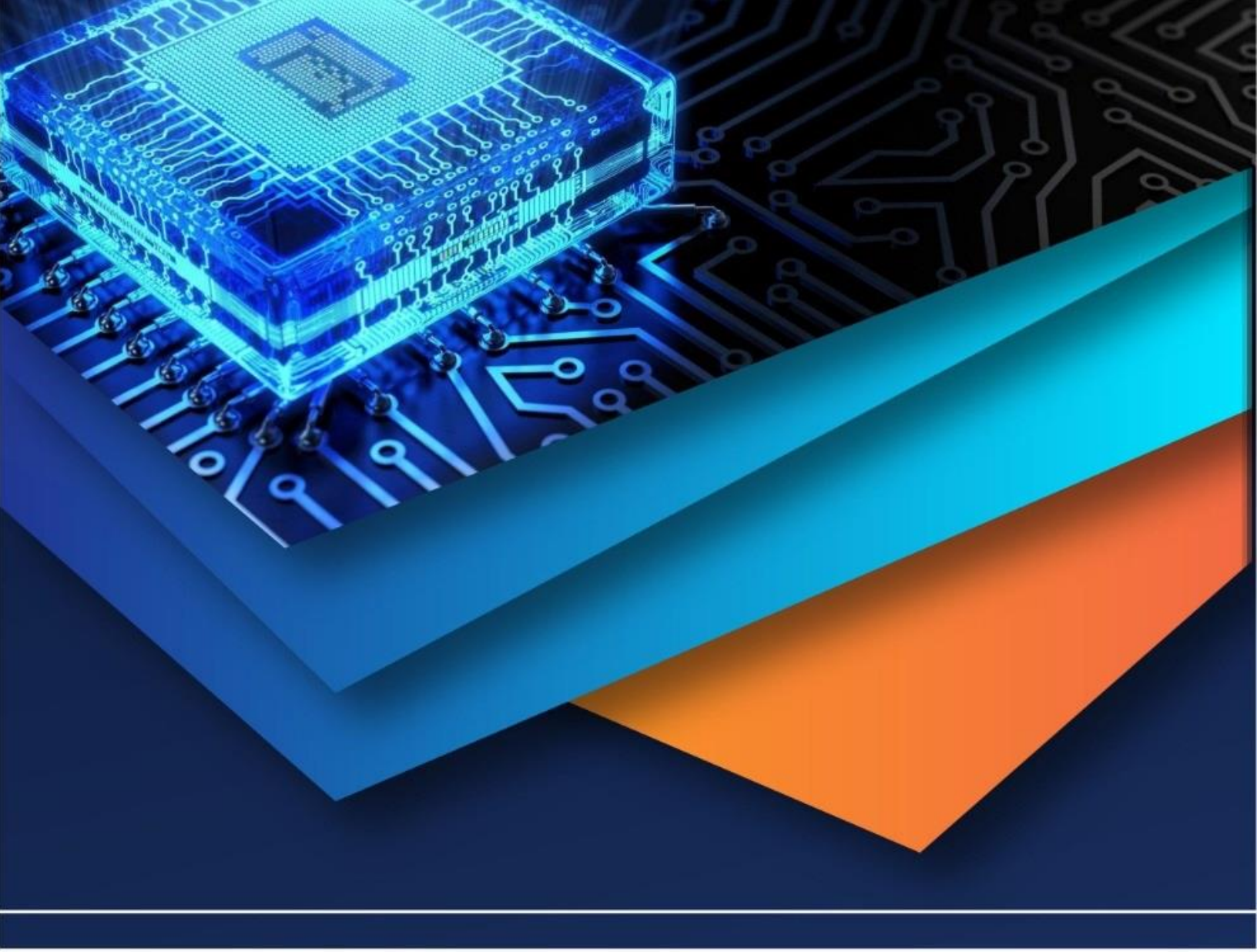

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