An Influence of the Structuring Element on Morphological Filtering for Medical Image Enhancement

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Abstract – **In the paper is presented an investigation of influence of the structuring element on morphological processing for medical image enhancement. Many common flat shapes, such as lines, diamond, and disk are investigated with the goal to find the most suitable structuring element and its size for most effectiveness of the pre-processing. This influence is presented by analyze of some objective quantitative estimations.**

Some experimental results are presented, obtained by computer simulation in MATLAB Environment.

Keywords – **Mathematical morphology, structuring element, medical image enhancement.**

I. Introduction

The goals of medical image enhancement include improvement of the visibility and perceptibility of the various regions and tasks such as cleaning the medical image from specific types of noise, enhancing the contrast among adjacent regions or features. A powerful nonlinear methodology that can successfully solve these problems is mathematical morphology.

Most morphological filters use extreme order statistics (minimum and maximum values) within a filter window, so they are closely related to order statistic filters [1]. The imaging modalities considered (X-rays, computed tomography, magnetic resonance and ultrasound) have a variety of different characteristics that call different filters and structuring elements.

In the paper is presented an investigation of the influence of the structuring element by morphological pre-processing of different modalities of medical images enhancement. By properly choosing of suitable form of structuring element, local structures can be eliminated or local geometry of the investigated object can be modified [2]. So can be solved problems with shape and contours of the investigated object and improved the quality of the diagnostic images. The applied algorithm calculates some objective quantitative estimation parameters as: Noise reduction ratio (CNR), Signal to noise ratio in the noised image (SNR_Y), Signal to noise ratio in the filtered image (SNR_F), Effectiveness of filtration (E_{FF}), Peak signal to noise ratio (PSNR) [3]. On the base of their analyze are selected the most suitable operation, form and size of the structuring element. It determinates the precise details of the effect of the operator on the medical image.

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II. Theoretical Aspects of the Problem

The structuring element consists of a pattern specified as the coordinates of a number of discrete points relative to some origin. For medical images can be used two-dimensional (2D) or three-dimensional (3D) structuring elements. Two-dimensional, or flat, structuring elements consist of a matrix of 0's and 1's, typically much smaller than the image being processed. The center pixel of the structuring element, called the origin, identifies the pixel of interest, or the pixel being processed. The pixels in the structuring element containing 1's define the neighborhood of the structuring element. Three-dimensional, or nonflat, structuring elements use 0's and 1's to define the extent of the structuring element in the x-and y-plane and add height values to define the third dimension.

By creating of flat structuring element for morphological filtering can be used many common shapes, such as line, diamond, octagon, pair, periodic line, rectangle, square and disk. The goal is to choose the suitable form of structuring element, according to modality of medical diagnostic image. The most used elements for medical applications are: diamond, line and disk [1].

Examples of line structuring element are given in Fig.1 [4].

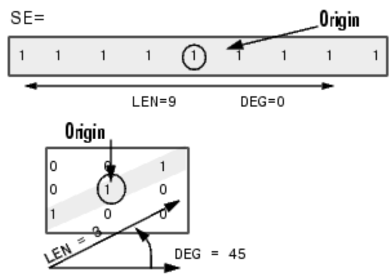


Fig. 1. Line –shaped structuring elements with the same length and different angle

The length of the line is approximately the distance between the centers of the structuring element members at opposite ends of the line, for example LEN=9. The angle (in degrees) of the line is measured in a counterclockwise direction from the horizontal axis, for example DEG=0 (DEG=45).

In Fig.2 is given an example of diamond-shaped structuring element, where R specifies the distance from the structuring element origin to the points of the diamond.

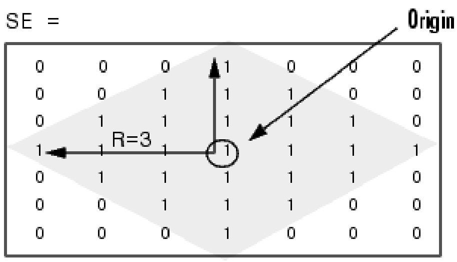


Fig. 2. Diamond –shaped structuring elements with R=3

In Fig.3 is given an example of disk-shaped structuring element, where R specifies the radius.

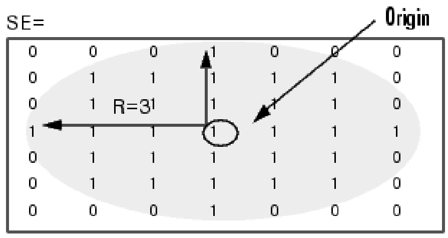


Fig. 3. Disk –shaped structuring elements with R=3

To enhance performance the structuring element can be broken into smaller pieces, that is a known as structuring element decomposition. This technique is applied for faster computing of the morphological operators [2].

The medical images of X-ray, magnetic resonance (MRI), computed tomography (CT) and ultrasound (US) have different characteristics and noise type [5]. Most of the X-ray images are but no truly isotropic and its quality varies depending on penetrating X-rays in an anatomically structures. CT presents images of cross-sectional slices of the body. CT images have a lower resolution as X-ray images, typically 512x512 pixels in digital format. The noise problem for X-ray and CT images arises from the fundamentally statistical nature of photon production. The quantum noise is dominant and comes from the quantization of energy into photons. This noise is not independent of the signal. It's Poisson distributed and independent of the measurement noise. The measurement noise is additive Gaussian noise and usually negligible relative to the quantum noise. It comes from the motion of patient. The typical noise for MRI images is additive Gaussian noise. The values of the noised components in the US image can be greater. The noise components in real US images have different character [5]. Typically noise is speckle noise and Gaussian noise for other noise components. An additive model presented the influence of the all complex noise components. The medical image morphological processing problems of clinical interest include improving the contrast and reducing the noise in images.

It is proposed an effective adaptive algorithm for selection of the most suitable morphological operation for image enhancement of all medical modalities [6, 7]. Regarding the enhancement, top & bottom hat filtering is well suited. It extracts the original image from the morphologically closed version of the image and increased the contrast of the object by means of increasing the details in the dark regions and near by contours.

A similar adaptive algorithm can be proposed for the structuring elements. On the base of analysis of some objective quantitative estimation parameters can be selected the form and size of the structuring element. The condition is: minimum value for CNR and maximum values for PSNR and E_{FF} .

III. Experimental Part

The experiments are realized by computer simulation in MATLAB 7.2 environment by using of IMAGE PROCESSING TOOLBOX. In experiments are used 20 real CT images on the area of the brain, 20 X-ray images on the area of the head and hand, 20 MRI images and 20 US images from cardiology, 24 bpp, in different size, and in different file format: jpeg and bmp, but all of them are converted into bmp. The morphological processing is realized by using of top &bottom hat operator with three types of structuring elements: disk-shaped, line and diamond-shaped. The obtained for CT images averaging results from simulation are given in Table 1.

TABLE I
EXPERIMENTAL RESULTS FOR CT IMAGES

Structuring element	CNR	PSNR [dB]	SNR_Y [dB]	SNR_F [dB]	E_{FF} [dB]
Disk (R=3)	0.3119	32.6	18.5875	20.5666	1.979
Line (LEN=3)	0.6405	24.3	18.5875	19.7034	1.116
Diamond (R=3)	0.4947	26.2	18.5875	18.5875	1.428

The most effectiveness of processing is obtained by using of disk structuring element (R=3).

The obtained for X-ray images averaging results from simulation are given in Table 2.

TABLE II
EXPERIMENTAL RESULTS FOR X-RAY IMAGES

Structuring element	CNR	PSNR [dB]	SNR_Y [dB]	SNR_F [dB]	E_{FF} [dB]
Disk (R=3)	0.8925	20.5	10.5178	11.0316	0.514
Line (LEN=2)	0.5123	26.1	10.5178	11.4901	0.972
Diamond (R=3)	0.7416	22.4	10.5178	11.2692	0.751

The most effectiveness of processing is obtained by using of line structuring element (LEN=2).

The obtained for MRI images averaging results from simulation are given in Table 3. The most effectiveness of processing is obtained by using of disk structuring element (R=3).

TABLE III
EXPERIMENTAL RESULTS FOR MRI IMAGES

Structuring element	CNR	PSNR [dB]	SNR_Y [dB]	SNR_F [dB]	E_{FF} [dB]
Disk (R=3)	0.3412	33.5	16.9749	17.2793	1.304
Line (LEN=3)	0.9131	23.3	16.9749	17.4741	0.499
Diamond (R=3)	0.7416	28.5	16.9749	17.8165	0.842

The obtained for US images averaging results from simulation are given in Table 4.

TABLE IV
EXPERIMENTAL RESULTS FOR US IMAGES

Structuring element	CNR	PSNR [dB]	SNR_Y [dB]	SNR_F [dB]	E_{FF} [dB]
Disk (R=3)	0.5989	22.6	15.5875	16.3106	1.723
Line (LEN=3)	0.3617	28.4	15.5875	16.7779	1.190
Diamond (R=3)	0.4862	25.3	15.5875	16.5687	0.981

The most effectiveness of processing is obtained by using of line structuring element (LEN=3).

The graphical interpretation of the obtained results for CNR by processing of different medical modalities is presented on the diagram in Fig.4. In the next presented diagrams CT images are marked with symbol “1”, X-ray images – with symbol “2”, MRI images - with symbol “3” and US images respectively with symbol “4”.

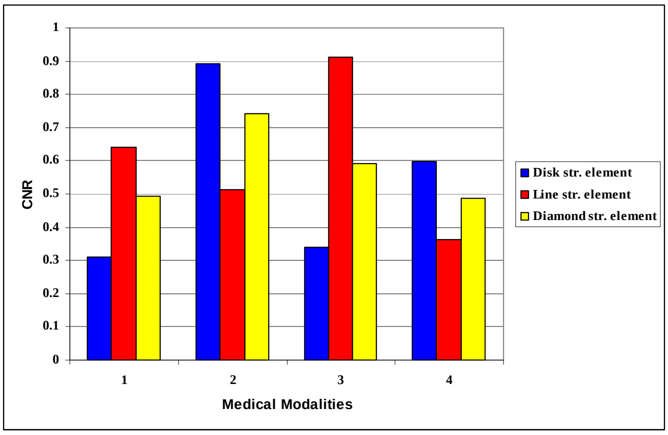


Fig. 4. Diagram of CNR

The minimum values of CNR (0.3) are obtained by using of disk-shaped structuring element (R=3) in the processing of CT and MRI images. It shows that the noise is three times reduced. The minimum value of CNR is obtained also by using of line structuring element in the processing of US images (CNR=0.4) and for X-rays (CNR=0.5).

The graphical interpretation of the obtained results for PSNR and EE_F is presented on the diagrams, respectively in Fig.5 and Fig.6.

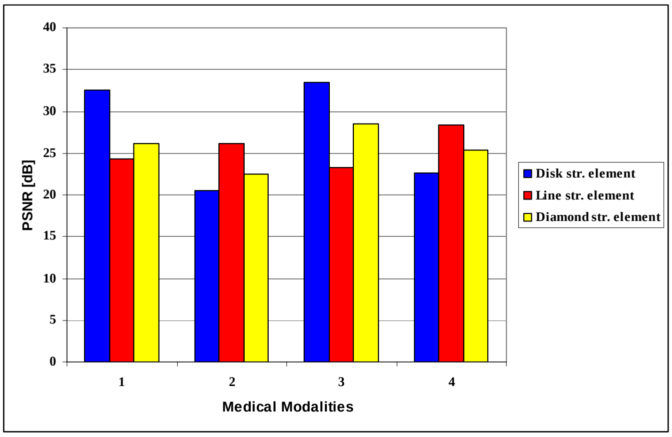


Fig. 5. Diagram of PSNR

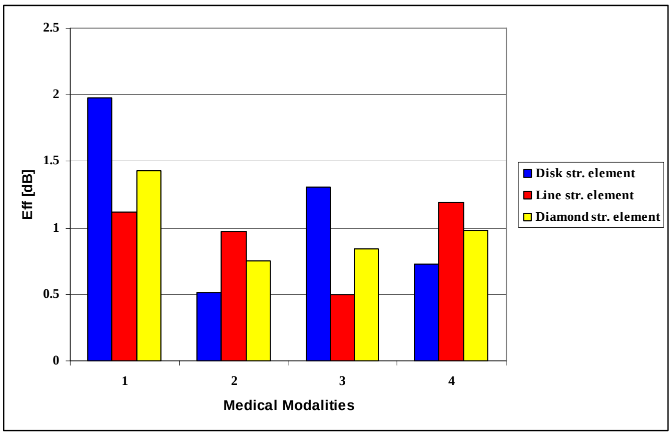


Fig. 6. Diagram of E_{FF}

The maximum values of PSNR and E_{FF} are obtained by using of disk-shaped structuring element (R=3) in the processing of CT and MRI images. The maximum values of PSNR and E_{FF} are obtained also by using of line structuring element in the processing of US images (LEN=3, ANGLE=0), and for X-rays (LEN=2, ANGLE=0).

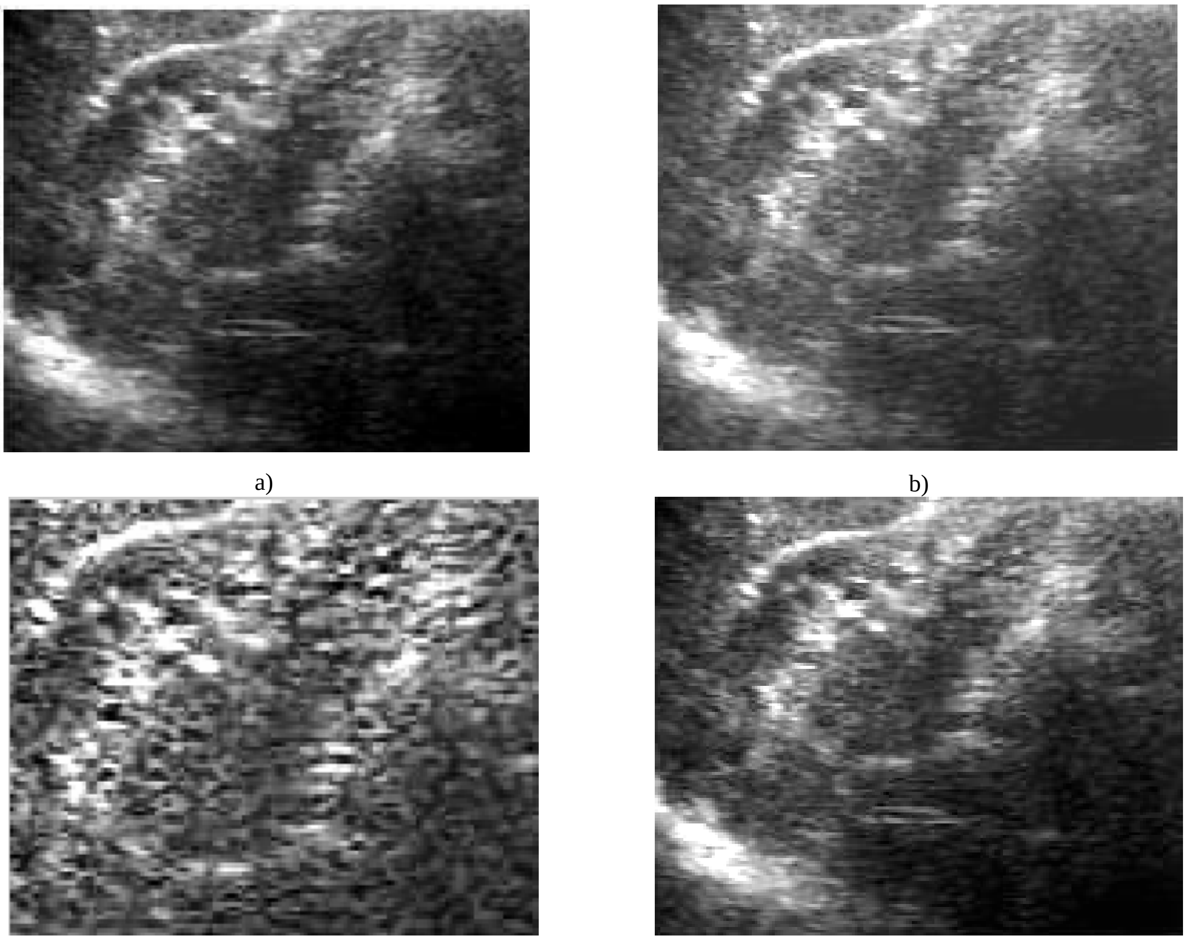
An illustration of the implemented experiments for US images is given in Fig.7. It presents the original US image of size 350x240 and its morphological modifications by top & bottom hat filtering, using the three structuring elements.

By using of disk-shaped structuring element and diamond-shaped structuring element can be obtained well-defined outlines of some tissues, but the values of the noised components in the image can be greater.

IV. CONCLUSION

The implemented theoretical and experimental investigations in the paper show, that the influence of structuring elements is very important by the morphological pre-processing of medical images of different modalities.

By processing of US and X-ray images, where the values of the noised components can be greater, the using of line structuring elements is suitable for well-defined outlines for separated organs or biological structures.



a) b) c) d)

Fig. 7 The original and processed US images: a) Original image; b) Processed US image with diamond structuring element; c) Processed US image with disk structuring element; d) Processed US image with line structuring element

The disk-shaped structuring elements are more suitable by processing of MRI and CT images.

The obtained experimental results (in numeral values) by the proposed morphological pre-processing of the medical images are in very good accordance with the subjective perception and enable more precise diagnosed of different disease.

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