The Use of the Wavelet Transform for the Formation of the Quantitative Characteristics of the Blood Cells Images for the Automation of Hematological Diagnostics

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Abstract: The light microscopy method is widely used in the diagnosis of the neoplastic diseases of the blood system. The experience and qualifications of the physician have a significant role in the outcome of microscopy studies of blood cells. But sometimes there is a dispute among experts on the identification of cell types. For this reason, the objectification of the blood cells description is an actual problem. One of the essential features in the classification of immature blood cells (e.g. blast cells) is a type of chromatin structure in the nucleus of these cells. The quantitative description of the blood cells images with using the wavelet analysis is discussed in the article. The description models on the basis of wavelet functions Haar, Daubechies, Cohen-Daubechies-Feauveau were studied. The selection of blood cells with different chromatin structure was formed to assess the effectiveness of the proposed models. The quantitative features were identified for the greatest discernment of the chromatin structure according to the results of the experiments. The proposed approach can be used to automate the diagnosis of hematologic diseases.

Keywords: blood cells classification, chromatin, wavelet transform, digital image processing.

1 Introduction

The blood test is one of the most common tests performed in the diagnosis of diseases. The automated hematology analyzers are used frequently in clinical diagnostic laboratories for these tests. Modern hematology analyzers allow to define up to 32 characteristics of blood. These characteristics include differential count of five major types of white blood cells: lymphocytes, monocytes, neutrophils, basophils, eosinophils. But even the most modern hematology analyzers are not able to replace microscopic research method, when you need to perform morphological analysis of blood cells, which is especially important in neoplastic diseases of the blood system, such as leukaemia and lymphoma.

The difficulties in blood cells correct classification take place due to the high variability of morphological characteristics of abnormal blood cells. Therefore, the results of the morphological examination of blood cells in the visual microscopic analysis depends on the experience and qualification of the doctor conducting the study. For this reason, the objectification of the blood cells description is an actual problem. In this task we can distinguish two directions. First direction is creation of making decisions support systems based on expert knowledge. Second direction is automated systems of computer microscopy [1-3].

Many researchers have considered the problem of classification of typical blood cells, but the automatic classification of immature forms of blood cells is studied insufficiently [4, 5].

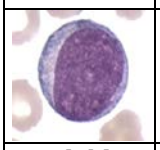
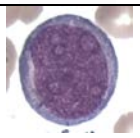
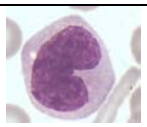
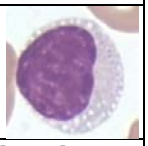
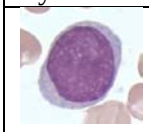
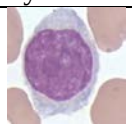
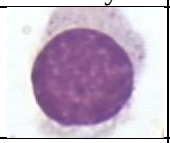
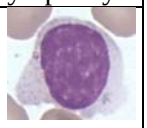
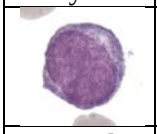
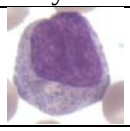
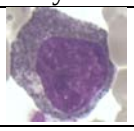
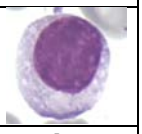
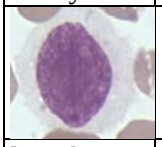
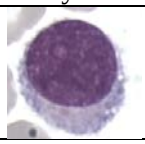
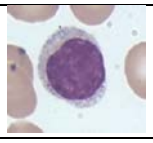
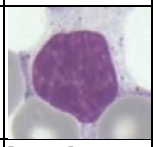
The present article is devoted to the development of models describing images of blood cells (including immature and pathological forms) for the systems of automated diagnosis of diseases of the blood system.

2 Problem Formulation

When the doctor performs microscopic examination of a blood smear it pays great attention to the assessment of chromatin structure in the nucleus along with commonly used features of shape, size and colour of cytoplasm and cell nuclei to classify immature forms of cells. The coarseness of chromatin is the one of the qualitative features used by doctors. In this case they consider up to 5 grades of coarseness - from gentle to coarse chromatin. In our study we used a selection of blood cell images, which was divided into 4 groups corresponding to

different degrees of coarseness of chromatin: gentle, gentler medium, medium, coarser medium. Table 1 presents examples of blood cells of different types, which are related to one of these groups.

Table 1.

The chromatin structure type			
gentle	gentler medium	medium	coarser medium
			
myeloblast	myeloblast	monocyte	lymphocyte
			
prolympho-cyte	prolympho-cyte	prolympho-cyte	lymphocyte
			
promyelo-cyte	promyelo-cyte	Myelocyte	lymphocyte
			
lymphocyte	lymphocyte	lymphocyte	lymphocyte

Digital microscopic images of blood smears from different patients with different pathologies were used as the source data for the study. Images were formed with the use of a microscope lens with a 100 fold increase (it corresponds to 1000 fold increase in the visual observation through the microscope eyepieces). The photographed blood cells were presented to the medical experts. They performed the cells assessment for determination chromatin coarseness rating. Table 2 presents characteristics of the cells selection used in this study.

It should be noted, that differences in coarseness of chromatin between cells belonging to adjacent groups of coarseness are conditional. There is not a sharp boundary between types of coarseness. And the assignment to one or another type of coarseness of chromatin is subjective.

The some types cells are inherent in a wide range of changes in the characteristics of the chromatin coarseness. For example, different lymphocytes can be characterized by coarseness of chromatin from the entire range - from gentle to coarse. While the immature forms of white blood cells (for example, the myeloblasts) have more gentle structure of chromatin compared with mature cells.

Table 2.

Chromatin coarseness	Number and type of cells
gentle	3 lymphocyte 139 myeloblast 1 prolymphocyte 34 promyelocyte
gentler medium	20 lymphocyte 20 myeloblast 13 prolymphocyte 15 promyelocyte
medium	20 lymphocyte 13 myelocyte 27 monocyte 36 prolymphocyte 1 promyelocyte
coarser medium	27 lymphocyte

In order to eliminate the subjectivity in the assessment of the characteristics of chromatin structure we propose to use methods of digital image processing, allowing to calculate the quantitative characteristics of coarseness of chromatin in the blood cells.

In fact the image of the blood cell nucleus can be attributed to textural images. A various approaches are used to describe the texture images in practical applications. Some of them are Fourier transform, spatial adjacency matrix, the matrix of the lengths of the series and others [6-10]. All of them are associated with the analysis of the spatial brightness distribution of the image points (or of the values of colour component for a colour images).

The wavelet transform is one of the tools to study the structure of the signal [11-17]. The effectiveness of such analysis depends on the type of wavelet functions and methods for the interpretation of the received set of coefficients after wavelet transform.

The objective of this study was to determine a model of calculation of the quantitative characteristics of chromatin structure on the basis of wavelet transforms, which would allow cells to divide into groups corresponding to the qualitative evaluation of the coarseness of chromatin.

3 Problem Solution

The obtained images of blood cells had been digitally processed in the following way. The image

segmentation was performed on the first stage. The cells nuclei were allocated in result.

The wavelet transform of selection region was performed on the second stage. The colour components for different colour models RGB, XYZ, HSL, Lab, Luv, LHC, HLS, HSV, YUV, YIQ, YCbCr, CMY were applied. Five types of functions - Haar, Daubechies 2-nd, 4-th and 8-th order and function Cohen-Daubechies-Feauveau 9/7 were used as a basis of wavelet functions. After performing the wavelet transform of images of the nuclei of blood cells for each of the 4 frequency bands the calculation of 14 of the generalized characteristics was carried out [18].

The most effective pair of signs was searched for on the criterion of minimum error classification type of chromatin structure on the third stage. Classification was performed using the method of comparison with the standard using Manhattan metric.

As a result two signs of coarseness of chromatin structure were found. The first sign X is value of the inverse of the entropy for the wavelet transform using Haar functions for the colour component Magenta of colour model CMY for first frequency band, the second sign Y is inverse wavelet variance-factor for first frequency range, using wavelet functions Cohen-Daubechies-Feauveau 9/7 and the colour component Yellow of CMY colour model. Numerical results of the analysis are shown in Table3.

Table 3.

№	Chromatin coarseness	1-st type error percentage	2-nd type error percentage
1	gentle – gentler medium	20	19
2	gentler medium – medium	27	40
3	medium- coarser medium	16	22
4	gentle – medium	9	17
5	gentler medium – coarser medium	4	13
6	gentle – coarser medium	3	0

It should be noted, that the selected features can be quantitatively reflect the change in the "coarseness" of the chromatin. It may be, the errors in the assignment of cells to neighboring classes coarseness of chromatin reflect errors made by the physician due to the subjectivity and lack of clear criteria for separation of cells by type coarseness of chromatin. The chromatin structure of cells of neighbouring coarseness groups is similar visually, so it is possible, cells with objectively different coarseness of chromatin could be referred by the doctor to one group of coarseness.

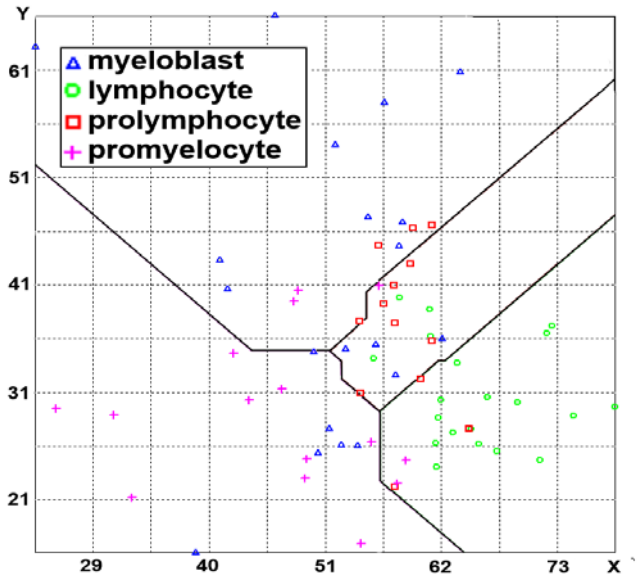


Fig. 1. Classification of 4 types of cells with the structure of chromatin gentler medium in a feature space X Y.

Analysis of the distribution of blood cells belonging to different cells types with the same type of chromatin structure in the space of features showed, that objectively quantitative characteristic values of cells of different types with the same structure of chromatin form markedly different clusters, which suggests, that subjectively assessed the same chromatin structure for different cells types has differences objectively (Fig. 1).

4 Conclusion

Preliminary results on the evaluation of the effectiveness of the wavelet transform for the classification type of the chromatin structure of blood cells are received. The study shows that using wavelet features for describing the characteristics of blood cells for automatic classification can improve the efficiency of classification of atypical and immature forms of cells, that will ultimately improve the quality of diagnosis of hematologic diseases. Further researches with a more representative selections of cells are needed. Other aggregate characteristics on a set of coefficients obtained by the wavelet transformation of images of blood cells needs to be investigated.

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