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Image Processing as an Analysis Tool in Medical Research

Oleksandr Zeleniy[1], Diana Rudenko[2], Valentin Lyubchenko[2], Vyacheslav Lyashenko[1]

[1]Department of Media Systems and Technology, Kharkiv National University of Radio Electronics, Ukraine
e-mail: lyashenko.vyacheslav@gmail.com

[2]Department of Informatics, Kharkiv National University of Radio Electronics, Kharkiv, Ukraine

Abstract: *The process of research is an important part of the general ideology of knowledge, understanding of the processes that occur at the macro- and micro- levels. Therefore, various methods, procedures, and approaches are used here. Methods and approaches for image analysis are tools for understanding the surrounding world. This tool of knowledge is widely used in various fields of research, practical applications. Image processing and analysis makes it possible to visualize areas of the real world that are difficult to access or invisible to humans. Image processing can also improve the visualization of real world objects, understand the mechanisms of their interaction. One of these priority areas of research is medicine. In this case, we can see the various processes that occur in the body, identify the foci of diseases, understand the mechanism of the course of diseases, and diagnose various diseases. For these purposes, various methods and approaches for image processing and analysis are used: image quality improvement, noise removal, contour extraction for different objects in the image, image segmentation, identification of potential objects, object recognition. The use of these methods and approaches for the analysis of medical images and the sequence of using these methods depends on the problem that needs to be solved in the process of analyzing the original image. The paper considers some approaches to processing medical images. The features of the use and the expediency of applying certain approaches to image processing are noted. The results obtained are illustrated on real medical images. This allows us to better understand the logic of this study.*

Keywords—image processing; diagnostics; medical image; preliminary processing; color segmentation; noise suppression; contour detection

1. INTRODUCTION

Medical research is one of the priority areas that have been rapidly developing in recent years [1]-[5]. Such studies allow not only understanding the processes that occur during the development of various diseases, to understand the mechanism of their course, but also to predict the appearance of certain diseases. At the same time, among the various topics for medical research, a special place is given to diagnostics. It is the diagnosis that allows you to reveal the mechanism of the course of the disease, prevent its sudden onset and provide the necessary assistance in advance. Thus, diagnostics is central to medical research. The selection of the necessary solutions depends on the results of the diagnostic process. Diagnostics helps to minimize the risks in identifying diseases, to choose the right treatment regimen and recovery of a person.

For diagnostics, various methods and approaches are used, various data are analyzed [6]-[8]. Such data may include time series, charts, qualitative characteristics of the disease, as well as various types of images [4]. One of the common types of images is images that are obtained as a result of photographing (visualization) of some process or object. These are the so-called medical images. An example of such images can be images that are obtained under a microscope [9], [10]. At the same time, such images can be divided into [11], [12]:

bilevel (or monochromatic) image;

halftone image;

color image;

image with continuous tone;

discrete tone image.

This diversity of images involves the use of various methods and approaches for their analysis and identification [13]-[15]. At the same time, various methods that are used in other areas of research can also be used for such an analysis [16]-[19].

The existing variety of methods and approaches for image analysis also suggests a certain structure of their use. Such a structure involves a preliminary improvement in the quality of the input image, noise removal, contour extraction for potential objects of interest in the image, image segmentation into separate components, identification of potential objects, recognition of potential objects and other similar actions [20]-[25]. Each stage of image processing involves the solution of certain tasks. At the same time, such tasks are determined by the subject area of the input image.

Thus, various methods and approaches in image processing can be considered as analysis tools. At the same time, as noted earlier, an important subject area is images that are used in medicine to treat diseases, identify various diseases, monitor the state of human health, and the functioning of the human body.

Therefore, it is important to know what methods and approaches for image processing should be used for the analysis of medical images. It is also necessary to know the features of using the image processing procedure in the process of analyzing medical images. These and some related questions are addressed in this study.

2. Related Works

There are many papers that address various aspects of the use of image processing methodology in medical research. At the same time, such works consider both general aspects of processing and analysis of medical images, and specific aspects of the corresponding image analysis.

In [26], the general aspects of building models for the analysis of three-dimensional medical images are considered. At the same time, the authors emphasize the existence of differences between natural images and medical images. And this fact must be taken into account when choosing and using methods for processing and analyzing the corresponding images. The authors also consider the possibility of using deep learning methods for the analysis of medical images. For this, it is proposed to transfer the training of the corresponding models from a natural image to a medical image.

In [27], various methods for analyzing medical images that are the result of microscopic analysis of biopsies in the diagnosis of breast cancer are considered. The authors solve the BACH challenge to advance methods for automatic classification of breast cancer. This is done based on the analysis of relevant histopathological images. The authors reviewed 64 methods, conducted their comparative analysis, and chose the most effective methods for the analysis of breast cancer. The paper notes that convolutional neural networks are the dominant method of analysis in the classification of breast cancer.

In the study [28], a comparative analysis of various methods for preprocessing CT and MR images of patients with prostate cancer was carried out. The authors note that the results obtained may be useful for teaching beginners in this field. The paper shows how the use of appropriate image pre-processing in the correct order can improve the performance of post-processing in terms of better classification and segmentation [28]. The authors also state that there are many publicly available algorithms, each of which is designed to solve a separate problem of computer vision as a whole. However, most of these algorithms cannot be directly applied to images in the medical field [28]. This is fully consistent with the objectives of our study. Thus, in order to be able to use publicly available algorithms for clinical purposes, a meaningful interpretation of medical images is necessary.

E. Vocaturo, E. Zumpano and P. Veltri consider the possibility of using image preprocessing for melanoma detection [29]. The paper considers the possibility of automatic early diagnosis of melanoma. The authors note that automated diagnosis provides a reliable “second opinion” to help clinicians decide whether a skin lesion is a benign mole or malignant melanoma [29]. The authors also note that the determination of effective detection methods to reduce the frequency of errors in diagnosis is the most important task [29]. At the same time, the paper states that pre-processing is the first phase of detection and plays a fundamental role: the elimination of noise and unnecessary details in the background of skin images to improve image quality [29].

The paper by S. V. M. Sagheer and S. N. George provides an overview of denoising algorithms for medical images [30]. The authors note that medical imaging is often justified in the follow-up of an already diagnosed and treated disease [30]. However, medical imaging, like any other imaging modality, is subject to noise and artifacts. The presence of noise makes images blurry and can make it difficult to identify and analyze diseases that can lead to high losses, including death. Therefore, noise reduction of medical images is a mandatory and important pre-processing method for further stages of medical image processing [30]. Thus, image preprocessing is an important step in the analysis of medical images.

R. Vimal Kurup, V. Sowmya, and K. P. Soman investigate the impact of data preprocessing on the classification of brain tumors [31]. The article provides a comparative analysis of the influence of data preprocessing methods on the classification of diseases. At the same time, the authors note that diagnosing the type of brain tumor at an early stage can lead to effective treatment. In terms of image processing, there are several methods that solve the problem of disease classification. Therefore, it is important to choose the most effective approaches for solving such a problem. The article uses a capsular network to classify brain tumors [31]. The use of this method shows that data preprocessing plays a vital role in improving the architecture of the capsule network [31].

The papers [32], [33] explore the possibilities of using fractal analysis methods for processing medical images.

The authors of the article [32] consider the fractal dimension for the analysis of medical images. The article shows that the concept of FD is widely used in many areas of image processing. This concept works on the basis of the self-similarity theory because it contains structures that are nested within each other. The authors note that fractal geometry can be applied in the analysis of medical images to detect cancer cells in the human body, since our vascular system, nervous system, bones and breast tissues are so complex and irregular in structure, but have some elements of nesting and self-similarity [32] .

The authors of the article [33] analyze changes in medical images. At the same time, they note that this is one of the most important areas in image processing, providing progress in the diagnosis and classification of diseases. The authors also emphasize that medical imaging is the most common diagnostic tool in modern medical practice [33]. At the same time, the most relevant areas for implementing the analysis of medical images are methods based on mathematical methods for processing input information. Among these methods, the authors single out calculations of the fractal dimension and the Hurst index [33].

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The paper [34] presents an overview of deep learning methods for the analysis of medical images. The article reviews new research in the field of analysis of 3D medical images using 3D CNNs (and their variants) in various fields of medicine, such as classification, segmentation, detection and localization [34]. The paper also considers the problems associated with the use of 3D CNN in the field of medical imaging [34].

A brief review of the literature shows that various methods and approaches can be used to analyze medical images. However, the use of such methods differs from their use for classical images. This fact must be taken into account when developing a general scheme for the analysis of medical images. Also important is the correct use of pre-processing techniques for medical image analysis.

3. Preprocessing in Medical Image Analysis

As shown earlier, the use of pre-processing methods is an important point in the analysis of medical images. Among such methods, methods for improving image quality and noise suppression methods can be distinguished. But the use of such methods should be balanced. The use of such methods should increase the efficiency of medical image analysis, and the necessary information should not be lost.

Various filters are used to implement image preprocessing methods. Among the filtering methods, it is worth highlighting: a filter with a finite impulse response (FIR), general nonlinear filtering (GNF), median filtering (MF), Wiener filter (WF) [35]. These are the most commonly used filtering methods.

As an example, consider images of E.coli on a digital image obtained under a microscope (Fig. 1) [36].

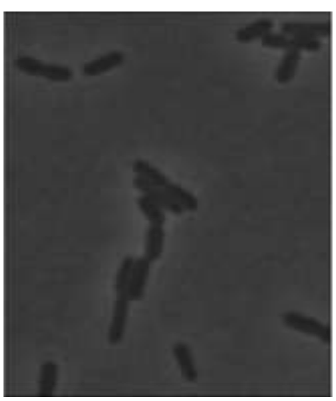
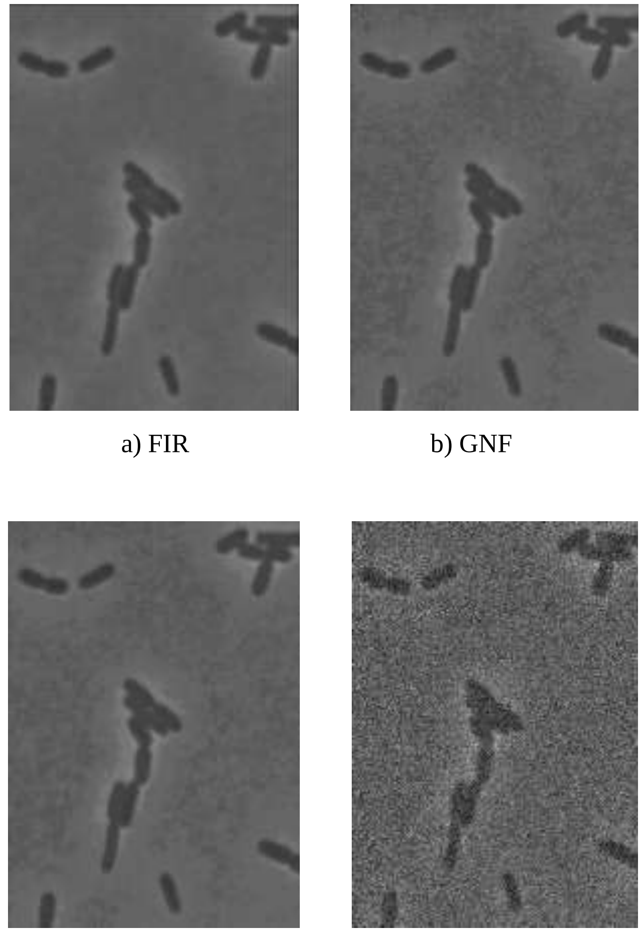


Figure 1: Example of a medical image (E.coli image)

We can observe a non-uniform background where the E.coli images are located. You can also talk about the complexity of separating objects into separate components.

On Fig. 2 shows the filtering results for the data Fig. 1.



a) FIR b) GNF

c) MF d) WF

Figure 2: Filtering results for the data Fig. 1.

We can see that the filtering results are different from each other. Somewhere the background became more uniform, but in some cases the background became grainy. This can make further analysis of the relevant medical image difficult.

Thus, the choice of an appropriate filtering method should be consistent and weighed. Such a choice should not lead to ambiguous results. Below is the result, which depends on the choice of the source image filtering method.

On Fig. 3 shows a fragment of another E.coli image [36].

On Fig. 4 shows the results of segmentation of E.coli with different approaches to filtering the original image in Fig. 3.

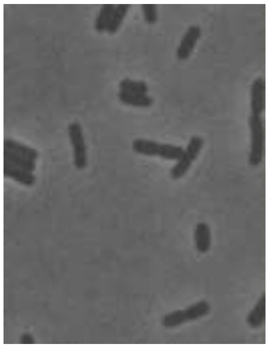
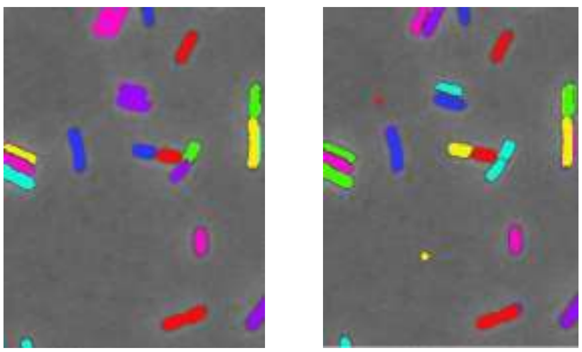
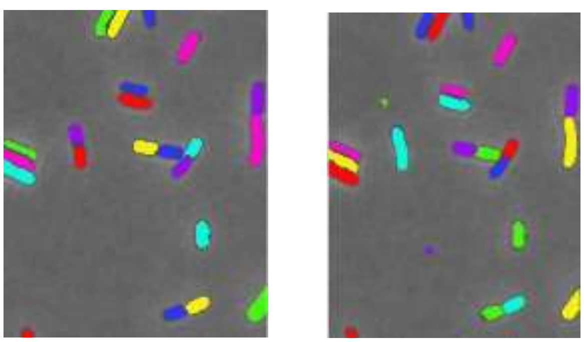


Figure 3: New E.coli image fragment



a) FIR b) GNF



c) MF d) WF

Figure 4: Results of segmentation of E.coli with different approaches to filtering the original image in Fig. 3.

It should be noted that we see different segmentation results depending on which filtering method was used on the original image. In some cases, the results differ significantly. This can naturally affect further processing and decision making based on such analysis. Also note that we do not consider the segmentation method. In this case, it is important to show the influence of the initial image preprocessing on subsequent medical image analysis procedures.

4. Wavelet Analysis as a Tool for Detecting an Edge in an Image

An important step in the analysis of medical images is the process of detecting the contours of objects that are in the image. Various contour detection operators are used for this [37], [38]. At the same time, the procedure for detecting the contour of objects can be implemented based on the ideology of wavelet analysis [4], [13], [14], [39]. This approach allows us to take into account both large and small details of the objects that are being studied. In other words, these can be images with different levels of object detail, where each object is important for analysis. This fact may be key in the processing and analysis of medical images. This is due to the fact that there are a lot of small details on medical images that can be seen against the background of larger objects. An example of such a medical image is shown in Fig. 5 [4].

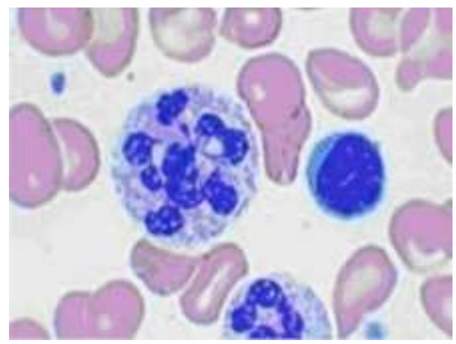
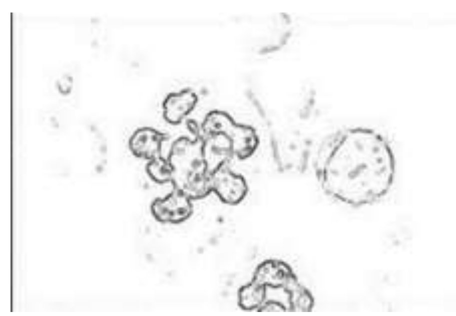


Figure 5: An example of a medical image with different levels of object detail

However, in this case, pre-processing procedures and images are also necessary. One of these procedures is to increase the contrast of the original image.

On Fig. 6 shows the results of contour detection using wavelet analysis without using the original image contrast procedure and after applying the original image contrast enhancement procedure.



a) without increasing the contrast of the image

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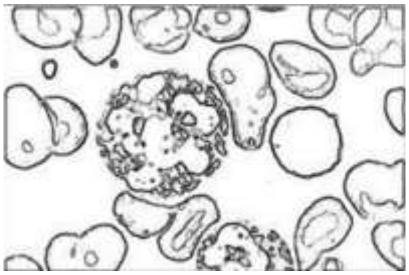
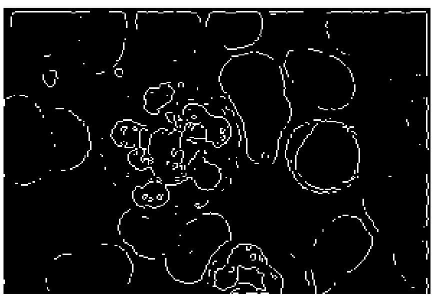


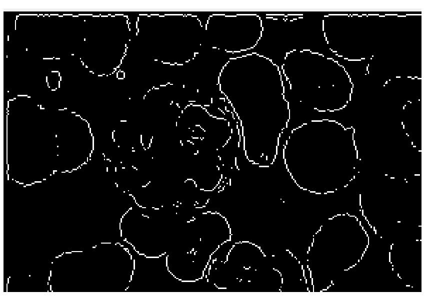
b) with increasing the contrast of the image

Figure 6: Results of contour detection using wavelet analysis

On Fig. 7 shows the results of contour detection using the Prewitt operator without using the original image contrast procedure and after applying the original image contrast enhancement procedure.



a) without increasing the contrast of the image



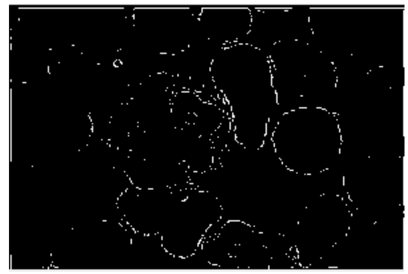
b) with increasing the contrast of the image

Figure 7: Results of contour detection using Prewitt operator

On Fig. 8 shows the results of contour detection using Roberts's operator without using the original image contrast procedure and after applying the original image contrast enhancement procedure.

We can see that applying the procedure for increasing the contrast of the original image significantly improves the results of wavelet analysis for edge detection.

a) without increasing the contrast of the image



b) with increasing the contrast of the image

Figure 8: Results of contour detection using Roberts's operator

However, the choice of contrast enhancement procedure is also important. Here you can highlight the method of changing the histogram in a given range with gamma correction (γ – parameter for gamma correction) [40], [41].

On Fig. 9 shows the results of contour detection using wavelet analysis after increasing the contrast of the original image (Fig. 5) for different values of γ.

a) γ =0.5

b) γ =1.3

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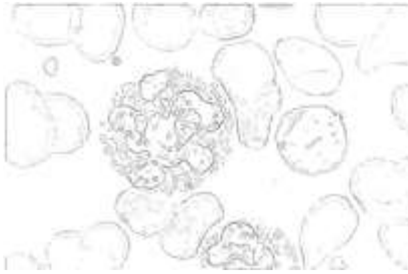
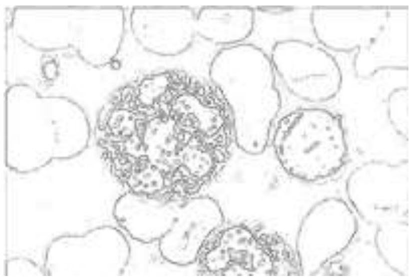


c) γ =2.4



d) γ =5.6

Figure 9: Results of edge detection using wavelet analysis after increasing the contrast of the original image at different values γ

We can see how the gamma correction parameter affects the edge detection results. This is important when processing medical images, detailing various details in such an image.

5. Conclusion

The paper considers the methods and approaches of image processing for their use in medical research. Such an analysis was carried out for such an object of research as medical images. These images help to visualize various processes and objects of a living organism that are not accessible or perceived by the human eye.

Based on the review of literature sources, it was concluded that it is important to use preprocessing procedures for the analysis of medical images. Examples of the corresponding stages of the analysis are given. Specific examples are carried out on real medical images. The importance and complexity of applying preprocessing procedures for the analysis of medical images is shown.

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