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Comparative Characteristics of Filtration Methods in the Processing of Medical Images

Pavlo Orobinskyi[1],Zhanna Deineko[2],Vyacheslav Lyashenko[1]
[1]*Department of Informatics, Kharkiv National University of RadioElectronics, Kharkiv, Ukraine*
[2]*Department of Software Engineering, Kharkiv National University of RadioElectronics, Kharkiv, Ukraine*
Corresponding Author: orbpster@gmail.com

ABSTRACT: *Digital image analysis is one of the research tools in various fields. Such a tool plays a special role in the study of medical images. This is due to the specifics of the data that can be displayed on medical images. Examples of such images are digital images of E.coli. These images were obtained under a microscope. Processing of such images provides additional information. We consider the filtering procedure as a method of preliminary image processing. Among these filtration procedures, we examine classical filtration methods and filtration, which takes into account the geometric dimensions of E.coli. The article presents the results of experiments. A comparative description of various filtration procedures is given. This is based on various image comparison metrics. It is concluded that it is necessary to take into account the geometric dimensions of E.coli when using filtration procedures.*

KEYWORDS: *E.coli, digital image, filtering methods, comparison metrics, geometric size, image preprocessing.*

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I. INTRODUCTION

A digital image is a representation of the real world. A digital image can be represented in the form of a matrix. Each point of the matrix (image) carries information. Analysis and processing of such information allows you to make decisions that are needed at a given time. Various methods are used for image processing – preliminary processing of the original image, image segmentation, identification of objects in the image [1], [2]. Therefore, digital images are used in various studies [3]–[5].

One of the areas of research where digital images are used is medicine. Such images allow you to diagnose the human body (individual organs), find possible diseases and conduct research in difficult conditions (to diagnose cells, tissues of various human organs). To do this, you can use images that are made under a microscope. These images contain various data structures. In cytology, it can be – red blood cells, white blood cells, plasma, platelets [4]. If we consider histology then it can be – various structures of separate tissues, cells [6], [7].

Images may also contain noise. The nature of such noise can be different. But this noise distorts the original information. Therefore, it is important to have an image without noise. This allows you to increase the accuracy of diagnosis of the human body, to establish the causes of a possible disease. To do this, use various filtering methods. However, it is important to know which filtering method best removes noise on medical images. These questions are the subject of this study.

II. MATERIALS AND METHODS

2.1 Image Filtering Methods

Image filtering is a method that removes noise and improves the quality of the original image. Among the filtering methods, it is worth highlighting: a filter with a finite impulse response, general nonlinear filtering, median filtering and Wiener filter [8], [9].

A finite impulse response (FIR) filter is a linear filter that provides consistent results. This filter is implemented through the correlation values between the studied quantities [10]. Thus, a quick scan of the original image is achieved. This allows you to quickly eliminate noise in the original image.

General nonlinear filtering (ONF) allows you to remove noise and not violate the edges of objects in the image [11]. These filters take into account the direction of objects in the image. ONF works with a moving average. This allows you to take into account various directions and not violate the edges of objects in the image.

Median filtering (MF) averages the values for a point in the original image [12]. MF is a special case of nonlinear image filtering. Each point for a new image is a median of values in a neighborhood of the original image. We average the noise. But we also keep the edges of objects in the image. MF allows you to remove noise in the form of individual points.

The Wiener filter (PV) is an inverse filter [13]. Therefore, the PV has low noise immunity. PV is used to recover defocused images. This filter makes the image clearer. But this can add (remove) points in comparison with the original image. PV is also used to reduce random noise.

When using filtering methods, the features of medical images should be considered. Among these features is the size of the objects in the image (SOI). Therefore, we can also consider a filtering method that takes into account the geometry of objects in the image. Then, as a primary coarse filter, it is proposed to consider as a unit object such a set that satisfies the following conditions:

the area of the object (which is being investigated) is within $S_{min} <= S <= S_{max}$,

the brightness of the object (which is being investigated) is within $\rho_{min} <= \rho <= \rho_{max}$,

$k_{min} <= k <= k_{max}$,

where:

S_{min} and S_{max}, ρ_{min} and ρ_{max}, k_{min} and k_{max} are the minimum and maximum values of the area, brightness, ratio of the shell area to the body area of objects, respectively.

Visually assessing the quality of filtering medical images is difficult. This is due to the geometry of the objects in the image, with the geometry of noise. Therefore, for a comparative analysis of filtering methods, it is necessary to use special metrics.

2.2 Image Comparison Tools

To compare and analyze filtering methods, you can use various image comparison tools (the original image and the image that has been processed). Among these tools, we can distinguish: standard error (immse), image quality estimation model (niqe), spatial image quality estimation model (brisque), structural similarity index (ssim), peak signal-to-noise ratio (psnr) [14], [15].

Immse measures the mean square difference between the actual and ideal values of the pixels. This is a risk function corresponding to the expected squared error loss. The value of immse is always positive. Values close to zero are better than higher values. This metric is easy to calculate [14], [16].

Niqe can measure image quality with arbitrary distortion. This metric allows you to evaluate image quality in comparison with a reference image and without a reference image. The niqe value is a positive number. Lower values reflect better image quality [17].

Brisque is an evaluator of spatial image quality. Such an assessment can be made in comparison with a reference image and without a reference image. A lower score for brisque indicates a better perception. Brisque values are in the range {0, 100}. Metrics without reference quality are superior to metrics with reference[14], [16], [18].

Ssim is used to measure the similarity between two images. If we have assim value of 1, then we are talking about complete structural similarity. A value of 0 indicates a lack of structural similarity [19].

Psnr shows the relationship between the maximum possible power of the original image and the power of distorting noise, which affects the accuracy of the image. The psnr metric is easy to compute, but does not match perceived quality well. The higher the psnr value, the better the score [14], [19].

2.3Examples of Images for Analysis

As the objects of study, we selected images of E.coli on digital images obtained under a microscope. E.coli is a type of bacteria. An example of such bacteria is E.coli [20]. E. coli is one of the important objects of biotechnology and microbiology.

E.coli prevents the development of pathogenic microorganisms. Most E.coli strains are not dangerous. However, some varieties of E.coli can cause severe foodborne illness [20]. This bacterium is transmitted to humans, mainly through the consumption of contaminated food. The number of such bacteria may increase with temperature. Therefore, it is important to control the amount of bacteria in the smear.

In Fig. 1 are examples of digital images of E.coli. We see various digital images of E.coli. It is also seen that individual E.coli form groups that must be identified as separate E.coli. Therefore, filtering is the key to digital image processing of E.coli.

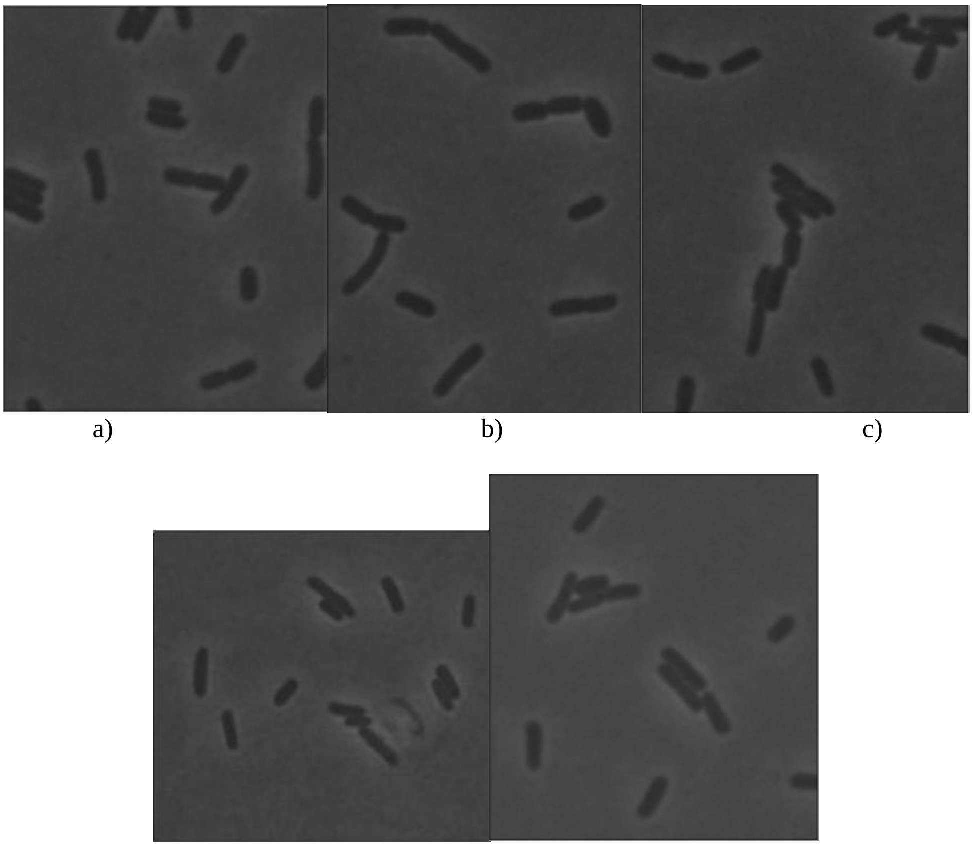

Fig. 1. Examples of digital images of E.coli

At the same time, it is important to note that each E.coli bacterium has its own geometric dimensions. The geometric dimensions of each E.coli bacteria are comparable. This is shown in Table 1.

Table 1. Minimum and maximum values of the area, circumference, brightness of the body and shell of a normalized object, the ratio of the shell area to the body of the object in a series of 100 tests

Parameter	Min	Max
Area (pixels)	492	896
The ratio of the area of the shell to the body of the object	0.34	0.43
Objectcircumference (pixels)	75	140
The length of the side of the object	18	60
The brightness of an object body (normalized object)	60	75
The brightness of the object shell (normalized object)	76	104

III. RESULTS AND DISCUSSION

To solve this problem, each image of Fig. 1 we will process sequentially with such filtration methods as: FIR, ONF, MF, PV, SOI. The results of such processing are presented in Fig. 2 (for Fig. 1c, as an example).

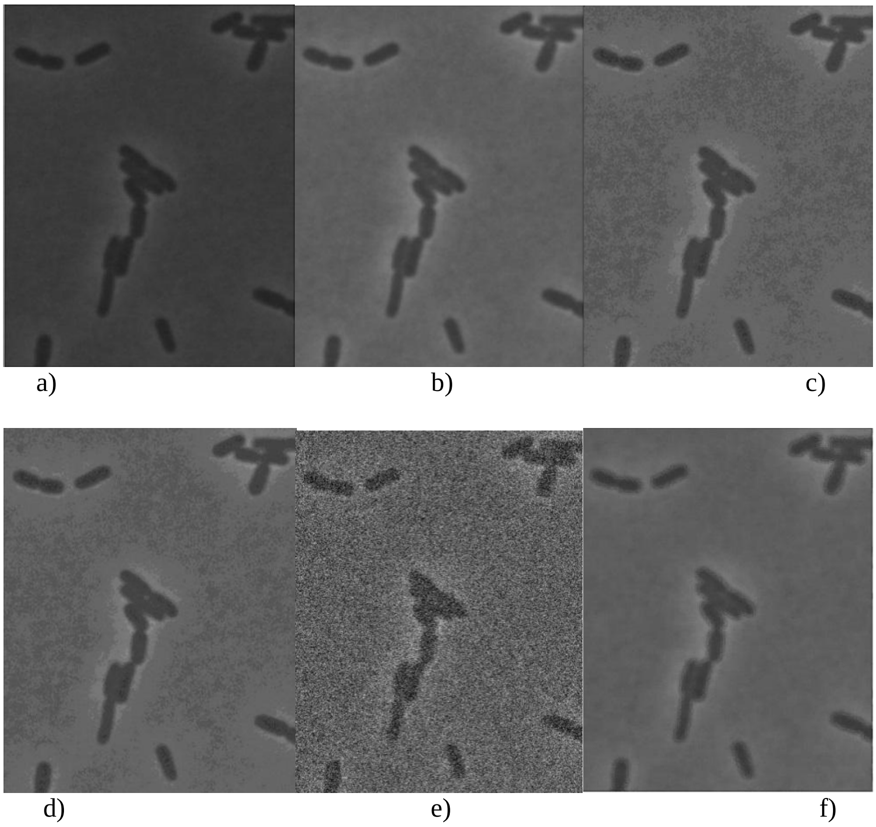

Fig. 2. The original image (Fig. 2a) and various filtering methods (FIR – Fig. 2b, ONF – Fig. 2c, MF – Fig. 2d, PV – Fig. 2e, SOI – Fig. 2f)

From Fig. 2 shows that the images differ one from one. Visually the best quality is Fig. 2b and Fig. 2f. In Fig. 3 shows the histograms for each of the images in Fig. 2.

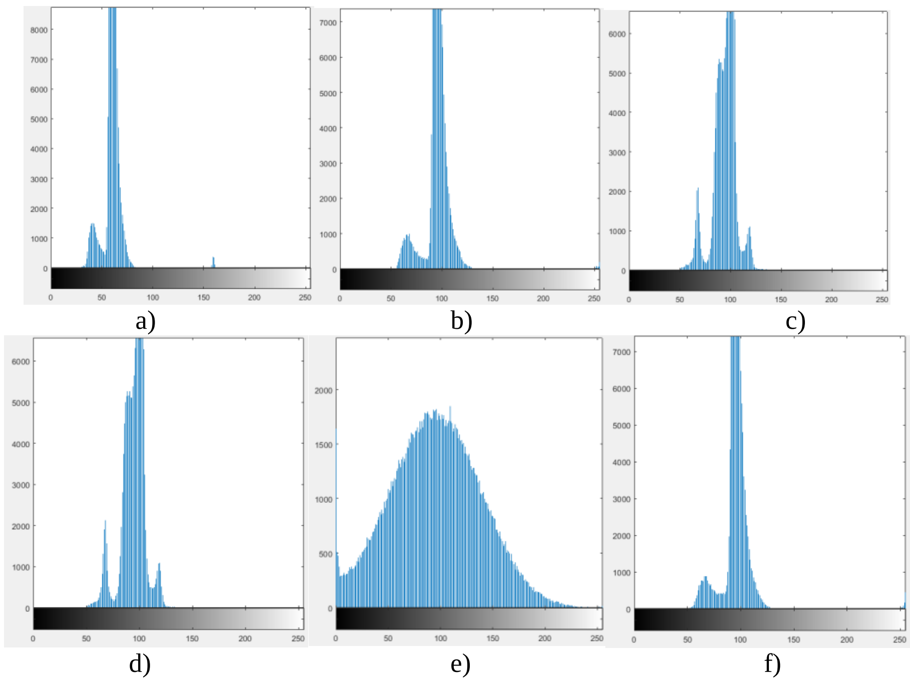

Fig. 3. The histogram of images for Fig. 2 (respectively)

We also consider comparison metrics to solve the problem. Table 2 – Table 6 presents the values of various comparison metrics for the images in Fig. 1, which are processed by various filtration procedures.

Table 2. The value of comparison metrics when using a filter – FIR

Comparison metrics	Images for comparison in accordance with Fig. 1				
	1	2	3	4	5
immse	46.5120	25.7399	103.0189	23.1489	38.6451
niqe	5.6603/5.2505	4.7736/5.7988	12.9427/5.9664	5.0664/4.7418	10.6843/5.8428
brisque	24.6497/42.9289	21.1052/ 42.2157	43.4582/43.4185	21.4578/42.9208	37.5530/41.4871
ssim	0.7142	0.8675	0.4488	0.8678	0.8453
psnr	31.4552	34.0247	28.0016	34.4855	32.2599

Table 3. The value of comparison metrics when using a filter – ONF

Comparison metrics	Images for comparison in accordance with Fig. 1				
	1	2	3	4	5
immse	0.0004	1.0987	0.9874	0.9987	1.006
niqe	5.6603/3.8007	4.7736/4.2443	12.9427/4.2692	5.0664/4.2647	10.6843/4.5431
brisque	24.6497/38.7338	21.1052/41.6658	43.4582/36.4679	21.4578/41.8636	37.5530/41.6706
ssim	0.7243	0.7674	0.5387	0.7617	0.7688
psnr	41.5425	43.2047	38.1027	44.1855	42.0432

Table 4. The value of comparison metrics when using a filter – MF

Comparison metrics	Images for comparison in accordance with Fig. 1				
	1	2	3	4	5
immse	23.9746	20,0967	29,8901	24,0075	28,0931
niqe	5.6603/3.8007	4.7736/4.2443	12.9427/4.2692	5.0664/4.2647	10.6843/4.5431
brisque	24.6497/38.7338	21.1052/ 41.6658	43.4582/36.4679	21.4578/41.8636	37.5530/41.6706
ssim	0.7323	0.8578	0.4597	0.8545	0.8398
psnr	15.6784	7.0946	12.017	14.4765	15.1209

Table 5. The value of comparison metrics when using a filter – PV

Comparison metrics	Images for comparison in accordance with Fig. 1				
	1	2	3	4	5
immse	1598.8477	1473.7612	1409.7861	1432.9812	1702.4628
niqe	5.6603/14.8102	4.7736/15.4617	12.9427/13.8564	5.0664/15.5676	10.6843/15.1806
brisque	24.6497/45.3700	21.1052/45.4104	43.4582/45.2445	21.4578/43.8545	37.5530/45.4739
ssim	0.7675	0.8891	0.6287	0.7905	0.8428
psnr	11.283	11.9876	12.0596	13.0781	10.974

Table 6. The value of comparison metrics when using a filter – SOI

Comparisonmetrics	Images for comparison in accordance with Fig. 1				
	1	2	3	4	5
immse	0.0050	0.4841	0.0472	0.3878	1.6976

niqe	5.6603/6.2785	4.7736/5.2080	12.9427/5.8558	5.0664/6.6466	10.6843/6.6785
brisque	24.6497/45.7842	21.1052/45.1426	43.4582/43.7697	21.4578/44.6827	37.5530/48.1759
ssim	0.7830	0.8723	0.8234	0.7986	0.7789
psnr	11.0599	11.2811	11.3823	12.2440	9.6943

Data analysis Table 2 – Table 6 shows that most of the values of the comparison metrics are comparable with each other. At the same time, the best values should be noted for ONF and SOI filters. Considering the visualization effect, we believe that the SOI filter is of the best quality. It is also important to consider the geometric size of E. coli when applying the filtration procedure. Therefore, the SOI filter gives the best result.

IV. CONCLUSION

The article discusses the application of various filtering procedures for processing digital medical images. We consider classical filtering procedures and a filtering procedure that takes into account the geometry of objects in the image. As an object of analysis, we consider digital images of E.coli.To compare different filtering procedures for digital images, we use visual comparison and image comparison metrics. A visual comparison showed the effectiveness of filtering procedures such as FIR and SOI. Image comparison metrics showed the best results for ONF and SOI. Thus, taking into account the geometry of E.coli, the best result is obtained by the SOI filtration procedure.The article presents the results of experiments. These results allow us to build accurate digital image processing models of E.coli.

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