

Machine Learning Techniques for the Classification of Blood Cells and Prediction of Diseases

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Abstract — Machine learning is defined as the acquisition of knowledge that is which takes data and learn from the data. The present study contains the classification of the four major components of blood such as RBCs, WBCs, Platelets, and plasma using the machine learning techniques. A complete blood count (CBC) is used to measure the features of the hematological parameters. The blood components and haematological parameters can be changed by some diseases, smoking, medicines and physical problems. Machine learning can detect the infected or distorted cells and then predict the problems and diseases due to the changes in cells and haematological parameters. Machine Learning is a pool of more than 100 classification algorithms, 75 preprocessing methods, 25 feature selection, and about 20 clustering and association rule methods. The study exhibited that the powerful techniques in the machine learning effectively classified, detected and predicted subtypes of blood cells, changes in count, shape, texture, and color of the blood cells. Convolutional Neural Networks and Support Vector Machine provide highly accurate results.

Keywords - Hemetological parameters; RBC; WBC and CNN;SVM

I. INTRODUCTION

Machine learning(ML) is the area of study that provides systems the ability to learn automatically and improve from experience without being explicitly programmed, which is defined as the acquisition of knowledge that is which takes data and learn from the data[1]. The aim of machine learning techniques are increasing accuracy, maximize the performance and its indispensable role in creating self-learning algorithms. Machine learning algorithms are applicable in a wide variety of applications, the varieties of applications are handled by the learning techniques such as supervised, unsupervised, semi-supervised and reinforcement learning[2]. The aim is to enlighten the way of machine learning techniques that used to exhibit the changes in the blood cells by reason of smoking and other diseases. Machine Learning algorithms are efficiently detected and predicted the problems (RBCs, WBCs, Platelet counts) and diseases (blood cancers, malaria, sickle cell anemia and Thalassemia using the blood parameters. Algorithms are effectively classified and segmented from the peripheral blood smear images, even if the images are complex, layered, overlapped and difficult to extract. The diversity shapes of cells such as irregular edges and subtypes of WBCs, distorted RBCs are efficiently classified and provide significant results.

Supervised learning algorithm consists of a dependent variable which is to be predicted from a given set of independent variables. Generate a function that maps inputs to desired outputs using these set of variables. The supervised learning can be mainly divided into two parts, they are classification, which is the organization of labeled data or categorical variable and regression, which is the prediction of trends in labeled data to determine future outcomes. Supervised Learning examples are Regression, Decision Tree, Random Forest, k-Nearest Neighbor, Logistic Regression, support vector machines [3]. Unsupervised learning algorithms input a set of data, and extract the structure in the data, like grouping or clustering of data points. It helps to finds all kind of unknown patterns in data and learns from test data that has not been labeled, classified or categorized and then provides the conclusion of data. In unsupervised learning includes clustering (the pattern analysis and grouping in unlabeled data) and association rule learning problem (to discover rules that describe large portions of the data). Supervised Learning examples are clustering algorithms and neural networks [4]. Semi-Supervised Learning is trained upon a combination of labeled and unlabeled data [5].

Reinforcement learning is all about making decisions sequentially. The input should be an initial state from which the model will start, the training is based upon the input, the model will return a state and the user will decide to reward or punish the model based on its output and there are many possible outputs as there are varieties of solution to a particular problem and the best solution is decided based on the maximum reward [6, 7].

BLOOD COMPONENTS AND HAEMATOLOGICAL PARAMETERS

Blood is a body fluid providing the body with nutrition, oxygen and waste removal. The average human adult has more than 5 liters or 6 quarts of blood in the body. The four main components of blood are plasma, red blood cells, white blood cells, and platelets and it has many different functions including transporting oxygen and nutrients to the lungs and tissues, forming blood clots to prevent excess blood loss, carrying cells and antibodies that fight infection, bringing waste products to the kidneys and liver and regulating body temperature. The blood that runs through the veins, arteries, and capillaries is known as whole blood, a mixture of about 50-55 percent plasma, which is the liquid component of blood, a mixture of water, protein, fat, sugar and salts.

Red blood cells or erythrocytes are the most abundant cell, which carries oxygen to the tissues, accounting for about 40-45 percent of blood volume. Red Blood Cells (RBCs) which form the largest fraction of cells in whole blood (99%) on a microscopic scale. The red blood cell is in biconcave shape with a flattened center. RBC disorders mean changes that affect RBCs. There are different types of RBC disorders, such as Anemia, Red cell enzyme deficiencies, Hemolytic anemia, Red cell membrane disorders, Hemoglobinopathies, Disorders of Heme production, Nutritional anemias, Polycythemia and Hemochromatosis.

White blood cells or leucocytes are part of the immune response, which fight against infections and diseases. WBCs made in the bone marrow and found in the blood and lymph tissue. The different types of WBCs are granulocytes (neutrophils, eosinophils, and basophils), monocytes, lymphocytes (T cells and B cells) and macrophages. Platelets or thrombocytes are irregularly shaped cell fragments, which help the blood to clot. Hemoglobin is the oxygen-carrying protein within RBCs, which efficiently carries oxygen from the lungs to the tissues of the body and helps in the transportation of carbon dioxide and hydrogen ions back to the lungs. The pigment in hemoglobin provides the red color to blood. The increase or decrease in the count in blood cells indicates a disorder such as Leukopenia, Leukocytosis, Neutropenia, Neutrophilic leukocytosis, Lymphocytopenia, Lymphocytic leukocytosis. Disorders of neutrophils and lymphocytes are the most common and monocytes and eosinophils are less common, and disorders involving basophils are rare.

The blood cell disorders and the alteration in hematological parameters are by the reason of many conditions such as extreme physical stress or emotional stress, smoking, pregnancy, or even extreme exercise. One of the dreadful smoke compounds is nicotine, can alter the normal rate of these parameters including, RBC, WBC and hemoglobin count [8, 9]. The alteration in the parameters may cause a greater risk for developing atherosclerosis, cancer, immune diseases polycythemia vera, chronic obstructive pulmonary disease and/or cardiovascular diseases [10]. Hematological parameters are tightly regulated traits with high clinical relevance and influenced by various factors like age, ethnicity, diet, genetics, and gender.

II. ROLE OF MACHINE LEARNING IN BLOOD COMPONENTS AND HAEMATOLOGICAL PARAMETERS

Machine Learning makes the inferences from the available data with mathematical and statistical methods and makes predictions about the unknown with the inferences. Machine learning is one of the best growing fields of computer science with a wide range of applications. Some past academic research has shown that after a certain period, the machines must be learned the data. Resultantly, researchers carried out studies in order to approach various problems by using various methods in machine learning. Machine learning algorithms have the ability to estimate, predict and classify the problems and its parameters.

TABLE I

Ref. no	Author & year	Title of the journal	Methods/ Tools	Merits	Demerits
11	RazaliTomari et al, 2014	Computer-Aided System for Red Blood Cell Classification in Blood Smear Image	Artificial Neural Networks (ANN)	The noises in the RBCs are abolished by utilizing morphological filter and connected component labeling and normal or abnormal RBCs are classified by using Artificial Neural Network (ANN) classifier with 83% accuracy.	Overlapped area reduces the accuracy; to overcome that, can exploit marker-based watershed segmentation with distance transform to improve the detection of the overlapped region.
12	Niranjan Chatap, SiniShib, 2014	Analysis of blood samples for counting leukemia cells	k-Nearest Neighbor, Support Vector	The system should be efficient, reliable, less processing time, smaller error, high accuracy	The diversity of cell shapes is a hurdle to classify the different types of WBCs and

		using Support vector machine and nearest neighbor	Machine (SVM)	(kNN=93%) and must be robust towards varieties that exist in individual, sample collection protocols and time	infected cells.
13	SedatNazlibilek, 2014	Automatic Segmentation, Counting, Size Determination and Classification of White Blood Cells	Neural Networks (NN), Principle Component Analysis	The system automatically counts the white blood cells, determines their sizes accurately and classifies them into five types such as basophil, lymphocyte, neutrophil, monocyte, and eosinophil using NN with PCA (95%)classifiers.	Complex layered cells, irregular edges and the different shapes of WBCs are the challenge to classify the subtypes cells
14	R Shouval et al, 2014	Application of machine learning algorithms for clinical predictive modeling: a data-mining approach in SCT	Decision Trees, Artificial Neural Network (ANN), Support Vector Machine (SVM)	Provided an accurate result in the prediction of stem cell transplantation for disease	Random Fluctuations in Small data set causes inaccurate result.
15	Syed HamadShirazi et al, 2015	Accurate Microscopic Red Blood Cell Image Enhancement and Segmentation	wiener filter, Curvelet transform, The snake algorithm, and Gram-Schmidt orthogonalization	A hybrid segmentation technique used to achieve an accurate result of complex and overlap objects by utilizing the capabilities of Gram-Schmidt orthogonalization and snake algorithm. TheCurvelet transform is used for image enhancement and noise removal.	The most common and dangerous defect of red blood cells is the abnormalities in shape. The segmentation of complex and overlapping objects present in microscopic blood cell images limits the accuracy of the results.
16	Charles B. Delahunt	Automated Microscopy and Machine Learning for Expert-Level Malaria Field Diagnosis	Convolutional Neural Network (CNN), Support Vector Machine (SVM)	CNN and SVM efficiently detects Malaria parasite (Plasmodium falciparum)	The magnitude of the different parasites are different, that make challenges in prediction.
17	RomelBhattacharjee, et al, 2015	Robust Technique for the Detection of Acute Lymphoblastic Leukemia	k-NN, Support Vector Machine (SVM), Artificial Neural Network (ANN)	The study provided high results in white blood cell detection accuracy and in malignancy (Acute lymphoblastic leukemia) classification.	Extraction of cells from a peripheral blood smear image is a tedious task, moreover, it contains so many outliers and inconsistencies in cells.

18	John A. Quinn, 2016	Deep Convolutional Neural Networks for Microscopy-Based Point of Care Diagnostics	Convolutional Neural Network (CNN)	CNN efficiently detects Malaria parasite (<i>Plasmodium falciparum</i>), Tuberculosis, Hookworm cells, and CNN also optimize the layout of the image.	Complex, overlapped cells reduced accuracy and difficult to access data from microscopic blood smear image is depends on the quality.
19	Hany A Elsalamony et al, 2016	Healthy and unhealthy red blood cell Detection in human blood smears using neural networks	Neural Networks, circular Hough Transform and Water Shed Algorithm	The experimental results have demonstrated high accuracy for healthy or unhealthy cells and the algorithm have been detected effective rates of sickle cells (100%), elliptocytosis cells (98%), microsite cells (100%), and cells with unknown shapes (99.3%) and even if cells are hidden, overlapped or ill-shaped using neural networks.	Difficult to get consistent results from visual inspection of cells, because the cell structure is complex.
20	Han Sang Park et al, 2016	Automated Detection of <i>Plasmodium falciparum</i> Using Machine Learning Algorithms with Quantitative Phase Images of Unstained Cells	Linear discriminant classification (LDC), logistic regression(LR), and k-nearest neighbor classification (NNC)	In this study, all methods provide high accuracy (LDC=99.7%, k-NN=99.5%) rates in classification.	The microscopic examination of the cells should be reliable and more morphological parameters can be extracting more information to detect, strengthen performance in distinguishing parasite-infected cells.
21	Syed H. Shirazi et al, 2016	Efficient leukocyte segmentation and recognition in peripheral blood image	Back Propagation Neural Network (BPNN)	An efficient strategy to cell segmentation of images using Wiener filter along with Curvelet transform for image and achieved high accuracy results for five types of blood cells 100%, 96.15%, 92.30%,92.30%, and 96.15%	The segmentation of complex and overlapping objects present in microscopic blood cell images limits the accuracy of the results. Difficult to get consistent results from visual inspection of cells.
22	Mohammed Khalaf, et al, 2016	Machine learning approaches to the application of disease modifying therapy for sickle cell using classification models	Dynamic-Convolutional Neural Network (CNN), Random Forest (RF)	Random Forest Classifier produced the highest levels of overall performance.	Overlapped RBCs in the microscopic image, increased dataset scales on rare cells, diverse Sickle Cell Disease RBC categories are challenging.
23	Jane Hung et al, 2017	Applying Faster R-CNN for Object Detection on Malaria	R-CNN	R-CNN provided 98% of total accuracy.	The microscopic examination of the cells should be reliable and more

		Images			morphological parameters can be extracting more information to detect, strengthen performance in distinguishing parasite-infected cells.
24	MAHDI EH POOSTCHI, et al, 2017	Image analysis and machine learning for detecting malaria		Using SVM and a mix of geometric, color, and texture features, their automatic detection of trophozoites achieved a sensitivity of 80.5%, white blood cell detection achieved 98.2% sensitivity and 72.1% specificity.	Technical problems may arise parasite detection using mobile phones in the study conducted.
25	Muhammad Imran Razzak et al, 2017	Microscopic Blood Smear Segmentation and Classification using Deep Contour Aware CNN and Extreme Machine Learning	Convolutional Neural Network (CNN), Extreme Learning Machine (ELM)	Higher classification accuracy is exhibited for RBC & its abnormalities detection and WBC (94.71% and 98.68%) using CNN and ELM.	The changes in normal RBC shape (biconcave with the central pale area), such as any deviation in cell shape (size, volume) or texture deviation (color) would result in abnormalities in cells that make difference in the accuracy.
26	Mengjia Xu et al, 2017	A deep convolutional neural network for classification of red blood cells in sickle cell anemia	Deep Convolutional Neural Network (dCNN)	Deep CNN classified all ill effected blood cells namely discocytes, echinocytes, elongated, granular, oval, reticulocytes, sickle, and stomatocyte.	Overlapped RBCs in the microscopic image, increased dataset scales on rare cells, diverse Sickle Cell Disease RBC categories are challenging.
27	Alexander Kihm et al, 2018	Classification of red blood cell shapes in flow using outlier tolerant machine learning	Convolutional Neural Network (CNN),	Accurately classified the RBC cells and other ill effected and unhealthy cells using CNN method and the study also reveal the complex fluid behavior of blood depending on the intrinsic properties of single red blood cells.	The diversity in erythrocytes like shape or texture deviation would result in abnormalities in cells that make a difference in the accuracy.
28	J. Rodellar et al, 2018	Image processing and machine learning in the morphological analysis of blood cells	Neural networks, decision trees, and support vector machines (SVM).	The research investigated in better feature extraction, classification and segmentation of abnormal cells.	Improved analysis of cells and establishments such as flow cytometers provides more accurate results in the classification of abnormal cells.
29	Taesik Go et al, 2018	Machine learning based in-line holographic sensing of	Support Vector Machines (SVM),	The research investigated accurately to discriminate hRBCs and iRBCs by integrating the DIHM	Both technological and methodological factors may influence the dataset because

		unstained malaria-infected RBCs	Logistic Regression, QDC, LDC, tree, and k-nearest neighbor classification	(digital in-line holographic microscopy) system and machine learning algorithms and the classification model trained by the SVM exhibited high classification accuracy (96%) for the training and testing sets.	the data extracted from the holographic microscopic image and poor feature extraction method affect the results significantly.
30	WeidiXie et al, 2018	Microscopy cell counting and detection with fully convolutional regression networks	Convolutional Neural Network (CNN), Fully Convolutional regression networks (FCRN)	The study used FCRNs for regressing density maps and also for both cell counting and detection tasks and the images are capable to extend the information has been encoded different layers.	The diversity of cell shape and overlapping cell clumps are the biggest challenges in density map prediction tasks.
31	Syed HamadShirazi et al, 2018	Extreme learning machine based microscopic red blood cells classification	Support Vector Machine (SVM), Extreme Learning Machine (ELM)	The ELM classifier has exhibited improved accuracy of results by increasing the number of hidden neurons with accuracy (94%), sensitivity (96%) and precision (95%).	The microscopic images of cells and tissues contain overlapping cells influence the results.
32	Fatimah Al-Hafiz et al, 2018	Red blood cell segmentation by thresholding and Canny detector	TCD algorithm	An automatic segmentation algorithm exhibited an average accuracy rate of 87.9% in red blood cell dataset.	Failed to detect the cell edges and the segmentation of complex and overlapped cells.
33	Hajara Abdul karimAliyu, 2018	Red Blood Cell Classification: Deep Learning Architecture versus Support Vector Machine	Support Vector Machines (SVM), Deep Learning	The major advantage of the study is that SVM classifier can classify the cells in all condition either small or large dataset and provide highly accurate results, while deep learning performs mainly on a huge dataset.	The most threatening effect of the RBCs is its shape abnormality, which arises associated with diseases anemia, malaria, and leukemia.
34	AshikurRahman, 2018	Automatic Detection of White Blood Cells from Microscopic Images for Malignancy Classification of Acute Lymphoblastic Leukemia	K-NN, Support Vector Machines (SVM), Decision Tree, Watershed segmentation.	The study provided high results in white blood cell detection accuracy of 93% and a malignancy (Acute lymphoblastic leukemia) classification accuracy of 93.6%.	Extraction of cells from a peripheral blood smear image is a tedious task, moreover, it contains so many outliers and inconsistencies in cells.
35	Liqun Lin et al, 2018	Leukocyte recognition with convolutional neural network	Convolutional Neural Network (CNN), K-means	The higher classification accuracy reached a maximum of 98.96%, and the average classification time is 0.39 s using CNN.	The diversity of cell shapes in WBCs subtypes and overlapping cell clumps are the biggest challenge in density map prediction tasks.
	SimgeÇel	Red and white	Artificial	The study accurately	The factors affecting

36	ebi and MertBurkayÇötelı, 2018	blood cell classification using Artificial Neural Networks	Neural Network (ANN)	Segmented the blood Cells from a PBS Image, classified 6 types of Blood Cells and also detected abnormality in cells using ANN. The Segmentation and Classification are used with the help of Monte-Carlo sampling through the whole microscope slide.	the efficiency is smearing quality and markers used for PBS. So the efficient technique must be followed in Peripheral Blood Smear (PBS) image preparation.
37	PrayagTi wari, 2018	Detection of Subtype Blood Cells using Deep Learning	Convolutional Neural Network (CNN), Naive Bayes, Support Vector Machine (SVM)	Improved classification of blood cells and the proposed CNN based model is Double Convolutional Layer Neural Network (DCLNN) is competing to SVM and Naive Bayes in all aspects with the baseline approaches.	Some of the rare subtypes of blood cells (basophil) couldn't get for classification.
38	XinZhen ga et al, 2018	Fast and robust segmentation of white blood cell images by self-supervised learning	Support Vector Machines (SVM)	Improved segmentation accuracy and efficiency and a fast touching-cell splitting algorithm, an effective cluster sampling strategy, and improved detection on the edges or boundaries using a novel weak edge enhancement operator (WEEO).	The diversity in subtypes of WBCs makes difficulty to extract the image and for segmentation.
39	Alan R. Andrade et al, 2019	Recent Computational Methods for White Blood Cell Nuclei Segmentation: A Comparative Study	Clustering Algorithms	The segmentation algorithms achieved average accuracy values higher than 97%, with an excellent kappa index.	The diversity of shapes causes the difficulty in segmenting leukocytes (especially neutrophils and eosinophils). The irregular edges and overlapping cells affect the segmentation.
40	Abdullah Elen et al, 2019	Classifying White Blood Cells Using Machine Learning Algorithms	Decision Tree, Multinomial Logistic Regression (MLR), Random Forest, k-Nearest Neighbor, Naive Bayes, Support Vector Machine	The Multinomial Logistic Regression (MLR) algorithm performed better average 95% test success.	The statistical and geometric characteristics were used to classify leukocyte cells, the fluctuations in the cell shape, texture and color influence the accuracy of classifiers.
41	Roopa B. Hegde et al, 2019	Comparison of traditional image processing and deep learning approaches for	Neural Network, Convolutional Neural Network	Efficiently classified 6 types of WBCs with an accuracy rate of 99% were obtained for full training CNN.	CNN is suitable for smaller sized images rather than resized larger images to the smaller size, reducing

		classification of white blood cells in peripheral blood smear images	(CNN)		the size of images may cause loss of information.
4 2	A.I. Shahin et al, 2019	White Blood Cells Identification System Based on Convolutional Deep Neural Learning Networks	Convolutional Neural Network (CNN)	The overall system accuracy achieved by the proposed WBCs Net is (96.1%) and classified 5 healthy subtypes.	Clarity and size of the microscopic images affect the accuracy. The varied shapes of WBCs subtypes are also challenging.
4 3	Deepak Gupta et al, 2019	Optimized Binary Bat Algorithm for classification of White Blood Cells	Decision Tree, k-Nearest Neighbor (k-NN), Random Forest, Logistic Regression	The work suggested an algorithm, has been implemented on a dataset of White Blood Cell images with an average accuracy of 97.3%.	Any variation from the average size, maturity or number of healthy blood cells pointing various hematological diseases, the proper detection and classification of such cells are obstacles in the study.
4 4	TatdowPansombut et al, 2019	Convolutional Neural Networks for Recognition of Lymphoblast Cell Images	Convolutional Neural Network (CNN), Support Vector Machines (SVM), Multi Layer Perception (MLP), Random Forest (RF)	The study shows that CNN classifier delivers better performance to identify normal lymphocytes and pre-B (B-lymphoblastic leukaemia) cells.	Difficult to get consistent results from visual inspection of cells due to the overlapped and complex structure of cells.
4 5	Qiwei Wang et al, 2019	Deep learning approach to peripheral leukocyte recognition	Convolutional Neural Network (CNN)	Exhibited the best generalization accuracy of 90.09% using CNN.	No sufficient studies in expand cell types and fine-grain recognition, especially abnormal leukocyte types.

With the above references, all the problems used machine learning techniques such as Artificial Neural Networks, Convolutional Neural Network, Decision Tree, Support Vector Machine, Multilayer Perception, Random Forest, k-Nearest Neighbor, Naïve Bayes, and Logistic Regression. Each technique used with respect to the functionality to study on classification, detection, and prediction of cells abnormality, counting, and disease prediction. For example, the Decision Tree can classify data by continually dividing the dataset according to a certain criterion and the Random Forest algorithm combines the decisions of many multivariate trees, each trained in different sets of training and solves classification problems. The Support Vector Machine is the indispensable machine learning algorithm, mainly designed to solve binary classification problems and based on the principle of structural risk minimization and based on convex optimization. In the classification process, the user-defined tree is primarily created. One of the most basic pattern recognition and classification methods is k-NN, which classify objects conforming to the nearest training instances. Regression analysis is one of the excellent methods in statistics, used to determine the relationship between two or more variables with cause-effect relationship and to make predictions on the subject with the relationship and Logistic regression (LR) is a nonlinear regression model

commonly used in machine learning, designed for two dependent variables. Multilayer Logistic Regression (MLR) is used to describe relationships between the dependent variable and independent variables.

III. CONCLUSION

The blood cell disorders and the alteration in hematological parameters and indices arise by the reason of many conditions such as extreme physical stress or emotional stress, smoking, pregnancy, or even extreme exercise. Machine learning techniques are stand out in classification, segmentation, detection, and prediction of blood components and parameters. The references made known the different types of machine learning techniques implemented in blood components to identify the types and subtypes and the classifications and segmentation of blood cells from the peripheral blood smear images. In future enhancement, it will be necessary to consider the quality of PBS images and complex- overlapped cells.

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