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Detection and Classification of Leukocytes in Bone Marrow Images Using ARTMAP Neural Network

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***Abstract*—** This paper provides a model-based tracking framework for classifying the leukocytes in bone marrow images. Detecting and classifying the leukocytes is an established problem in image analysis and machine learning. This system aims to automate the process of detecting, differentiating and classifying the leukocytes. The process of automatic recognition requires the extraction of individual cells, generation of features and finally the classification using ARTMAP Neural Network classifier.

For many illnesses, classifying the blood cell is used as a diagnostic technique in the detection of many illnesses, particularly leukemia. This system uses two phase methodology. The first phase includes the preprocessing methods of the bone marrow images. The second phase, classifies these features using pattern recognition techniques into a number of given families. This system uses the ARTMAP Neural Network classifiers for characterizing different types of cells.

***Keywords*—** Classifier, ARTMAP, Neural Network

I. INTRODUCTION

Biomedical Informatics has recently been in the forefront of research and development due to its potential in disease diagnosis, discovery and classification. The requirement for converging of the organic sciences with the universe of software engineering has for the most part emerged because of the immense measure of data from the genetic material. Detection and classification of blood cells is an issue in image analysis and AI. This classification of leukocyte is important since it is used for diagnosing many diseases, particularly leukemia. This paper focuses on automating the classification of leukocytes in bone marrow images using the digital image processing and neural networks.

In the present day, medical field produces a huge amount of heterogeneous information day by day. For instance, the medical information may contain SPECT pictures, signals like ECG, quality capacity examines, Electronic Medical Records EMR, DNA sequencing, clinical data like temperature, cholesterol levels, and so forth., just as the doctor's understanding. Automated methods are expected to assist people with tending to this issue. As an ever increasing number of medical procedures utilize imaging as a favored indicative apparatus, there's a prerequisite to create strategies for proficient mining in databases of images.

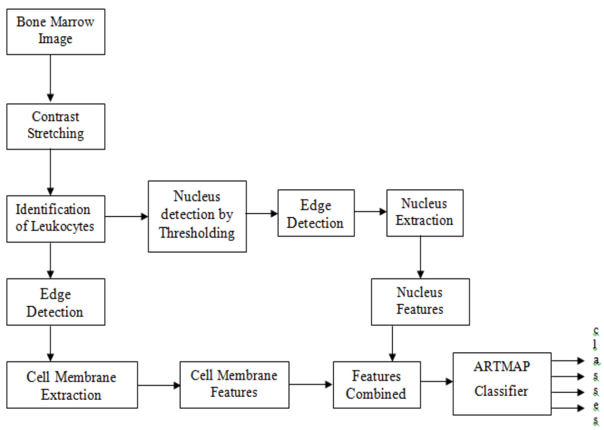

Figure 1: The modules of the classification system

Importantly, we can see that the medical domain has an important social contributions since its solution have a beneficial impact on human being and their welfare. Most of the physicians are having problems while diagnosing the illness. For this situation, they need to take care of the issue of reasoning certain sicknesses or detailing a treatment dependent on perceptions and information about related medical field. For this need in bioinformatics, we propose the use of ART neural networks.

II. RELATED WORK

Gail a. Carpenter, Stephen Grossberg and John h. Reynolds [7] proposed the classification of Nonstationary Data. They used ARTMAP: Supervised Real-Time Learning and Classification algorithm, which has two modules ARTa and ARTb. Based on their online and offline stimulations, the ARTMAP system's learning is self-stabilizing and is an self-organizing expert system.

Chen Pan, Xiangguo Yan, and Chongxun Zheng [9] proposed a classification method for Recognizing the blood and bone marrow cells using kernel-based image retrieval. The features of the cell is extracted from the Kernel Principal Component Analysis. They have used Support Vector Machine for the classification and have achieved 90.5% classification accuracy.

Carolina Reta1,Leopoldo Altamirano1, Jesus A. Gonzalez1, Raquel Diaz-Hernandez1,Hayde Peregrina1, Ivan Olmos, Jose E. Alonso, Ruben Lobato [8] proposed a methodology for the detection of Acute Leukemia. They have used the cell separation algorithm to categorize the overlapped cells. They recommend the classifiers like k-Nearest Neighbor , Random Forest, Simple Logistic, Support Vector Machines, and Random Committee, as they give better results for classifying the acute leukemia cells.

III. DDETECTION OF LEUKOCYTES

The first stage in this system is the image preprocessing. Image processing in this system involves cell segmentation. Segmentation includes the way towards dividing the image into different regions. The point of division is to find the objects and their boundaries to easily analyze the image. Each cell is segmented into two regions: nucleus and cell membrane. From the nucleus and cell membrane regions, a set of quantitative parameters are calculated. This paper focusses on separating each of the leukocytes in two steps. In the first step, we process the cell membrane and in the next step we process the nucleus.

A. CELL MEMBRANE EXTRACTION:

To identify the leukocytes in the blood images, the adaptive pre-filtering and the segmentation process is done. The input is an image, in which the contrast stretching filter is applied in order to highlight only the leukocytes from the image. Then the Edge detection mechanism is used to trace the external and the internal boundaries of the cell. After which the dilation is used to connect the separated points of the perimeter and this makes the cell as the connected item.

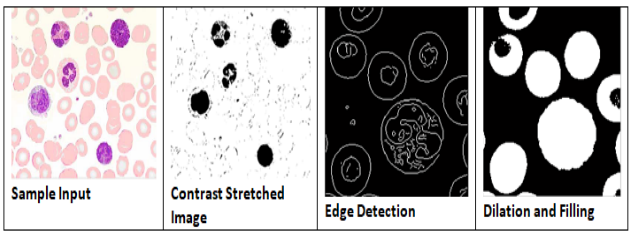

Figure 2: Cell Membrane Extraction

B. NUCLEUS EXTRACTION:

The second step is extracting the internal part in the cell, called Nucleus. Here again, the Contrast stretching filter is applied to extract the Nucleus. To differentiate between the Nucleus and Non-Nucleus regions, a threshold value is set. Next the Edge detection mechanism is used to trace the boundaries of the Nucleus. After which the Dilation and the Filling is used to make the nucleus as a connected item.

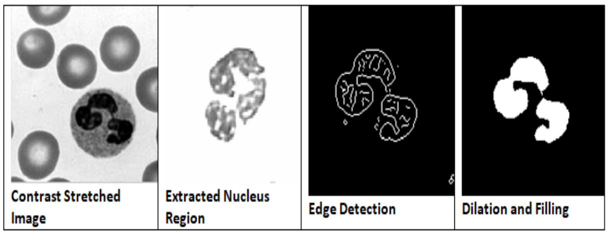

Figure 3: Nucleus Extraction

C. FEATURE EXTRACTION :

Now each cell has been segmented into two regions: nucleus and cell membrane. A good descriptive features are needed to classify each cell. Therefore, from the extracted nucleus and cell membrane images, a set of quantitative parameters like Perimeter, Area, Filled Area, Length, Eccentricity, Convex Area, the number of lobes are calculated to classify the leukocyte.

IV. TTHE ARTMAP SYSTEM

The proposed model for the leukocyte classification process is designed with ARTMAP neural network architecture. ARTMAP, the family of supervised learning ART networks built up from a pair of Adaptive Resonance Theory modules. ART_a and ART_b are the pair of Adaptive Resonance Theory modules. These modules are connected via, an inter-ART associative memory. This associative memory is defined by a map field F_{ab}. This map field is used to control the learning from ART_a to ART_b recognition categories. Since the adaptive resonance theory is a supervised predictive mapping model, the first phase will be the training phase. During this phase, the ART_a module receives the input pattern a(p) and the ART_b module receives the pattern b(p) , which is the correct prediction. Now all the three modules learn and finds its resonating category *K*. The map layer is associated with a vigilance parameter ρab. The module then performs the dynamics of ART_a and finds its resonating category *J*. Then the map field match function is computed and the vigilance test is performed. If the vigilance test is true then the map filed is updated. During the inference phase, the ART_a module receives the input pattern a(p). Then the degree of association with the ART_b is computed. If ART_a's resonant category *J* is found then predicted class *K* is obtained. It achieves these properties by using an internal controller that conjointly maximizes predictive generalization and minimizes predictive error by linking predictive success to category size on a trial-by-trial basis, using only local operations. A schematic of the ARTMAP is shown in Figure -4.

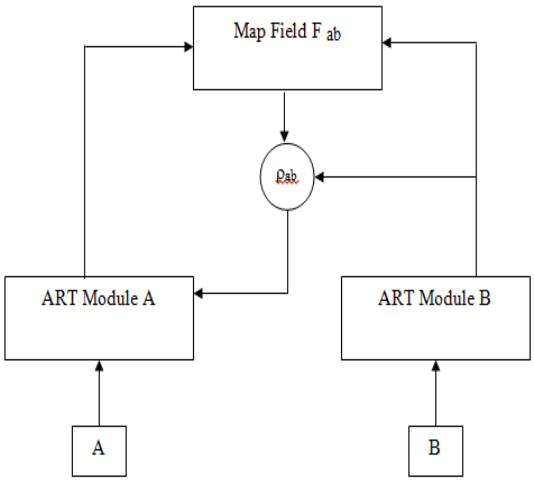

Figure 4: The ARTMAP System

A. CLASSIFICATION METHODOLOGY:

The classification procedure for training and evaluating requires a set of known patterns for training the classification. This classification then needs an external teaching procedure. Each of the training pattern is assigned with weights. The system will adapt with the weights according to the response from the network to the training patterns. The weight is proportional to the amount of the error when classifying the input pattern. The supervised learning model has two phases: a training phase and a performance phase.

In the training phase, the model is trained with a set of sample bone marrow images. The training set must consist of sample patterns from all the classes being categorized. The inputs to the ARTMAP model is the cell membrane extraction features and the nucleus features. These training patterns is given as the inputs to ART_a module and the predicted pattern is given as input to the ART_b module. During the training phase, the system learns the patterns and the corresponding category. Once acceptable results have been obtained from the training phase, the network may be used in the performance phase.

In the performance phase, an unknown pattern is given as the input to the ART_a module. Now the neural network will perform the recognition task for which it is trained.

B. CLASSIFIER EVALUATION:

This section computes the average performance statistics of training subsets. Classifier evaluation measures includes the hits and false rates for each class, overall accuracy. The confusion matrix is used to compare the performance of a classifier. Using Confusion matrix we can visualize the results of the Classification Algorithm.

A confusion matrix contains information about actual and predicted classifications done by a classification system. Performance of such systems is usually evaluated using the information within the matrix. The confusion matrix for this leukocyte classification is depicted in the Table- 1.

The meaning of the class labels are as follows:
(1)Basophil
(2) Immature Basophil
(3) Eosinophil
(4) Immature Eosinophil
(5) Neutrophil Promyelocyte
(6) Neutrophil Band
(7) Neutrophil Metamyelocyte
(8) Neutrophil Myelocyte
(9) Neutrophil
(10) Monocyte
(11) Immature Monocyte
(12) Lymphocyte

Table 1: The Confusion Matrix for leukocyte Classification

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)		
45	0	0	0	0	0	0	0	0	0	2	3	(1)	Basophil
0	52	0	2	0	0	0	0	0	0	3	2	(2)	Immature Basophil
0	0	32	0	0	0	0	0	3	0	0	0	(3)	Eosinophil
0	0	0	52	0	0	0	0	0	0	1	1	(4)	Immature Eosinophil
0	0	0	0	10	1	1	2	0	0	0	0	(5)	Neutrophil Promyelocyte
0	0	0	0	1	11	2	0	0	0	0	0	(6)	Neutrophil Band
0	0	0	0	0	1	9	0	0	0	0	0	(7)	Neutrophil Metamyelocyte
0	0	0	0	0	2	2	12	0	0	0	0	(8)	Neutrophil Myelocyte
0	0	1	0	0	0	3	2	42	0	0	0	(9)	Neutrophil
0	0	0	0	0	0	0	0	0	10	0	0	(10)	Monocyte
3	1	0	0	0	0	0	0	0	2	43	0	(11)	Immature Monocyte
2	0	0	0	0	0	0	0	0	2	1	11	(12)	Lymphocyte

V. EXPERIMENTAL RESULTS

ARTMAP model has been used and it is seen that the instances of class basophil have a probability of 45/50 (90%) of being classified correctly and the remaining being classified as immature monocyte and lymphocyte. The class monocytes has been classified correctly. The best classification accuracy appears in the class monocyte. Neutrophil bands are correctly classified with 86% and the reminders are misclassified as neutrophil promyelocyte and neutrophil metamyelocyte.

The most common confusion occurs in the class neutrophil band, neutrophil promyelocyte, neutrophil metamyelocyte, neutrophil myelocyte. Immature cells or blasts in the blood are also classified with more than 85% accuracy. However, in bone marrow, neutrophil myelocytes, neutrophil promyelocytes, neutrophil band classified wrongly in about 21% of the cases. The reason is mainly because the cells in bone marrow can be deformed to any arbitrary shapes due to the environment pressure. The number of available learning and testing data vary with different classes. From the Table-2, accuracy in recognizing different cells is changing and also it depends on the type of cell and on the actual number of data used in learning.

Table 2: Experimental Results

Class	Learning Data	Misclassified	Test Data	Misclassified
Basophil	50	5	46	3
Immature Basophil	59	7	60	5
Eosinophil	35	3	34	1
Immature Eosinophil	54	2	54	1
Neutrophil Promyelocyte	14	4	10	1
Neutrophil Band	14	3	12	2
Neutrophil Metamyelocyte	10	1	11	1
Neutrophil Myelocyte	16	4	13	2
Neutrophil	48	6	37	2
Monocyte	28	0	18	1
Immature Monocyte	49	6	45	3
Lymphocyte	14	3	10	1

VI. CONCLUSION

To automate the system for the detection and classification of leukocytes from microscopic images, we started with the detection of leukocytes by extracting the cell membrane and the nucleus separately. The image processing techniques using MATLAB was applied. Then the features are extracted. Later the ARTMAP module is trained with sample patterns and was used for the recognition and the classification of cells. This helps the discovery of the leukocyte cell classification. The computational efficiency of ARTMAP is good. The ARTMAP classifier is a good self-learning algorithm, with the trained patterns, the classifier was able to classify the leukocyte cells. It also has the ability to retain the previously learned patterns In future, we can still fine-grain the recognition process for classifying the abnormal leukocyte types.

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