World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(REVIEW ARTICLE)

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Advanced classifiers for red blood cell detection: A comprehensive survey

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World Journal of Advanced Engineering Technology and Sciences, 2025, 15(01), 093-097

Publication history: Received on 24 February 2025; revised on 31 March 2025; accepted on 02 April 2025

Article DOI: https://doi.org/10.30574/wjaets.2025.15.1.0177

Abstract

Recently many researchers concentrate on Blood cell segmentation and identification in pattern recognition. The blood cells play a crucial role in assessing health, as blood serves as a key indicator of well-being. The study highlights the impact of normocytic and microcytic red blood cell (RBC) analysis in clinical applications, particularly in diagnosing conditions like leukemia, anemia, and infections. This review paper investigated various techniques for detecting and classifying red blood cells based on their morphological characteristics and image processing algorithms. The red blood cells image samples were used for feature extraction techniques which involve thresholding, edge detection, and morphological operations etc. Pattern recognition system which involves stages like image acquisition, preprocessing, enhancement, segmentation, feature extraction, and algorithm implementation.

Keywords: Red Blood Cell (RBC); Image Processing; Microcytic; Normocytic; Feature Extraction; Classifier

1. 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 new born 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 study 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][16].

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

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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].

This paper is arranged as follows: - Section two which gives the general ides and architecture of generalized pattern recognition system. Section three contributes literature survey on different feature extraction technique, different classification methods and their performance. Finally, section four concluded this paper.

1.1. System architecture

General Pattern recognition system for RBC detection and classification is stated as database, feature extraction, classification and decision. Its structure is illustrated in figure 1.

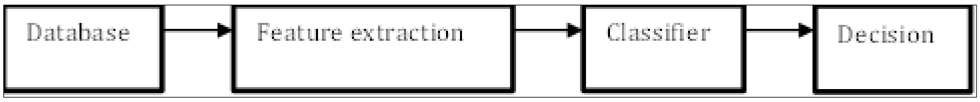

Figure 1 RBC detection and classification pattern recognition system

The essential steps of RBC detection and classification are: Data Acquisition, Preprocessing, Feature Extraction, and Classification. The first stage in of this system is data collection i.e. blood smear images. Input data always contains some amount of noise and certain preprocessing is needed to reduce its effect. Second stage is featuring extraction. A good feature extraction scheme should use and enhance those features of the input data which make distinct pattern classes separate from each other. The classifier uses these features to assign the sensed object to a category [4].

2. Literature review

In recent years, numerous researchers have focused on the identification and segmentation of red blood cells (RBCs) using various pattern recognition methods to diagnose different blood disorders. This section provides a brief overview of previous research papers with highlighting the feature extraction techniques and classifiers they utilized as follows.

Kan Jiang et al. (2006) has worked on “A Novel White Blood Cell Segmentation Scheme Based on Feature Space”; this study extracted color and texture features from blood smear images. Multi-dimensional feature space representation was employed to differentiate white blood cells from red blood cells (RBCs) and background. Gaussian Mixture Models (GMM) were used for feature clustering and enhancement. A Gaussian Mixture Model (GMM) was applied for segmentation and separation of WBCs. The proposed method showed high segmentation accuracy for WBCs compared to traditional thresholding and edge-detection techniques [5].

Nasrul Humaimi Mahmood and Muhammad Asraf Mansor (2012) has worked on "Red Blood Cells Estimation Using Hough Transform Technique"; author converted red blood cell images to the HSV color space, focusing on the Saturation (S) channel to highlight red blood cells (RBCs) and applied morphological operations, including thresholding and morphological techniques, to segment and extract RBCs from the background and other cellular components. Hough transform applied to detect and count circular shapes corresponding to RBCs in the processed images. The method achieved an estimation accuracy of approximately 96% compared to manual counting [6].

Anuja Vane et al. (2016) has studied “Classification of RBCs Using Image Processing to Detect Malarial Parasites”; this study utilized image processing techniques to enhance blood smear images, facilitating better visualization of red blood cells (RBCs) and used segmentation methods to isolate RBCs from the background and other cellular components. Employed morphological operations to refine the shapes of the segmented RBCs, aiding in accurate feature extraction. The study implemented pattern recognition algorithms to classify RBCs as either infected or uninfected by malarial parasites. This proposed system demonstrated high accuracy in detecting malarial parasites within RBCs, offering a reliable tool for early diagnosis [7].

Athira Sreekumar and Ashok Bhattacharya (2014) has experimented on “Identification of sickle cells from microscopic blood smear image using image processing”; in this study, the authors developed a method to detect sickle cells in blood smear images using image processing techniques. The process involved converting images to grayscale, enhancing them, and applying a median filter to reduce noise. Segmentation was performed using a thresholding technique, followed by morphological operations to remove unwanted objects. Features based on color, texture, and cell geometry were extracted, and a computer classifier was trained to assess the images. The study reported an accuracy rate of approximately 90% in identifying sickle cells from microscopic blood smear images [8].

Biplab Kanti Das et al. (2014) has implemented "A New Approach for Segmentation and Identification of Disease Affected Blood Cells"; this study introduced a novel method for segmenting and identifying diseased blood cells in microscopic images. The authors employed morphological filtering to reduce noise in blood smear images, enhancing the quality of the images for further analysis and edge detection techniques were utilized to highlight features of interest, particularly the contours of the nucleus and cytoplasm of blood cells. The approach is useful for detecting various diseases, including leukemia, by analyzing blood cell morphology. The proposed method effectively detected the nucleus and cytoplasm of blood cells, facilitating the identification of disease-affected cells with accuracy of 85% [9].

Mojtaba Taherisadr et al. (2013) has worked on “New approach to Red Blood Cell classification using morphological image processing”; this study involved capturing digital images of Giemsa-stained blood smears using a Nikon DS-Fi1 camera attached to a microscope at 1000x magnification. The paper discusses extracting features related to the shape, internal central pallor configuration, circularity, and elongation of red blood cells. Morphological filtering was applied to reduce noise, and edge detection techniques were utilized to highlight the contours of red blood cells (RBCs). A decision logic was used to classify the various types of red blood cells. The proposed method successfully identified and classified RBCs into 12 distinct types [10].

Magudeeswaran Veluchamy et al. (2012) has studied “Feature extraction and classification of blood cells using Artificial Neural Network”; this paper discusses using morphological operations such as thresholding, erosion, and dilation for segmentation, followed by estimating first and second-order gray level statistics, algebraic moment invariants, and geometrical parameters, which were analyzed to assess their potential in discriminating between normal and abnormal blood cells. A backpropagation neural network was employed to classify the blood cells based on the extracted features. The classification efficiency was reported to be 80% for normal cells and 66.6% for abnormal cells [11].

M. A. Fadhel, et al. (2017) has implemented “Image processing-based diagnosis of sickle cell anemia in erythrocytes”; the paper uses morphological filtering to reduce noise in red blood images, enhancing the quality of the images. Edge detection techniques were utilized to highlight features of interest, particularly the contours of the nucleus and cytoplasm of blood cells. Circular Hough Transform (CHT) applied to detect circular (normal) red blood cells (RBCs) by identifying their circular shapes. Region proposal approach utilized to detect non-circular (sickle-shaped) RBCs by identifying regions that deviate from circularity. By using rule-based classification the system classified RBCs based on shape analysis, distinguishing between normal and sickle-shaped cells without employing machine learning classifiers. This study reported that the system could effectively detect and classify normal and sickle-shaped RBCs [12].

Nicoleta Safca et al. (2018), has studied “Image Processing techniques to identify Red Blood Cells”; the paper uses various image processing techniques such as binarization, contrast enhancement, noise elimination, morphological operations (dilatation, erosion), labeling, and extraction of features like area, perimeter, and diameter. The classification process involves two phases: the first separates red cells into normal and abnormal types, and the second classifies the abnormal cells into three subclasses based on factors like form factor, circularity factor, and deviation factor. This research noted 96% accuracy rate during classification [13].

Ekta Gavas and Kaustubh Olpadkar (2021) has employs “Deep CNNs for Peripheral Blood Cell Classification”; The paper benchmarks 27 popular deep convolutional neural network (CNN) architectures on the microscopic peripheral blood cell images dataset. The dataset is publicly available and contains a large number of normal peripheral blood cells acquired using the cella vision DM96 analyzer and identified by expert pathologists into eight different cell types. The study utilizes a Deep Convolutional Neural Network (CNN) as the primary classifier for categorizing blood cells. The accuracy rate achieved by the CNN in classifying blood cell images was reported to be 99.51% [14].

Muhammad Shahzad et al. (2021) has implemented “Semantic Segmentation of Anaemic RBCs Using Multilevel Deep Convolutional Encoder-Decoder Network”; The study proposed a multi-level deep convolutional encoder-decoder network to preserve pixel-level semantic information extracted in one layer and then passed to the next layer to choose relevant features. This helps in precise pixel-level counting of healthy and anaemic-RBC elements along with morphological analysis. The classifier used in this research is a multi-level deep convolutional encoder-decoder network. The model achieved training, validation, and testing accuracies of 0.9856, 0.9760, and 0.9720 on the Healthy-RBC dataset, and 0.9736, 0.9696, and 0.9591 on the anaemic-RBC dataset. The IoU and BFScore of the proposed model were 0.9311, 0.9138, and 0.9032, 0.8978 on healthy and anaemic datasets, respectively [15].

Manish Bhatia et al. (2023) has studied "A Novel Deep Learning based Model for Erythrocytes Classification and Quantification in Sickle Cell Disease"; the study developed an 18-layer deep CNN architecture specifically designed to extract features from erythrocyte images, focusing on distinguishing between normal and various abnormal morphologies associated with Sickle Cell Disease (SCD). The extracted features were processed through the deep CNN model to classify erythrocytes into three categories: discocytes (normal), oval, and sickle-shaped cells. The proposed model achieved a test accuracy of 81% in classifying the erythrocyte shapes, outperforming other models evaluated in the study [16].

Mohamed Elmanna et al. (2024) has worked on "Deep Learning Segmentation and Classification of Red Blood Cells Using a Large Multi-Scanner Dataset"; the research employs deep learning methods for the segmentation and classification of red blood cells (RBCs). The study implemented a U-Net model for automatic RBC image segmentation and an EfficientNetB0 model for classifying RBC images into eight different classes using a transfer learning approach. The proposed framework achieved an average classification accuracy of 96.5% on the test set [17].

3. Conclusion

This review paper explored automated approaches to enhance the efficiency and precision of RBC classification, which is crucial for diagnosing various blood disorders. The literature review on red blood cell (RBC) identification and segmentation highlights significant advancements driven by image processing, machine learning, and deep learning techniques. Many earlier studies employed traditional image processing techniques like thresholding, edge detection, Circular Hough Transform, Watershed Segmentation, and morphological operations for feature extraction. Feature extraction techniques, including shape, texture, and color-based descriptors, play a vital role in distinguishing healthy RBCs from abnormal ones. Recent studies have also leveraged deep learning-based feature extraction, significantly enhancing identification accuracy. Researcher adopted various methods like watershed algorithms, active contour models, deep convolutional neural networks (CNNs), encoder-decoder networks and region-based segmentation to improve the accuracy and efficiency of RBC segmentation and classification. Overall, the reviewed methodologies demonstrate promising progress in automating RBC analysis, contributing to faster and more accurate diagnosis of hematological disorders.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict-of-interest to be disclosed.

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