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Wavelet Analysis and Contrast Modification in the Study of Cell Structures Images

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ABSTRACT

Image processing is one of the data analysis tools. It is also a tool for getting more information. Such a tool occupies a special place for data research in the field of medicine. The imaging of cellular structures is an important example of medical data. The article describes the procedure for analyzing images of cellular structures. This procedure includes: changing the contrast of the image and using wavelet analysis to highlight the edges of objects in the image. Examples are given. The efficiency of the considered procedure is shown in comparison with classical methods.

Key words: Wavelet Analysis, Contrast Modification, Prewitt Operator, Roberts's Operator, Image Processing, Cell Structures Images.

1. INTRODUCTION

A cell of any human organ is the subject of research in various fields of biology and medicine. This is due to the fact that the cell contains a lot of information about the state of human health. Then the analysis of the cell helps to early diagnose a possible disease. Cell analysis methods can be different. One of such methods is cell image analysis [1]-[3]. This method allows you to visualize and understand the processes that take place inside the cell.

Cell images can be obtained using an electron microscope and are intended for further study and research [4]. In this case, both the image of one cell and the image of many cells can be considered. In both the first and second cases, such images can be called cellular structures, since they represent a complex organization of living objects. An example of such cellular structures is [5]-[7]:

an image of a blood smear, where leukocytes, erythrocytes and blood plasma are isolated;

the image of histological preparations, where you can see sick and healthy cells;

image of cells of internal organs.

Thus, different images of cellular structures can be viewed. Various image analysis techniques and algorithms are used to understand such images. The selection of the most effective methods for image analysis is a subject of ongoing research. This is due to the possibility of such analysis in real time, the need to obtain the most adequate and effective results. We can also get more information. These and similar issues are discussed in this article.

2. REVIEW OF THE LITERATURE

There are many studies that discuss the processing and analysis of cellular structures images.

In [8], visualization and analysis of the dynamics of cellular structures are discussed. In particular, the article considers images of erythrocytes and analyzes the dynamics of changes in erythrocytes. This is important for understanding the properties of the plasma membrane.

J. Dabass and R. Vig discuss improving the quality of medical imaging [9]. At the same time, the authors emphasize that improving the quality of medical images is a challenge. This is due to the fact that it is necessary to determine the criterion for improving the quality of the original image. Nevertheless, each researcher determines such a criterion based on a specific task. This makes comparative analysis difficult.

In [10] various methods of increasing the contrast of the initial medical image are investigated. This allows you to select the method of increasing the contrast of the image that is most effective. It is shown in the work that the most effective result can be obtained using the fuzzy masking

method. But these findings relate primarily to the analysis of microscopic images of blood.

Optimization of procedures for improving the contrast of medical images is also considered in [11]. The authors show that poor contrast can cause difficulties in the construction of computer vision systems. Therefore, we used a method to optimize the procedures for increasing the contrast of the original images. Also discussed is a new approach for detecting the edges of objects in the image.

Y. A. Hamad, M. N. Qasim, A. A. Rashid and M. E. Seno investigate various algorithms for analyzing medical images [12]. Particular attention is paid to the geometry of objects that are present in medical images. This helps to solve various problems that arise during the analysis of such objects. Attention is also paid to methods of preliminary processing of visual data. This is necessary to increase the brightness and contrast of the studied images.

R. Supriyanti, S. Suwitno, H. B. Widodo and T. I. Rosanti discuss contrast enhancement in terms of highlighting the edges of objects in medical images [13]. This problem is also solved using the wavelet ideology.

The article [14] analyzes various methods and algorithms for studying images of living cells. The authors of this study provide a review of image preprocessing, segmentation and data visualization techniques. These methods are an important tool for the analysis of cellular structures images.

The identification of individual objects in blood cells is considered in [15]. For this, the authors use the method of semantic segmentation. At the same time, special attention is paid to methods of preliminary image processing.

Thus, we see that the topic of this study is relevant and has various solutions. Therefore, we will first consider the general procedure for analyzing images of cellular structures.

3. GENERAL PROCEDURE FOR IMAGE ANALYSIS OF CELLULAR STRUCTURES

To reveal the general procedure for analyzing images of cellular structures, it is necessary to determine the purpose of such a study. A review of the literature on this topic shows that the main purpose of analyzing images of cellular structures is to identify objects in the original image. To solve this problem, it is necessary to detect and highlight the edges of all objects that are in the medical image. Thus, the main goal of the procedure for analyzing images of cellular structures is to highlight the edges of objects that are in the medical image.

In a formalized form, this can be written as follows:

$$B \xrightarrow{\ g\ } E \,, \tag{1}$$

B – the initial image of some cellular structure,
E – the processed image, which shows the edges of objects,
g – some image processing operation.

Traditionally, edge selection algorithms are used as the operation g. Among such algorithms, one can distinguish those that include the detection of the edges of the image using the operators of Roberts, Sobel, Prewitt, and Canny [16]. These algorithms work with masks of a certain type. Then the new values of individual points of the image are determined by its convolution between the values of individual points of the input image with the considered masks. Each operator has its own specific mask.

$$B \xrightarrow{\ g(O)\ } B \otimes M(O) \to E \,, \tag{2}$$

$g(O)$ – some image processing operation. Such an operation is defined by one of the operators O (Roberts, Sobel, Prewitt, Canny),
$\otimes$ – the operation of convolution between the original image and the mask of some operator O,
$M(O)$ – the mask of one of the operators O.

However, the use of classical operators to select the edges of objects has its own specifics. This specificity is determined by the original image. Therefore, to select the edges of objects in the image, a method based on the ideology of wavelets is also used.

The ideology of wavelets allows you to detect differences in brightness values at each point of the original image. For this, special functions are used – the wavelet function [17]. These functions are applied to the columns and rows of the original image. Then we get an image of the edges for the original image in two «projections» – by columns and by rows. After convolution of these two «projections», we get an image of the edges of objects in the original image.

$$B \Rightarrow \begin{cases} B_c \xrightarrow{\ w\ } E_c \\ B_r \xrightarrow{\ w\ } E_r \end{cases} E_c \oplus E_r \} \to E \,, \tag{3}$$

B_c – «projection» of the original image by columns,
B_r – «projection» of the original image line by rows,
E_c – processed «projection» of the original image by columns,

E_r – processed «projection» of the original image line by rows,

w – image processing operator – a special wavelet function. As a rule, we use the Deboshi-1 wavelet,

⊕ – convolution between two results of processing the original image in two «projections».

To improve the efficiency of the selection of the edges of objects in the image, you can also use algorithms for increasing the contrast of the image. Contrast is one of main characteristics of image because it is directly related to the brightness of pixels that are the sources of information about the objects in the image. Modifying the contrast of the image makes some of its details more distinct, which is allow improving both image perception accuracy, as well as the efficiency of its further processing [10].

However, using algorithms to increase the contrast of an image can cause new dots to appear in the image. This affects the effectiveness of edge detection. This is especially important when processing medical images. At the same time, classical methods for detecting the edges of objects are most sensitive to changes in the contrast of the original image [18].

Then the general procedure for analyzing images of cellular structures consists in preliminary transformation of the original image (if appropriate) and selection of the edges of objects in the image.

4. DATA FOR ANALYSIS

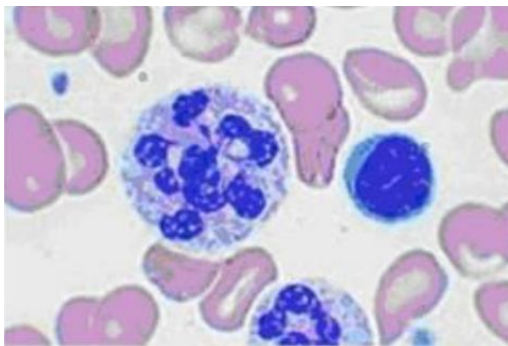For our study, consider several images of cellular structures (Figure 1 – Figure 3).

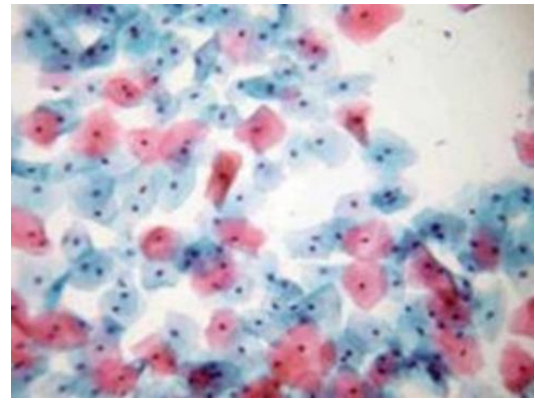**Figure 1:** Image cells in pernicious anemia

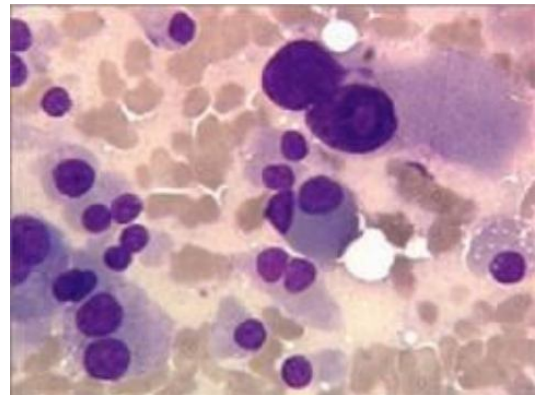**Figure 2:** Cellular composition of cervical smear

Figure 3: Medullary (C-cell) cancer

We see that the images of cellular structures are different. These images are different from each other. At the same time, these images are difficult for computer vision to perceive. The exception is the image in Figure 1. Let's carry out our analysis.

5. RESULTS AND DISCUSSION

For the analysis we will use the edge selection operator – Prewitt and Roberts. These are the most commonly used operators in medical imaging analysis. To increase the contrast, we use a simple histogram equalization procedure. Moreover, this alignment is done automatically [14], [15].

Figure 4 – Figure 6 show the results of objects edge detection in the image using wavelet analysis, Prewitt operator and Roberts's operator, respectively (without increasing the contrast of the image).
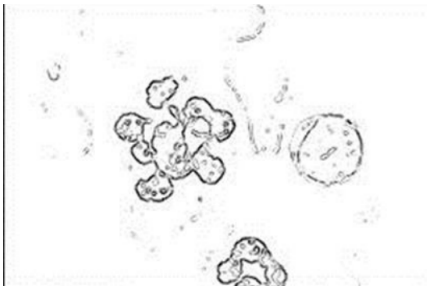
Figure 4: The result of selecting the edges of objects using wavelet analysis (without increasing the contrast of the image)
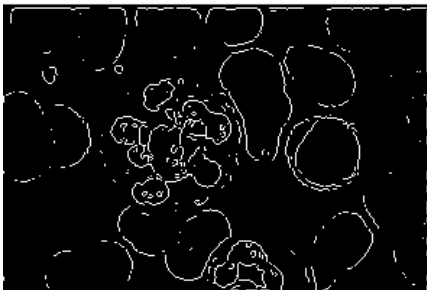

Figure 5: The result of selecting the edges of objects using Prewitt operator (without increasing the contrast of the image)
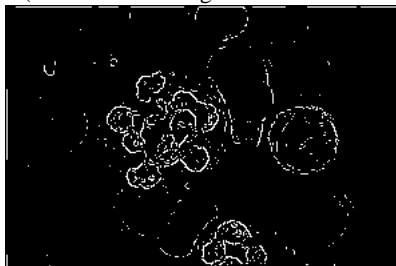

Figure 6: The result of selecting the edges of objects using Roberts's operator (without increasing the contrast of the image)

We see that the Prewitt operator gives the best result.

Figure 7 – Figure 9 show the results of objects edge detection in the image using wavelet analysis, Prewitt operator and Roberts's operator, respectively (with increasing the contrast of the image).
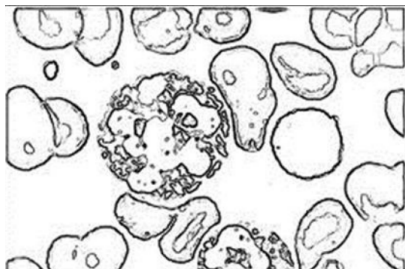

Figure 7: The result of selecting the edges of objects using wavelet analysis (with increasing the contrast of the image)
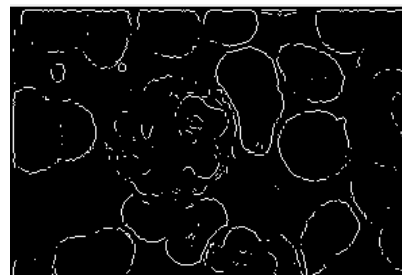

Figure 8: The result of selecting the edges of objects using Prewitt operator (with increasing the contrast of the image)
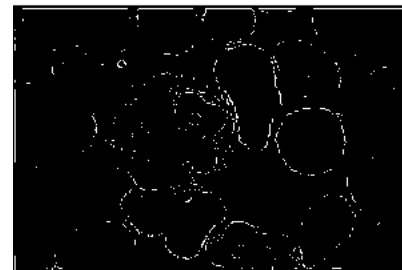

Figure 9: The result of selecting the edges of objects using Roberts's operator (with increasing the contrast of the image)

Now we see that the wavelet analysis gives the best result.

We did similar processing for all images (Figure 1 - Figure 3). Table 1 shows the results of such processing. These results reflect the percentage of correctly selected edges of objects. To do this, we used the opinion of five experts and averaged these values.

Table 1: Results of selection of edges of objects (for different images and different methods of edge selection)

Figure number	without changing the contrast of the image	with changing the contrast of the image
wavelet analysis		
Figure 1	51%	97%
Figure 2	47%	88%
Figure 3	34%	92%
Prewitt operator		
Figure 1	75%	79%
Figure 2	68%	54%
Figure 3	35%	28%
Roberts's operator		
Figure 1	52%	54%
Figure 2	22%	34%
Figure 3	7%	8%

We see that the Prewitt operator highlights the edges of objects better if we process the image without pre-processing (without changing the contrast of the image). Roberts's operator gives the worst result for the images we analyze.

At the same time, the wavelet analysis is the best result after preliminary processing of the original images (with changing the contrast of the image). Moreover, this result is the best

compared to the result obtained using the Prewitt operator (without changing the contrast of the image).

Thus, the procedure for analyzing images of cellular structures in order to isolate edges on objects consists of preliminary increasing the contrast of the original image and using wavelet analysis for subsequent image processing.

6. CONCLUSION

The article discusses various aspects of the analysis of cellular structures images. For this, a brief analysis of the literature on the research topic was carried out. It is shown that the main purpose of this analysis is to detect the edges of objects that are in the image.

The result of this study is the development of a general procedure for the analysis of cellular structures images. The main points of this procedure are to increase the contrast of the original image and use wavelet analysis to highlight the edges of objects. The efficiency of the considered procedure is shown.

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