REVIEW ARTICLE

USING THE METHODOLOGY OF WAVELET ANALYSIS FOR PROCESSING IMAGES OF CYTOLOGY PREPARATIONS

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ABSTRACT

Processing of microscope images in medicine is one of the priority research areas. This is due to the fact that such studies allow conducting comprehensive diagnosis of human health state, identifying and preventing the development of diseases in the early stages, providing additional research in non-standard symptomatic forms of rare diseases. In this connection, first of all image processing of cytology preparations holds a special place as one of the common set of microimages in medicine. However, the specific complexity of visualization process of cytology preparations and their subsequent processing with the use of automated processing determines the necessity to study new possibilities to use new approaches to image processing. Exactly this fact was the basis for considering the possibility to use wavelet analysis as a tool for processing cytology preparations images. On certain examples of cytology preparation images the results of application of one of the wavelet analysis procedures is shown.

Keywords: wavelet analysis, image, contrast enhancement, cell, medicine, cytology preparation.

INTRODUCTION

Processing real objects' images, processes and phenomena is one of the ways of perception of the world around us. At the same time, image processing allows studying the processes that cannot be seen or analyzed by means of human vision. One such directions of application of a common ideology of image processing is medicine. In this case, images of real objects are those of different organs, tissues, parts of human skeleton, obtained with the help of special methods of their visualization: X-ray microtomography, positron emission tomography, ultrasonic analysis, light and electron microscopy.[1-5]

Among the many real objects that allow studying human body, one can underline the cytology preparations images. It is connected with the following facts. On the one hand, cytology preparations are objects of microcosm, which allow for a more in-depth studies of the human body, to study the dynamics of its operation and to diagnose possible diseases in the early stages of their development; On the other hand, these are special images that differ in their visualization of microcosm objects, which necessitates the use of a variety of image processing techniques to obtain information about objects, processes, and phenomenon under study.

The General Ideology of Post-Processing of Cytology Preparations Images (Literature Review)

As an example of separate works that use the ideology of imaging processing for studying of cytology preparations the following research work can be provided. B. Krawczyk and P. Filipczuk, which deals with the cytological image segmentation to isolate the cell nucleus.[6] A. Gençtav, S. Aksoy and S. Önder, discussing the issues of segmentation and classification of cells cytology preparations images, where segmentation process involves automatic thresholding to separate the cell regions from the background.[7] S. Singh and R. Gupta, which examines the possibility of applying the texture analysis methods for cytology preparations.[8] E. Ensink et. al, who study the issues of the selection of threshold for image segmentation of cytology preparations.[9] Y. M. George et. al, offering to conduct automated segmentation of cells in the images of the cytology preparation under study, where authors talk about the necessity to change the histogram of the input image in order to enhance its contrast.[10] R. Malviya et. al, which deals with nucleus localization in the cytology preparations images under study.[11]

Nevertheless, the many authors point out that there may be some ambiguity while localizing nucleus. The reason for such ambiguity is the emerging difference in the relative staining intensity of the clinical samples examined. Possible errors in segmentation of cells on cytology preparations images as a result of the arising differences in relative intensity of their staining is also studied by E. M. van Ingen et. al.[12] At the same time N. Dey et. al, talk not only about the possible influence of the relative staining intensity of the preparations under study on the quality of their image processing.[13] N. Dey et. al, determine the whole range of problems connected with the processing of microscopic images in medicine, where the primary goal is to obtain high quality image for its further thematic processing.[13]

Thus, the overall ideology of cytology preparations image processing pursues its goal as the selection of certain parts of the image (cells, nucleus) for further study of their changes (changes in cell shape, the change in the area of a cell) or for the calculation of certain quantitative characteristics (number of cells, the number of nuclei, cells' area). At the same time, particular attention is paid to the methods of cytology preparations source images (filtering, change of contrast, histogram equalization) in order to enhance the information they contain. However, it should be noted that by simply changing the brightness, contrast or by filtering it is impossible to solve arising issues with proper quality while processing cytology preparation images. Based on noted above, the following objectives of this study can be pointed out:

– Explanation of method of cytology preparation images processing;

– Reviewing the ideology of preprocessing of cytology preparation images for their processing method under discussion;

– Conducting experiments based on the suggested method of cytology preparation images processing.

Basics of Wavelet Analysis for Image Processing

In order to solve the set of issues connected with cytology preparations image processing the methodology of wavelet analysis will be considered. The selection of wavelet analysis method for further cytology preparations images processing is based on the fact that wavelet processing allows taking into account the particular characteristics of the images under study by decomposing source data into a plurality of approximate and detail coefficients, in particular by image edge detection.[14] In addition, image processing results obtained with the help of wavelet analysis, are often more informative.[15,16]

Wavelet analysis is based on wavelet transform. Wavelets are obtained by shifting and scaling a single function – parent wavelet.[17] If the signal is discontinuous, only those wavelets will have high amplitudes, which maxima will appear near the discontinuity point. This allows detecting image edge on the image under study. The sharper the transition, the higher the derivative value is. Smooth transitions will have small derivative values.

Behind the formalization of the continuous wavelet transform (CWT) there's the use of two continuous and integrable along the whole axis [1] functions:[17,18]

– wavelet – function $\xi(t)$ with zero integral value

$$\int_{-\infty}^{\infty} \xi(t)dt = 0, \quad (1)$$

determining the details of the signal and generating extended fractions;

– scaling function $\varphi(t)$ with a unit value of integral

$$\int_{-\infty}^{\infty} \varphi(t)dt = 1, \quad (2)$$

determining a rough approximation of signal and generating approximation coefficients.

However, CWT function can be applied only for one-dimensional signals, and image is a two-dimensional signal. Therefore, in order to be able to apply CWT to detect image edges it is suggested to consider the following analysis and edge detection procedure:[14]

- let's perform calculation for horizontal discontinuities of the original image F, represented by matrix defined by its readings $f_{ij} \in \{0,1,...,P\}, i = 1,2,..., N, j = 1,2,..., M$ on a square lattice $P \times K$. To do this, we use the following formula to get the so-called matrix of wavelet spectrogram W (based on the sequential processing of each line of the original image F):

$$W[f_{ij}] = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} f_{ij} \xi(\frac{t-b}{a})dt, \quad (3)$$

where $\xi(\frac{t-b}{a})$ is a mother wavelet that meets the condition (1),

a, b – scale and center of temporary localization which determine the scale and bias function $\xi(t)$ in accordance with the terms of scaling (2);

$\lfloor f_{ij} \rfloor$ indicates the number of the processed string of the original image F to get a plurality of values of its wavelet spectrogram.

Parameters a, $b$are chosen so that the corresponding linear dimensions of the matrix of wavelet spectrogram W correlate with linear dimensions of the original image F, and at the same time possible parameter of wavelet transform are taken into account.

Then, based on the analysis of the obtained spectrogram (W for each raw of the original image F) we select its certain line PP based on the condition:

$$PP = \max(\frac{1}{P}\sum_{i=1}^{P} w_{ij}), \quad (4)$$

where w_{ij} is the element of wavelet spectrogram of the analyzed row (line) of the original image F.

This selection is determined by the fact that we select that part of spectrum of the original image row (line), which corresponds to the largest discontinuity area of the original signal between its readings (see comments above).

The selected in such a way line (row), will correspond to the line (row) in matrix F_g which characterized the matrix of horizontal discontinuities of the original image F.

Processing of all lines of the original image F allows obtaining the matrix of horizontal discontinuities F_g through the following sequence of transformations:

$$F \xrightarrow{\text{CWT lines}} W \xrightarrow{\text{selection line}} F_g$$

- in a similar war we calculate the vertical discontinuities of the original image F for each column. For this purpose, use formula (3) and the formula similar to formula (4) to select certain line from the obtained wavelet spectrograms of each column of the original image F:

$$KK = \max(\frac{1}{K}\sum_{i=1}^{K} w_{ij}). \quad (5)$$

Processing of all columns of the original image F allows as a result obtaining the matrix of vertical discontinuities F_v, due to the following sequence of transformations:

$$F \xrightarrow{\text{CWT column}} W \xrightarrow{\text{selection column}} F_v.$$

- add matrixes of vertical and horizontal discontinuities into one matrix that displays the edge of the original image based on CWT methods. For visual clarity, matrixes are horizontal, vertical discontinuities, as well as generalized matrix showing the edge of the original image can be inverted.

In this work, to consider the possibility of using wavelet analysis as a tool for processing cytology preparations images, parameter $a = 20$, and parameter b ($b = P$ or $b = K$) correlates with the linear dimensions of the original image in accordance with the procedure of constructing the matrix of wavelet spectral pattern for rows and columns of the image respectively.

Test Images and Their Preprocessing Before Wavelet Analysis

In order to identify the possibility of using wavelet analysis as a processing tool for cytology preparations images, some images have been selected. The images are publicly available on the Internet (Fig. 1 and Fig 2).

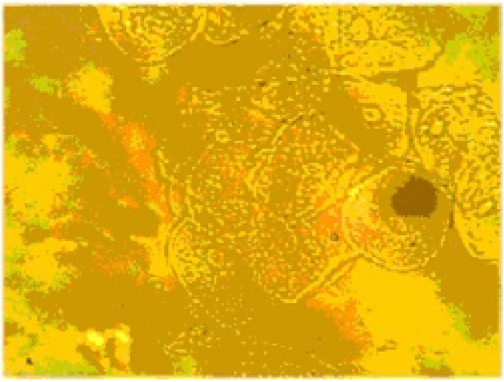

Fig.1. Image No.1

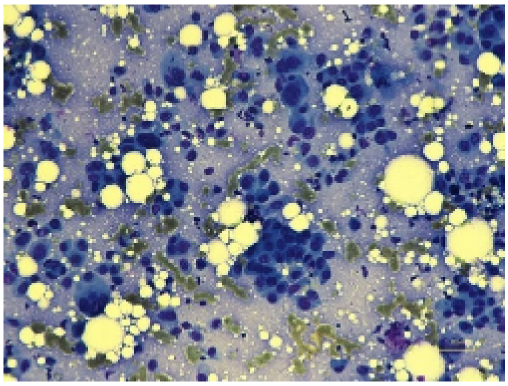

Fig.2. Image No.2

The presented images of cytology preparations are different in their structure and complexity of perception, which allows evaluating the possibility of using wavelet analysis methodology as a tool for their processing. Moreover, all images are presented in color. However, the implementation of certain functions of the general methodology of wavelet analysis involves the work with gray-level images. Therefore, all the original images must be submitted in the form of corresponding gray-level (halftone) images. This is the first stage of the original images pre-processing.

As noted above, one of the necessary stages of preprocessing of microscopic images in medicine is their contrasting. Changing the contrast of the image allows improving both image perception accuracy, as well as the accuracy (efficiency) of its further processing. It is very important for microscopic images in medicine, an example of which are images of cytology preparations. Therefore, to further analyze the halftone images, they all were contrasted.

At the same, the selection of different levels of contrast enhancement for the images under study is first of all determined by the necessity to test the possibility of using wavelet analysis for cytology preparation image processing.

Results of Wavelet Transform of Cytology Preparations Images and Discussion

Thus, wavelet transform of cytology preparations images will be held on halftone images, one of which is the source (primary) image obtained from the corresponding color image, and the second one is a contrasted image of the original grayscale (halftone) image. As a wavelet transform of cytology preparations images the method of selecting special features of the images was used, described in the part "Basics of wavelet analysis for image processing".

Fig. 3 shows the results of wavelet transform for image No.1 (a – processing of the original halftone image, b – processing of contrasted halftone image).

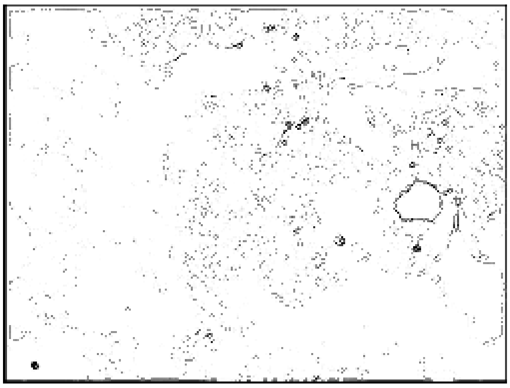

Fig.3a). Results of wavelet transform for image No.1

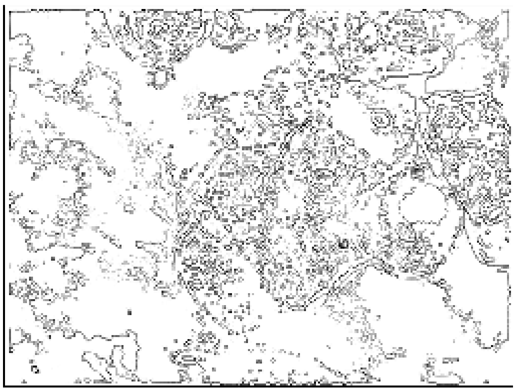

Fig.3b). Results of wavelet transform for image No.1

Fig. 4 shows the results of wavelet transform for image No.2 (a – processing of the original halftone image, b – processing of contrasted halftone image).

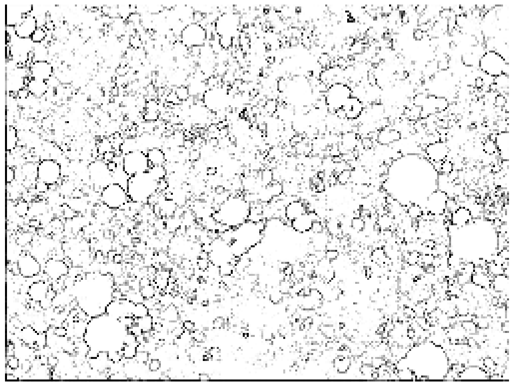

Fig. 4a). Results of wavelet transform for image No.2

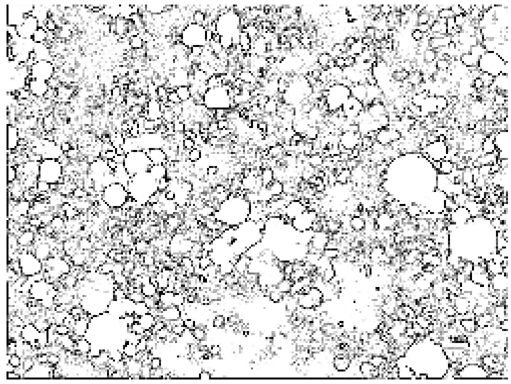

Fig. 4b:. Results of wavelet transform for image No.2

As it can be seen from data on Fig. 3 and Fig. 4 the described method of image wavelet transform allows detecting first of all edges of separate objects represented on the corresponding images. The used wavelet transform also allows highlighting the specific features of cytology preparaions of separate objects (cells) in the images. At the same time, on basis of shown in Fig. 3 and Fig. 4, it can be stated that the use of the studied wavelet transform provides more information for images that have been contrasted.

In the case where wavelet processing was applied to a less contrasted image, the result was the allocation of the darkest areas in the original images. This corresponds wither to cell edge detection (Fig. 4a).

In the case where wavelet processing was applied to a more contrasted image, the result is not only more accurate cell edge detection, but the allocation of the internal structure of these cells (Fig. 3b). This allows for a more detailed qualitative and quantitative analysis of the internal structure of the cells represented in the images of cytology preparations. In particular, it is possible to analyze the textural changes that occur within the cell, to analyze in more details the individual elements of cells' structure, to calculate the dynamics of change in the cell nucleus, the nucleolus, intracellular filaments, etc.

Nevertheless, it is possible to combine the results of wavelet processing of images with different contrast. This will help solving different problems: from localizing only cell nuclei to the study of the internal structure of cells. Then the general ideology of the procedure for the use of wavelet analysis as a tool for cytology preparations images processing can be presented as follows:

the necessity to transform the original image is determined;
color image is converted to halftone (gray-level) image;
the necessity to change contrast of the original halftone image is determined;
wavelet transform of the original halftone image and of contrasted halftone image is conducted;
Conclusions are made on basis of wavelet transform results (additional processing procedures are applied to the obtained images in this case: calculating cell nuclei, cells, cells' area, etc.).

In any case, the discussed above one the procedures of wavelet analysis shows that it is possible and feasible to use wavelet analysis as a tool for processing cytology preparations images in order to obtain additional information to conduct diagnostics and assess the state of human health.

CONCLUSIONS

In summary, the paper deals with the possibility and feasibility issues of applying wavelet analysis for processing cytology preparations images. As a separate wavelet analysis procedure, which is proposed to be applied to processing of cytology preparations images, the procedure of allocating specific features on the presented images is discussed.

The proposed procedure of processing of cytology preparations images allows to qualitatively (in terms of their visualization) allocating: cells' edges, cell nuclei, revealing in more detail textural features of cells' images, which allows analyzing cell structure.

At the same time, one of the specifics of application of wavelet transform for cytology preparation images analysis has been marked out. Such specific feature is the necessity to process halftone images and feasibility of changing contrast of halftone image. Inparticular, the article shows different results of wavelet processing for original and contrasted halftone images. Nevertheless, it does not narrow, but instead extends the potential of using wavelet analysis for processing cytology preparations images depending in the context of the problem.

REFERENCES

1. Schlüter S, Sheppard A, Brown, K, Wildenschild D. Image processing of multiphase images obtained via X‐ray microtomography: a review. Water Resources Research. 2014;50.4:3615-3639.
2. Gaemperli O, Shalhoub J, Owen D, Lamare F, Rimoldi OE, Davies AH, Camici PG. Imaging intraplaque inflammation in carotid atherosclerosis with 11C-PK11195 positron emission tomography/computed tomography. European heart journal. 2012;33.15:1902-1910.
3. Sikdar S, Rangwala H, Eastlake EB, Hunt I, Nelson A J, Devanathan J, Pancrazio JJ. Novel method for predicting dexterous individual finger movements by imaging muscle activity using a wearable ultrasonic system. Neural Systems and Rehabilitation Engineering, IEEE Transactions on. 2014;22.1:69-76.
4. Eklund A, Dufort P, Forsberg D, LaConte SM. Medical image processing on the GPU–Past, present and future. Medical image analysis. 2013;17.8:1073-1094.
5. Ciresan D, Giusti A, Gambardella LM, Schmidhuber J. Deep neural networks segment neuronal membranes in electron microscopy images. In Advances in neural information processing systems. 2012:2843-2851.
6. Krawczyk B, and Filipczuk P. Cytological image analysis with firefly nuclei detection and hybrid one-class classification decomposition. Engineering Applications of Artificial Intelligence. 2014;31:126-135.
7. Gençtav A, Selim A, Önder S. Unsupervised segmentation and classification of cervical cell images. Pattern Recognition. 2012;45.12:4151-4168.
8. Singh S, Gupta R. Identification of components of fibroadenoma in cytology preparations using texture analysis: a morphometric study. Cytopathology. 2012;23.3:187-191.
9. Ensink E et al. Segment and Fit Thresholding: A New Method for Image Analysis Applied to Microarray and Immunofluorescence Data. Analytical chemistry. 2015;87.19:9715-9721.
10. George YM, Bagoury BM, Zayed HH, Roushdy MI. Automated cell nuclei segmentation for breast fine needle aspiration cytology. Signal Processing. 2013;93.10:2804-2816.
11. Malviya R, Karri SPK, Chatterjee J, Manjunatha M, Ray AK. Computer assisted cervical cytological nucleus localization. TENCON 2012-2012 IEEE Region 10 Conference. IEEE, 2012:1-5.
12. van Ingen EM, Leyte-Veldstra L, Al I, Wielenga G, Ploem IS. Automated Cytology Using a Quantitative Staining Method Combined with a TV-based Image Analysis Computer. Cancer Control: Proceedings of the 12th International Cancer Congress, Buenos Aires, 1978. Elsevier, 2013:45-67.
13. Dey N, Ashour AS, Ashour AS, Singh A. Digital Analysis of Microscopic Images in Medicine. Journal of Advanced Microscopy Research. 2015;10.1:1-13.
14. Kobylin O, Lyashenko V. Comparison of standard image edge detection techniques and of method based on wavelet transform. International Journal of Advanced Research. 2014;2(8):572-580.
15. Lyashenko V, Deineko Z, Ahmad A. Properties of wavelet coefficients of self-similar time series. International Journal of Scientific and Engineering Research. 2015;6(1):1492-1499.
16. Lyashenko V, Kobylin O, Ahmad MA. General Methodology for Implementation of Image Normalization Procedure Using its Wavelet Transform. International Journal of Science and Research (IJSR). 2014;3(11):2870-2877.
17. Kingsbury N. Image processing with complex wavelets. Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences. 1999;357(1760):2543-2560.
18. Heil CE, Walnut DF. Continuous and discrete wavelet transforms. SIAM review. 1989;31(4):628-666.